Report of a Workshop on

Cropping Systems Research in Asia

INTERNATIONAL RICE RESEARCH INSTITUTE

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1982
INTERNATIONAL RICE RESEARCH INSTITUTE
LOS BAÑOS, LAGUNA, PHILIPPINES
P.O. BOX 933, MANILA, PHILIPPINES

The International Rice Research Institute (IRRI) receives support from a number of donors, including the Asian Development Bank, the European Economic Community, the Ford Foundation, the International Fund for Agricultural Development, the OPEC Special Fund, the Rockefeller Foundation, the United Nations Development Programme, and the international aid agencies of the following governments: Australia, Belgium, Brazil, Canada, Denmark, Federal Republic of Germany, India, Japan, Mexico, Netherlands, New Zealand, Philippines, Spain, Sweden, Switzerland, United Kingdom, United States.

The responsibility for this publication rests with the International Rice Research Insitute.

ISBN 971-104-076-X

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Foreword

The Cropping Systems Conference at IRRI 3-7 March 1980 served as a forum for researchers from the Asian Cropping Systems Network. Sixty papers were presented and discussed; more than 90 cropping systems researchers and extension workers from Asia and IRRI took part in the forum. The papers covered a wide range of research that has resulted in workable cropping patterns that are acceptable to Asian farmers and can increase food production.

This volume represents a major source of information for the Asian Cropping Systems Network. It reflects the work of the Asian Cropping Systems Working Group, which has guided the building of the Network and helped shape its research programs since 1974.

These proceedings, plus the recently published *Methodology for on-farm cropping systems research* and the proceedings of the 1976 *Symposium on cropping systems research and development for the Asian rice farmer*, provide evidence of progress in cropping systems research. The continuity of cropping systems research is reflected in the many names that appear in both the 1976 symposium proceedings and these 1981 proceedings.

Dr. V. R. Carangal, IRRI agronomist and Cropping Systems Network coordinator, served as the conference coordinator. Drs. H. G. Zandstra, R. A. Morris, E. C. Price, J. A. Litsinger, K. Moody, and S. Jayasuriya served as technical editors for the conference proceedings. IRRI Editor W. G. Rockwood and Assistant Editor Gloria Argosino edited the conference papers and group reports. The International Development Research Centre, Canada, partially funded the Conference.

M. R. Vega
Acting Director General

Opening remarks

N. C. Brady

It is with great pleasure that I welcome you to the International Rice Research Institute and officially open this 1980 Cropping Systems Conference. My colleagues and I at IRRI appreciate your presence here and your contribution to the development and implementation of a unique methodology for cropping systems research.

When I joined IRRI nearly 7 years ago there was considerable discussion about the future of multiple cropping as a means of increasing the food supply in rice-growing countries of Asia. Dr. Richard Bradfield had effectively demonstrated on a small plot at IRRI that four or five crops a year could easily be grown in an area where only two crops a year were being produced.

Furthermore, the total annual production of food on Dr. Bradfield's plots was 4 to 10 times that of nearby farmers. He and fellow scientists working in national programs called attention to the fact that the principles being used in China and parts of Indonesia could be applied to greatly increase food production in other areas of South and Southeast Asia.

The research of Dr. Bradfield and his associates in national programs proved that the biological potential for food production in the tropics was severalfold greater than actual production levels. But they did not identify the reason for this huge performance gap. Some assumed ignorance and resistance to change on the part of the farmers as a primary deterrent to progress. Others blamed the agricultural extension system for its failure to inform the farmers about the new crop technology. Still others reasoned that unwise policies and farmers' aversion to risk made it difficult for them to adopt more intensified cropping systems.

To some extent each of these reasons probably explained part of the performance gap. But another explanation was put forth by a group of scientists, some of whom are at this conference. They claimed that a primary reason for slow adoption of crop intensification was that the so-called improved cropping systems did not adequately fit farmers' needs. These systems did not consider the farmers' limited financial and labor resources, nor did they supply a proven technology that would make the new systems work.

This alternative explanation became the basis for the revolutionary research methodology that participants in this conference helped develop and are using to design and test new and improved cropping systems and put them into practice on farmers' fields. The methodology put the farmer as the primary focus for the

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research. He became part of the research team. Furthermore, the process of designing and testing improved cropping systems was seen as multidisciplinary. Physical and biological scientists were joined by social scientists and economists to develop cropping systems based not only on their physical and biological potential but also on their social and economic acceptability to the farmer.

To maximize opportunities for scientists from one country to learn from those in other countries, the rice-based cropping systems network was initiated. This network has not only encouraged mutual education but permitted the testing of the new methodology in a variety of agroclimatic situations. And it has demonstrated again and again the essentiality of a multidisciplinary approach if the farmer is to be provided with workable improved cropping systems.

I take this opportunity to congratulate you on the remarkable progress you have made during the past 5 years in developing and testing revolutionary ideas on how cropping systems can be improved. You have refuted the pessimists who said you would fail. You have at least partially converted the more traditional researchers who initially looked upon your activities as simply disguised extension programs. And you have shown some decision makers that intensified cropping systems can be used to produce more food.

Rut the job has only begun. The methodology you have developed needs further refinement and testing. It has uncovered serious weaknesses in the component technology, which must be strengthened if the new systems are to be effective. The economic analysis of the results obtained has generally lagged behind the physical and biological studies. And we have only begun to ascertain the potential for the use of models to permit some prediction of how the function of new systems would change if environmental factors and basic inputs of money, labor, and chemicals were modified.

This conference gives you an opportunity to evaluate your past performance and to plan future research and training efforts. It also gives you an opportunity to place on record both your accomplishments and your plans.

I wish you well in those tasks.

The role of cropping systems in increasing food production and farmer prosperity

Sadikin, S. W.

It is a pleasure and challenge to address this important cropping systems conference as we move into the 1980s, and to share in the exchange of ideas, information, and knowledge. It is a challenge to examine the role of cropping systems in increasing food production and farmer prosperity. Naturally, I must draw impressions and examples from my experience in Indonesia whose situation, I believe, is not greatly different from that of other countries of Asia.

At the end of the 1960s, there was cautious optimism about the positive turn in the struggle against hunger and malnutrition in food-deficient Asia. Technological breakthroughs in food production were brought about, particularly by high yielding food crop varieties. Farmers were quick to grasp the new technologies that proved suitable and profitable to agribusiness. Governments gave high priority to agricultural development, to expanding job opportunities in the rural areas, and to raising farmers' income. Some countries, particularly in Southeast Asia, spared no effort in securing internal social and political stability as a prerequisite for development and economic growth. There was recognition of the need to alleviate poverty and hunger among the lowest income groups to create a dependable social and political base for growth and development.

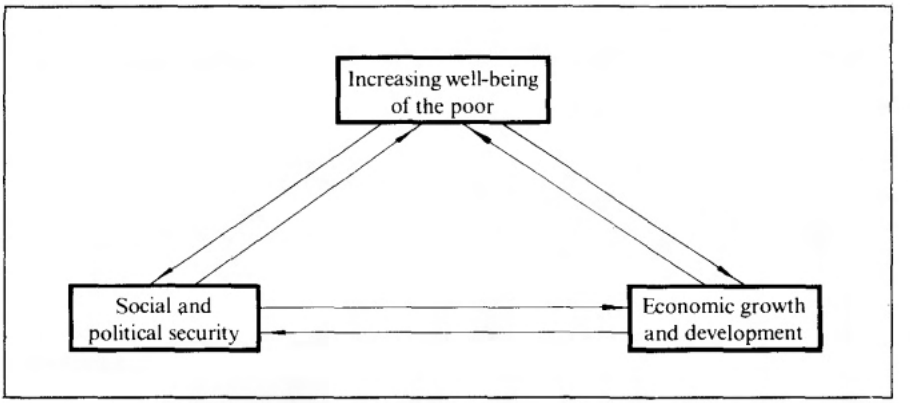
In general, Asia welcomed the 1970s with optimism and hope. Despite droughts and floods, harvests were relatively good throughout the decade. Severe droughts in some areas had adverse effects on food production and Asian grain reserves in the early 1970s, but didn't create widespread suffering among the poor as they had in the 1960s.

Some Asian countries deserve praise for their growth and economic achievements during the 1970s. In the agricultural sector, the strong supportive linkage of research to development was recognized. Developing countries in Asia increased their investments in national agricultural research systems to strengthen their research capability and their capacity to absorb, adapt, and apply the new knowledge and technology to their specific environments.

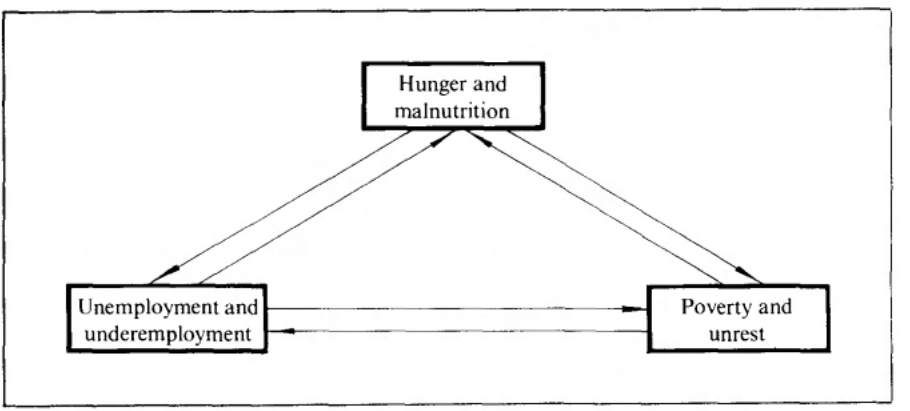
But as we enter the 1980s, those encouraging developments in the 1970s reveal many sobering facts—perhaps alarming prospects—about Asia's agricultural and

Member, IRRI Board of Trustees, and director general for Agricultural Research and Development. Jakarta, Indonesia.

food situation. I illustrate this by referring to the interacting conditions in the following diagrams:



The first diagram has what can be considered the three positive conditions needed for continued development of Asia's countries and, collectively, of the region. Agriculture is only one of the many sectors expected to contribute to these conditions.



The second includes negative conditions that the agricultural sector can, or should, influence more directly. In rural Asia, where we find most of the population, the basic aspects of poverty, hunger, and unemployment are closely linked and often inseparable. Because most Asian nations are agrarian and developing, national leaders look to the agricultural sector to provide the food needed to reduce hunger and malnutrition, to provide additional employment to generate the income needed to purchase available food and other consumer goods and, through these two accomplishments, alleviate poverty and prevent unrest.

The agricultural sector, however, does not bear the full responsibility for the prevention of unemployment, poverty, and hunger in all rural areas. Several Indonesian experiences illustrate this point:

- Some of the islands of eastern Indonesia have very long dry seasons during

which food cannot be grown. Food must be stored or imported — both expensive alternatives in these economically poor areas.

- Residents of the area around Bojonegoro, East Java, experienced hunger during a brief period in the 1950s when their tobacco crop, on which they were dependent for cash income, failed and they had no money with which to buy available food.
- During the 1960s in South Sulawesi, one of Indonesia's rice bowls, the closure of a factory that employed many local residents deprived the people of cash with which to purchase available food.
- In the Karawang area east of Jakarta, there was hunger in the center of a major rice-producing area because irrigation facilities were closed for essential repairs.

These examples illustrate the need for linkage and interaction among the several sectors of the economy that affect one or more of the conditions of unemployment, poverty, and hunger.

The uncertainty about social stability and political security throughout Asia, both now and in the foreseeable future, dims the hope for a consistent agricultural development and food production strategy. The demand for food continues to outstrip the supply. Population growth and the influx of unskilled labor into the agricultural sector reduce efficiency and lower farm income per capita. The jobless and the poor are not decreasing in number and those who are living close to the brink of hunger and starvation will continue to blur Asia's rural perspective in the 1980s.

It is reassuring to note that IRRI has a sincere and legitimate concern for the well-being of the small farmer, for returns from the farmer's land and labor, and for the expected increase in profitability for the farmer through the application of new technology. But the question of how to improve the income of the rice farmer is a vast and complex problem, even if we narrow it to the question of how a rice-based cropping system can improve the farmer's income.

A problem of this magnitude deserves a concerted cooperative effort. The Cropping Systems Research Network, with its focus on rice-based cropping systems, is an excellent example of the interaction that can exist between an international research center and national research programs. Those of us in the national programs are indebted to IRRI for demonstrating the potential for land productivity with intense cropping patterns, the development of appropriate research methodologies, and for showing the way to involving the farmer in on-farm cropping systems research. For contributions from the national programs, we cite the opportunities to employ the many *living laboratories* in our countries, which feature diverse agroclimatic and socioeconomic environments. We also provide the opportunity to study and learn from our stable, traditional cropping systems that have evolved over years of trial and error. But our most important contribution should be human resources, our scientists and trainees who infuse the cropping systems network with new opportunities and challenges, and our farmers who operate the cropping systems.

The small farmer of Asia has demonstrated himself to be an excellent manager of scarce resources, primarily capital, as well as an excellent manager of labor. What is not so clear is whether we in the professional sector — policy makers, administrators, researchers, or teachers — fully appreciate the importance of astute observa-

tion of the farmer's current practices or the need for communicating with him to fully understand why he does and why he frequently does not adopt our apparently beneficial technology or programs.

One reason farmers have not responded as expected is that pricing or input subsidy policies have not given them the incentive to diversify production from the major staple food crop — rice. This has been the case in many Asian countries and in Indonesia until recently. However, with the planning for Indonesia's Third 5-year Development Plan, the advantages of and need for diversification of the food supply are stressed and appropriate incentives for production of crops other than rice are presented.

This Conference, which is to address the use of cropping systems as a strategy for increasing productivity and the income of small farmers in the 1980s, reminds me of the 1969 FAO conference in Rome where I chaired a technical committee that designed the FAO basic strategy for the 1970s. That FAO strategy became known as the Five Areas of Concentration, namely:

- promotion of high yielding varieties of basic food crops,
- filling the protein gap,
- war on waste,
- mobilization of human resources for rural development, and
- earning and conserving foreign exchange.

The FAO cast its strategy in an activist and operational mode. Similarly, this conference calls for an activist, operational concept to be elaborated, evaluated, and considered as one component of an Asian agricultural development strategy for the 1980s.

As a research administrator, I am often called on to provide the production or supply projections that our research indicates are justified. Thus I raise this question as a challenge to this conference: Has about 15 years of cropping systems research provided the neccessary confidence and answers with which to accurately project the role of cropping systems in the 1980s? If we agreed that the agricultural sector remains an appropriate vehicle for national development in most Asian countries, the choice of an appropriate strategy for utilizing our resources in the treatment of poverty, hunger, and unemployment becomes paramount.

The cropping systems research to date has adequately demonstrated the following potentials for adopting cropping systems as a development strategy in contrast to rice monoculture:

- improved stability of food supply throughout the year,
- increased total food production per land unit per year, generally accompanied by an increase in total income for the farmer,
- improved distribution of income throughout the year,
- increased total employment of labor per land unit per year,
- improved distribution of labor use throughout the year, and
- improved nutrition for the farm family from crop diversification.

With these improvements enhanced by government policies favoring crop diversification, it appears that cropping systems will play a significant role in the 1980s. But there are still problems to be solved and challenges to be addressed.

One of the challenges is to optimize the use of the limited resources to increase

both food production and profitability for the small farmer. One obvious resource is the increasing number of early-maturing, pest-resistant rice varieties available as the base for the system. Rice breeders are evaluating the potential use of such varieties in the cropping system. Similar accomplishments are realized in other crops. In the last decade, significant strides have been made toward the development of a lowland tomato and potato, for example. Thus, in developing appropriate cropping patterns, the cropping systems specialist has not only a larger selection of varieties to choose from, but also a larger range of crops, which could enhance nutritional and income levels.

We commend the Asian small farmer for his managerial ability in optimizing production inputs and resources; however, the increased diversity of crops in a cropping system creates secondary problems of seed supply, harvesting, handling, storage and marketing with which he may not be able to cope. We researchers. administrators, and policy makers must take note of this likelihood. We must be aware of the research needs and opportunities in the areas of these secondary problems — seed supply, postharvest handling, and on-farm storage and processing. Crop diversification is likely to lead to the production of more of the perishable products such as fruits and vegetables. With a verified potential quantity and quality of such crops, the establishment of food processing plants becomes *feasible.* When the application of a cropping systems strategy can justify that development, a significant advance on the road to increasing production, reducing hunger, and providing employment will have been made.

The management of irrigation water is of increasing concern to rice farmers. The amount and reliability of the water supply determine the type of rice production and related rice-based cropping system in a specific area. The expansion and improvement of irrigation systems create an ideal environment for the implementation of intensification programs such as Indonesia's BIMAS and the Philippines' Masagana 99. But with increased intensification of rice production have come increased pest attack and concern for yield stability. The potential of coordinated or communal cropping systems as the means for breaking the pest cycle as well as covering the time irrigation dams are being repaired, ditches cleaned, etc. has yet to be exploited in a modern broad-scale pest or water management system. Such systems must be implemented with caution, however, because they could create peaks of demand for available labor, especially in rice planting and harvesting seasons, and thereby further skew the labor distribution pattern. No doubt there will be need for trade-offs in the development of appropriate cropping systems.

Numerous other systems justify further research. Cropping systems will include diverse plant species, including perennials, and there are opportunities for including fish and ducks in the rice-based cropping system. Even though the production of fish and ducks in rice fields is practiced in Indonesia and other Asian countries, we are probably not fully exploiting the potential of the incorporation of animals into an integrated farming system. This is an additional challenge for research and development. The value of nutrient recycling through plant residues as well as manure also deserves further study as does the use of grasslands to support animals and prevent soil erosion on undulating terrain.

It is clear that effective cropping systems research and implementation require a

multidisciplinary research approach and team effort. This has specific implications for the management of research and development activities. The research organizational structure must provide the authority and flexibility to accommodate the multidisciplinary team research effort.

I have mentioned cropping system profitability several times. Profitability will certainly be an important consideration in the small farmer's adoption of new technology or production programs. However, many of our farmers' holdings are very small in area and may be considered a family enterprise rather than an agribusiness. In such cases, the production of crops for the family's food supply is more important than the profitability of the crop grown. Choices and decisions made on this basis may not appear to be rational economic decisions. These situations require special consideration and the application of an index of well-being different from the common one of profitability or net income.

Much attention is currently being given to the landless laborers' plight as the poorest of the poor, and indeed their problems require special attention. We must remind ourselves, however, that the emphasis on food production must remain with persons with some land resources. Admittedly the land tenure problems in many Asian countries constrain both maximum employment and food production. It would appear that agriculture's contribution to the problem of the landless laborer will be primarily in providing employment. But the agricultural sector cannot solve this problem alone and needs to link itself with other institutions.

The landless laborer problem is particularly acute in Indonesia where the Government has set goals of transmigrating 100,000 families/year from Java to the outer islands of Sumatra, Kalimantan, and Sulawesi. The logistics of the operation alone are staggering. Suitable land resources must be selected and at least a minimum of infrastructure provided. Cropping and farming systems appropriate to the agroclimatic conditions of the area must be developed. All this must be done with a minimum of damage to the ecosystem and environment. The backstopping of our transmigration efforts through agricultural research is an important activity and an awesome responsibility. Obviously, we must work in harmony with other public sectors such as public works, and health and education. We in Indonesia are very much involved in the process of linking our agricultural research to other development sectors and we hope that the 1980s will be remembered as the decade of institutional breakthroughs,

DISCUSSION

Kasmo: I underline what the author has strongly emphasized in this paper, that "the backstopping of our transmigration efforts through agricultural research is an important activity . . . "

I suggest that this conference should encourage research activities such as have been done by Drs. McIntosh and Effendi in Lampung and South Sumatra, to cover larger transmigration areas, including tidal swamp areas.

Aung Khin: Burma made a policy decision in 1970 that the Agriculture Department must carry out cropping systems research on different cropping patterns in those areas. Recently,

we started increasing the area under early-maturing rice (less than 150 days) from 40% to 60% of the total with a view to putting more area under multiple cropping. Burma is making a concerted effort to transfer the research results to farmers' fields in as short a time as possible.

M. L. Malla: Recently we discussed the role of cropping systems research in rice production in the terai and the hill areas. Regional directors and subject matter specialists of different disciplines realized the importance of component technology research for specific sites. For the higher hills, cropping systems should collaborate with livetock development on the point of recycling organic matter to increase fertility and production and to reduce the problem of fertilizer shortage. Extension programs in rainfed areas must be focused on increasing cropping intensity in wetland rice fields on the basis of present rainfed cropping systems research in place of a monocropping approach. In Nepal, we have a complicated climatic and socioeconomic environment. We therefore discussed with different agencies plans to start cropping systems research that considers multiple cropping at sites in different climatic zones.

Hoque: Two important issues have been raised by Mr. Sadikin:

- Although the cropping systems research programs have been successful in shifting the direction of agricultural research from crop-oriented research to the systems-oriented approach in several Asian countries, we need to ask ourselves how successful we have been in making our national governments accept the cropping systems approach as a strategy for the ongoing and future agricultural production programs.
- Cropping systems research vs farming systems research. Considering that many Asian farmers are subsistence farmers, probably we have to start thinking of modified cropping systems models that integrate at least some important components of farm enterprises with those of the cropping systems.

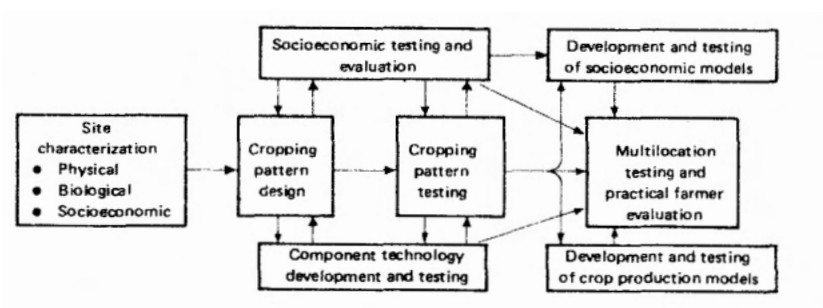
Potential of increasing production and cropping intensity of rainfed wetland rice fields in Asia

N. C. Brady

Extension workers often find that farmers will not adopt new technology developed in basic and applied research programs. Usually, there is nonadoption because it is not to the farmers' advantage to use the technology, something the researchers would have known if they had tested it on farm.

The Asian cropping systems research approach avoids this nonadoption risk from the very beginning because farmers are involved in field experimentation by the researcher. More important, the on-farm research is preceded by a study of what the farmer is doing and his reasons for doing it, and by a consideration of what the farmer is likely to accept in the future. The general research approach by the Asian cropping systems network uses the methodology shown in Figure 1. It illustrates the points that I would like to make.

This logical methodology is designed to select and test improved cropping systems and to evaluate them in multilocation trials in farmers' fields. When considering intensification of cropping in rainfed areas, it is important to ascertain the probability of success of any new cropping pattern or system.



1. On-farm research methodology developed and used by IRRI cropping systems scientists and cooperators in 8 Asian countries.

Director general, International Rice Research Institute, Los Baños, Philippines.

A first step is characterization of the environment - climatic, soil, and socioeconomic factors — in an area or region to determine the potential for increased cropping intensity. This step is particularly important in rainfed areas because the environment relating to water is difficult or impossible to control. Characterization of the landscape position improves the prediction of probable success of a new cropping pattern or system.

Site selection for cropping systems research uses the knowledge of environmental characteristics and considers the potential for increasing cropping intensity as well as the competency and interest of cooperators, especially the farmers. The success of new cropping systems in rainfed areas will depend to a considerable degree upon the willingness of the farmer to implement a change or changes once they have been decided upon.

Utilizing environmental characteristics along with the component technology and socioeconomic information, the researchers design cropping patterns and systems that they think will have potential to increase production. The physical, biological, and socioeconomic limitations and opportunities are considered in designing new systems, which are then promptly tested in farmers' fields.

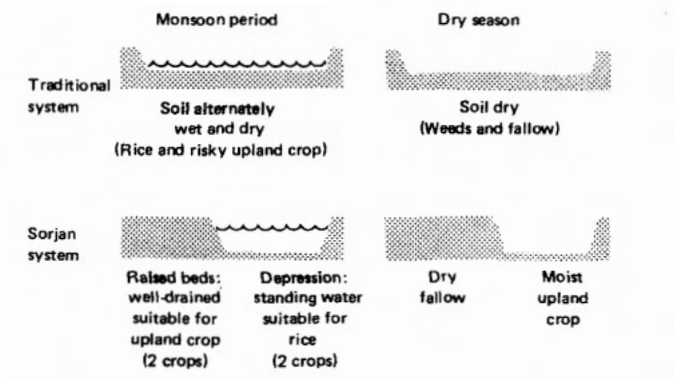
Testing involves a comparison of new cropping patterns and systems with those in use by the farmer. These tests are in terms of yield and total production and in terms of economic and social changes. The researchers must determine not only what the systems will produce but whether the farmers can or will adopt them. Sufficient data are collected to develop models that permit the extrapolation of research results to areas with different environmental conditions. Such models are also useful in predicting results that may be obtained in the same site following a change in climatic or economic environment.

As the capability to develop and use these models develops, you will greatly increase the usefulness of your research because you will not have to run new experiments in areas with slightly different environmental and other characteristics.

Concurrent with the testing of cropping patterns and systems, biological and physical research is under way to develop an improved component technology. Such research is highly pertinent to areas where rainfall variability markedly affects the suitability of the new technology. For example, weed populations are drastically affected by year-to-year climatic differences and by changes in cropping pattterns. Research must be done to ascertain needed changes in weed management and to allow full utilization of the potential of the newly designed system or the design of a still better cropping system.

I call attention to two other areas where I believe this component techology and a tie-in with the traditional farmer would be quite appropriate:

- We are excited at IRRI about the so-called sorjan system which we borrowed from Indonesia (Fig. 2). This is an example of a farming system that must be examined critically. The system provides soil and water environments conducive to high yields of rice and of upland crops during the different periods of the year. Thus, during the months of the rainy season, upland crops grow on raised beds with good drainage and yield remarkably well, while rice grows well in the wet depression. In the dry season, the upland crops are shifted to the depressions and are provided with good soil moisture. This is an example of a component of



2. A sorjan system permits the production of 2 upland crops on raised well-drained beds, and 2 rice crops in depressions during the rainy season and an upland crop in the depressions during the dry season.

traditional technology that can be used.

- We have called the attention of plant breeders to the value of rice varieties with good ratooning ability. The fact that within 60 days a farmer can sometimes get as much as 2-3 t of rice/ha with little additional work is significant. Breeders are responding and the collaboration between the breeders and the cropping systems specialists in this regard is interesting.

I don't believe I can overemphasize the need for close cooperation between the traditional *researchers* and the cropping systems scientists to try to develop better component technology.

Socioeconomic monitoring and analysis likewise proceed simultaneously with, or as part of, improved cropping systems design and testing. This is one of the most critical elements in the methodology and one that has challenged both the economists and the biologists. The economists must monitor and evaluate the new systems as well as the old in terms of their use and productivity of labor, land, power, and financial inputs. The economists' data must be used increasingly by the biologists to determine technology changes that must be made to make a cropping system more acceptable to a farmer. Again, models permit some estimation of the probable effects of changes in various socioeconomic inputs on the success of given cropping systems.

Even though the researchers may feel that their primary responsibility is over once a pattern or system has been tested under their supervision, production programs to encourage farmer adoption of a pattern or system require close collaboration between the researcher and extension specialist. Multilocation pilot testing on farms is an essential part of a preproduction testing and is best accomplished through research and extension cooperation.

The rapidity with which farmers will adopt improved cropping systems has been adequately demonstrated in several countries within the Asian Cropping Systems Network. An example is the adoption of double-cropped rice in Iloilo province, Philippines, where the percentage of farmers who had adopted double-cropping increased from about 2 to 50 within 3 years after the research program was initiated.

The Iloilo farmers did not hesitate to change once they saw clearly an economic advantage to do so. They demonstrated the error in judgment on the part of many from the more developed world who think that the primary reason for the low yields in the tropics is the backwardness of the farmers. The Iloilo adoption rate will equal that of hybrid maize and any other such new practices in the more developed world. The notion that the farmers in the tropics are backward and resistant to change is a great fallacy. If the farmers see some obvious advantage, they will not hesitate to change.

Increased cropping intensity in rainfed areas is critical in the years ahead. About a third of the anticipated future increases in food production in Asia is expected to come from rainfed areas. Tens of millions of rice farmers who have rainfall as their only source of water must increase their food production significantly during the next few decades. Research to intensify cropping in rainfed areas is critical to the success of cropping systems programs, far more than is the case for irrigated areas, which have already received most of the research attention.

In rainfed areas, the uncertainties of water supply and the insufficiency of improved technology limit immediate progress in cropping intensification. Luckily, much of the research on irrigated rice is directly applicable to the rainfed rice field. However, additional research must be done to develop rice varieties more resistant to drought on the one hand and to sudden increases in water depth on the other.

The Asian Cropping Systems Network has developed a methodology that maximizes farmer involvement and has the interdisciplinary inputs needed for improving and testing cropping systems. This methodology provides for linkages between rice scientists concerned with more basic research and with extension specialists who encourage pilot testing and work for final widespread adoption by farmers.

Institutional requirements for cropping systems research

Hubert G. Zandstra

Of the available arable land in 1970, nearly 71% was under cultivation in Asia, 58% in developed countries, and a low 17% in Latin America (Herrera 1976). Increased food production in Asia will depend mostly on an increase in the crop yield per hectare and the number of crops produced per year.

Emphasis on the generation of agricultural technology that increases annual output per hectare will therefore continue. Such technology should capture the potentials for increasing food production by increasing the yield per crop and the number of crops per year and by improving the combination of cropping patterns on the farm. The design and testing of this technology require radical departures from the common within-field, within-crop perception of agricultural research. The cropping systems research methods developed by the International Rice Research Institute (IRRI) in collaboration with national programs represent a multicommodity, environment-conditioned approach to agricultural research.

This paper describes the experiences in programs of countries in the cropping systems network and at IRRI. It pays particular attention to organizational and institutional requirements and to consequences of cropping systems research methods, and suggests aspects that should receive future emphasis.

THE NEED FOR ADAPTED TECHNOLOGY

Improved, short-duration crop varieties, early crop growth establishment techniques, new fertility and pest management alternatives, farm machinery, and expanded irrigation are available. They have at times resulted in remarkable increases in production of rice and wheat (e.g. in Colombia and northwestern India). The rapid early adoption of new varieties and the associated intensification of management methods, however, did not continue.

In analyzing the adoption of new technology, Brady (1977) recognized that such factors as rice policies and institutional support for the farmer limit increased production. He indicated that the most important limitation was probably technological. Climatic variability, soil-related production constraints, and the farmers'

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limited power, labor, and cash resources lead to a lack of fit of production technology. Poorly adapted recommendations reduce farmers' returns from their investments, raise input requirements excessively, and substantially increase risks.

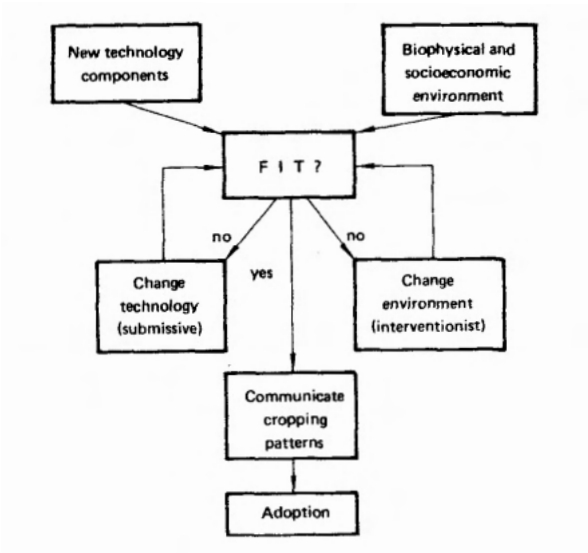
To achieve a better fit of production technology to the farmers' physical and socioeconomic environment, research and development activities must change the technological formulation (Fig. 1). This is called the submissive approach to technology development (Zulberti et al 1979). The changes may involve characteristics such as crop maturity, resistance to pest and diseases, and tolerance for soil-related constraints. Purchased inputs may be reduced, although the danger is that benefits from the recommendations will also be reduced. Peak power and labor requirements can often be reduced by use of alternative crop schedules.

Alternatively the production environment can be changed. This interventionist approach often requires restructuring of existing institutions. Typical changes — irrigation, drainage, terracing, or deep plowing — modify land types. Others may increase credit availability, reduce credit costs, change cost-price relationships, ensure availability of inputs and markets, or improve technology delivery systems.

A mixture of approaches is evidently needed. Agricultural research must condition its activities to the biophysical and socioeconomic environment and consider the combination of crop enterprises encountered on small farms.

CROPPING SYSTEMS RESEARCH

Cropping systems research identifies cropping systems that increase food production through the introduction of additional crops or improved management practices into existing production systems. In this process, the technology is subjected to carefully specified resource limitations.



1. Acceptance of new technology can be achieved by modifying either the technology or the environment.

painfall patterns, irrigation classes, landscape and soil types, labor availability, and market structure create environmental complexes to which the improved technology must be exposed. The task of addressing each environment separately belongs to national agricultural research organizations. It is IRRI's task to 1) help provide methodology that suits the national organizations and allows them to formulate improved cropping systems for the predominant environmental complexes in their region, and 2) identify management techniques that will overcome common limitations to the intensification of common rice-based cropping patterns.

Research goals and methods are traditionally discipline or commodity oriented. To develop a methodology for on-farm cropping systems research IRRI, with support from the International Development Research Centre (Canada), invited Asian national research organizations to form the Asian Cropping Systems Working Group. Composed of cropping systems research scientists in South and Southeast Asian countries (Cropping Systems Working Group Reports 1975), the group incorporated experiences in on-farm research gained at IRRI (Harwood 1976) and elsewhere (Laird 1968, Houser 1970, Cady 1974, Baker and Norman 1975, Zandstra et a1 1975) into a framework for cropping systems research (Cropping Systems Working Group 1976).

After extensive experimentation by IRRI and national programs, the Working Group expanded this framework into a methodology for on-farm research (Cropping Systems Working Group 1978, 1979). The research is related to a specific production environment, allows farmers to participate in the design and testing of new multiple cropping technologies, considers several commodities and crop-to-crop interactions, is multidisciplinary, and identifies clearly the different tasks of the research team members.

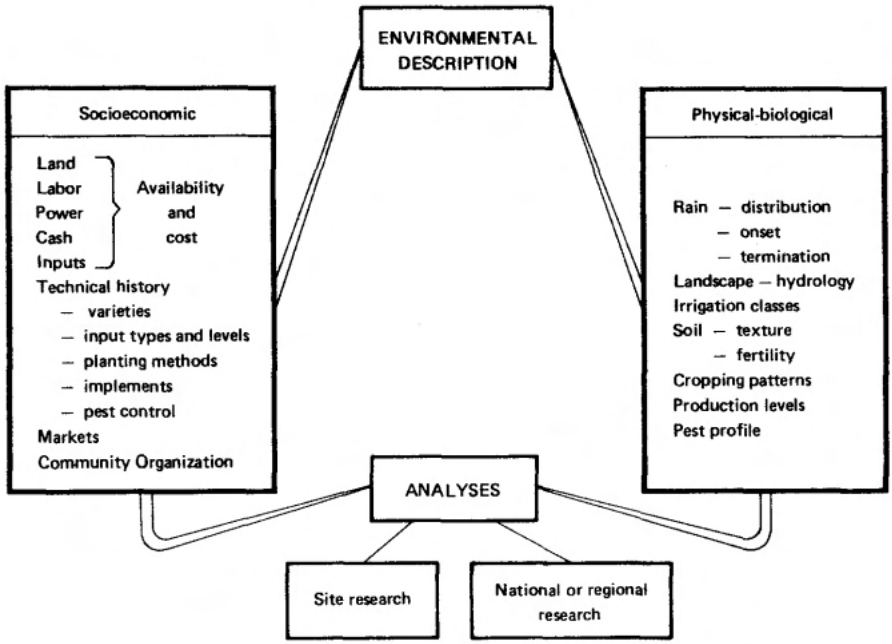
Site-related cropping systems research methodology

The framework for cropping systems research as developed by the Asian Cropping Systems Working Group has six phases. Research activities and instruments have been developed for each phase so that the type of research at a site is a result of the farm environment that prevails. The specific methods for each of the activities have been reported in the eight Working Group Reports (Cropping Systems Working Group Reports 1975-79). A brief description of the research phases follows.

Selection of the target areas. The target areas are geographical areas representative of a large homogeneous production zone. They should be priority areas for development by the national government, so that when the potential for production increases is demonstrated, support for production programs will be given.

Site description. The first activity is the description of existing cropping patterns, physical environment, constraints to production, and socioeconomic environment. The characteristics of the farm environment will decide research priorities at the site and supporting research stations (Fig. 2). At this time the area is divided into land types, each of which may require a different production recommendation.

Design of cropping patterns. Design includes the development of alternative cropping patterns that are well adapted to the area. Considering the physical and socioeconomic site characteristics, performance of cropping patterns and the available component technology for the crops in the pattern, numerous practices must be



2. Socioeconomic and physical-biological environmental factors need to be measured at the farm community level.

specified for all crops in each pattern (Fig. 3). Many can be specified on the basis of existing knowledge and local methods, but others require separate experiments. Component technology research may be conducted in national, regional, and other experiment stations or in the cropping systems research sites.

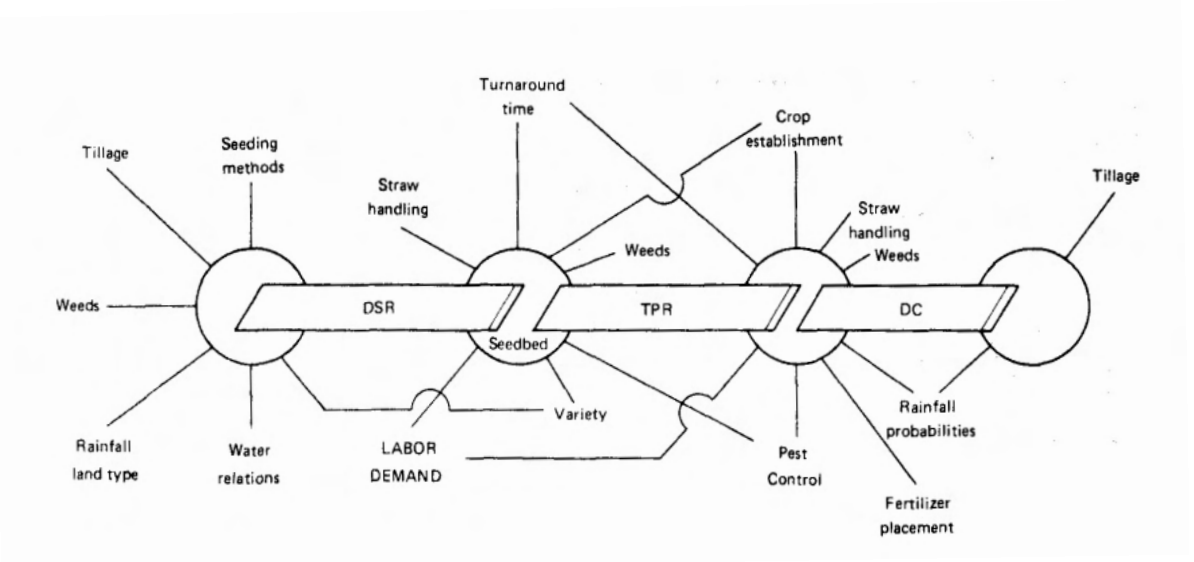
Testing of cropping patterns. The designed cropping patterns and selected management components are tested in their respective environments in farmers' fields (Fig. 4). Farmers participate by managing the cropping patterns, with frequent advise and constant monitoring by the research staff. Problems that limit intensification of production are identified and fed back to discipline- or commodity-oriented researchers.

Applied research and preproduction testing. The most profitable cropping pattern from the testing phase is evaluated in many sites within the intended environmental complex. In this phase, the researchers should include those institutions responsible for the formulation and implementation of production programs.

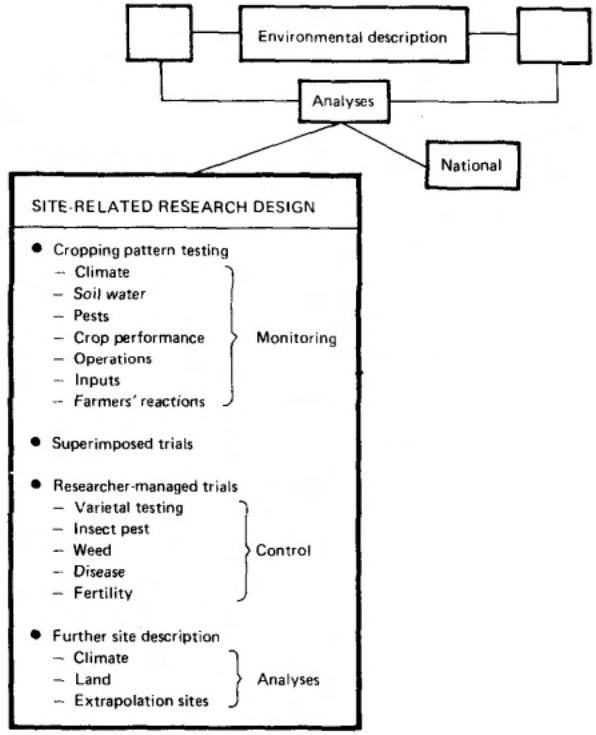
Production program formulation. As soon as promising cropping patterns are identified and their management is specified, extension institutions can start a production program. The research team should be involved in program formulation and training of extension workers for the production program.

INSTITUTIONAL REQUIREMENTS OF SITE-RELATED CROPPING SYSTEMS RESEARCH

The site-related research method is now applied by nearly 20 research teams throughout South and Southeast Asia (Carangal l977) (Fig. 5). Many teams receive



3. Assigning a component technology to a pattern requires a careful selection from many alternatives. DSR = dry-seeded rice, TPR = transplanted rice, DC = dryland crops.



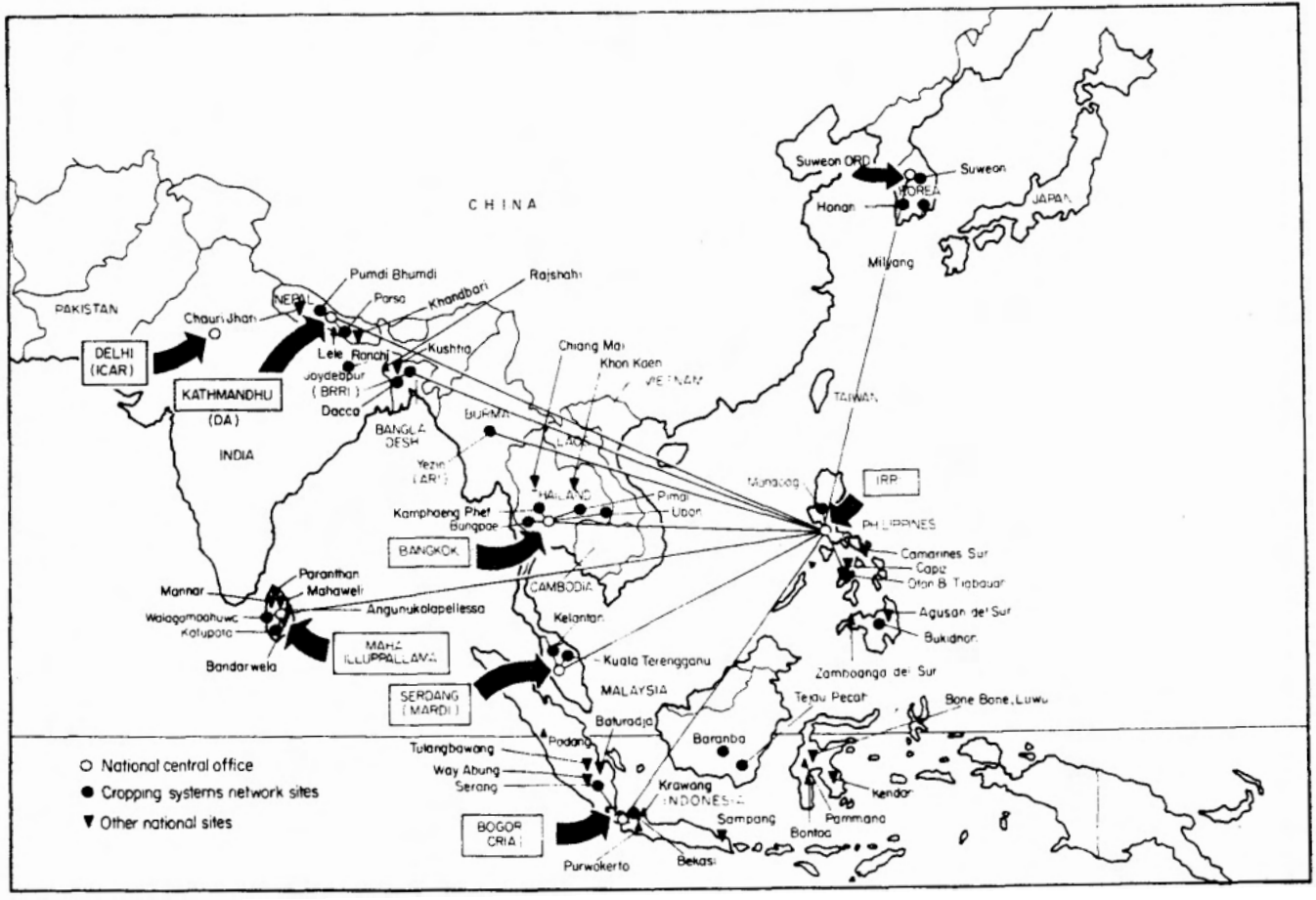
4. Research in farmers' fields assembles cropping patterns and fine-tunes component technology.

advice and backup from regional or central research stations and university-based senior staff in national programs. The capabilities required for the research model become clear as the on-site research proceeds.

At the site

The research team at the site is the instrument of cropping systems research. It is the contact point between the research structure and the on-farm reality it must address. It must be able to identify environmental complexes.

The team must be trained in farm survey methods to be able to determine the farm resource base and to identify the existing management practices and their relation to important governmental factors at the site. They must relate to the farmers and interpret the farmers' comments. In addition, the team must be able to plan and execute experiments, and analyze and interpret results. It must participate in the definition of research priorities for the site and in the planning of the experiments and surveys. The members must be encouraged to form a strong multidisciplinary unit that formulates hypotheses about the type of production technology required for the land types at the site. Thus, the team becomes a dependable source of information about farm-level production techniques and can critically evaluate the performance of technical innovations at the site. It is particularly important that the site team consult with local extension and irrigation personnel who can provide guidance in the selection of farmer cooperators and details about the technological history of the site.



5. The Asian Cropping Systems Network sites, 1979.

Regional and national support

Technical support. Experience throughout the network shows that the teams at the site derive strong motivation from the realization that they are addressing the real, everyday problems of farmers and that their solutions immediately affect the farmer-recipient group with whom they identify. In addition to this motivation, however, the teams need to maintain contact with research institutions and recent research results. They also need guidelines for environmental descriptions, research designs, farm surveys, experimental designs, and interpretation and presentation of results.

The research centers should have a group of specialists with advanced training and experience in site-related research. These technical support groups can comprise researchers at existing regional or national experiment stations. The teams' expertise can initially be built up by multidisciplinary team discussions at the stations and by work with other site teams. Ideally, national or regional technical support team members should be selected from outstanding site researchers that have received advanced training.

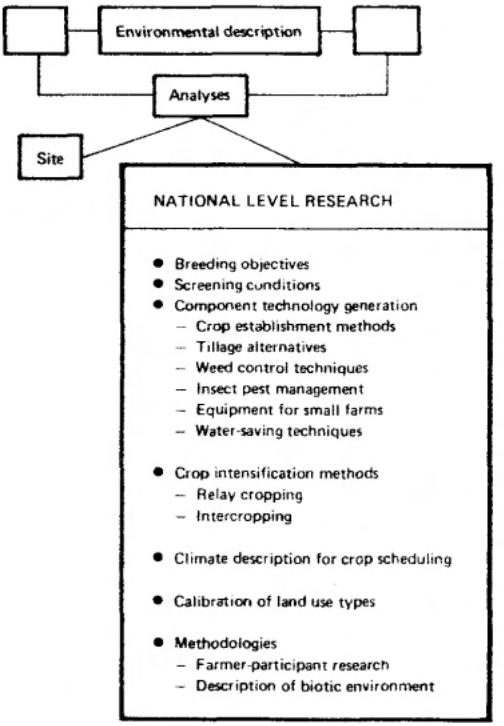
In addition to providing methodological and motivational backup to the teams, the support group provides contacts with experts for consultations on specific problems: identification of rare pests, minor element deficiencies, or disease problems. They also provide the link to analytical services.

Technology. Up to this point, cropping systems research has been discussed in terms of operations designed to incorporate available knowledge, processes, and materials (biological, physical, human, and institutional) into crop production methods suitable for identified environments with clearly defined farm resources and institutional support structures. The nature of site-related research forces the sites to depend completely on technology available to them. This comes from international, national, and university research on one hand, and from the farmers in the region on the other hand. At the national level, there is a need for continued backup by commodity- and discipline-oriented researchers to resolve bottlenecks to increased production identified at the farm level (Fig. 6). In addition, the national and international institutes must continue the development of on-farm research methods that will improve site operations. To achieve this, commodity- and discipline-oriented researchers should visit on-farm research sites and invite opinions on research needs and priorities.

Experiences with cropping systems research in the Asian Cropping Systems Network

The research methodology for cropping systems research continues to be strengthened by Working Group Committees, and the model is applied by national programs in more than 50 sites in 8 Asian countries. Results have advanced to production levels in Indonesia (McIntosh and Effendi 1979), Sri Lanka (tank-based system) (Fernando 1978), and Iloilo Province in the Philippines (Nicolas et al 1980). Countries collaborating in the network have identified several areas for future research.

Technical. Technical needs to ensure success of cropping systems research at the sites are:



6. National or regional research responds to problems identified in the sites.

- Techniques for obtaining active participation of farmers in the on-farm research process.
- Improved methods for evaluating performance of cropping patterns. Simple whole-farm budgeting techniques must be developed. Partial budgets of field-level cropping patterns now used ignore trade-off relationships between fields within the farm enterprise. Recent work by Barlow et al (1979) shows that techniques which capture these interrelationships can lead to a different performance ranking of alternative cropping patterns. Their linear programming-based whole-farm analysis values the major resources of land, labor, and capital according to their availability and to the demand for them at a particular time during the production process. The need for whole-farm maluations of alternative technologies was also recognized by Flinn (1979).
- Better methods of describing land and climate to improve our ability, to schedule crops and predict their performances (Morris et al 1979). Agroclimatic zones within the tropics, which are reasonably homogeneous with respect to land, soils, and climate, and therefore to crop adaptation, are relatively small. Agro-ecological zones in peninsular South and Southeast Asia appear especially small. The effects of landscape and associated hydrology on the duration of flooding and the availability of water to crops weaken our ability to describe the physical environment.

- Continued research on such crop intensification techniques as relay cropping, intercropping, and ratoon cropping.
- Specific methods for the delineation of environmental homologues to which results of cropping systems research can be extended.
- Methods for overcoming difficulties in crop establishment and weed control for dry-seeded rice.
- More research on crop establishment for dryland crops, particularly grain legumes, after wetland rice (Syarifuddin 1979). On medium- and heavy-textured soils, dryland crops following rice have access to sufficient water to complete their growth cycle with little additional rain, if there are methods to ensure good stand even where rains occur at seeding time. This research should include varietal screening for tolerance for wet condition at establishment and for drought after flowering.
- More information on the effects of land preparation methods for rice and the performance of dryland crops after wetland rice. It may be necessary to modify the rice culture to better accommodate dryland crop production after rice.
- In-depth studies to evaluate long-term effects of crop intensification on soil qualities, particularly in soils susceptible to erosion and in soils with a low cation exchange capacity.

Organizational. The research in a large number of sites in Asia has provided insights into the institutional constraints to on-farm testing of technology.

- The change from discipline- or commodity-oriented research on station to interdisciplinary multiple cropping-oriented research on farmers' fields is made difficult by the existence of research institutions and traditions that were not designed to cope with requirements of on-farm research.
- Institutions responsible for the generation of new production technology — a completely specified, carefully tested sequence of cropping management activities — should acquire capabilities in disciplines not normally represented among their staff. In most countries the capabilities in soil and land classification, soil fertility and crop improvement, farm management economics, climatic analysis, and irrigation and water management are in different departments or institutions of the Department of Agriculture.
- The location-specific and multidisciplinary nature of on-farm research requires intensive communication among researchers. This can only be achieved if the research is designed and interpreted by the team responsible for the field work. Decentralizing research can make the team an efficient instrument for understanding the farmer and his production system and for evaluating the performance of profitable alternatives. The network experience is that field teams accept this responsibility and are strongly motivated by the goal orientation of their research.
- Field teams require methodological and analytical backup from centrally located, experienced cropping systems researchers. The team needs to be continuously reminded of the need to understand *why* the farmers' production system and alternative technologies behave as observed. The team must be encouraged to build up an internally consistent model of the research site that incorporates results from surveys, experiments, and farmers' comments.

- The infrastructural support that operates in a target area greatly influences the technology that cropping systems researchers will generate. The relationship between institutional support for agricultural production and the level of production farmers and researchers should aim for needs careful analysis. A realistic understanding of the kind of credit, inputs, price, and market support that can accompany production programs will improve goal setting for on-farm research.
- Many aspects of cropping systems research are new and require the training of site teams and national support scientists. Leaders of country programs identified short-term training at IRRI and degree training and help with the establishment of in-country training programs as the first three priorities for IRRI support to the network (Hoque et al 1979).
- Experimentation with technology delivery system will broaden the understanding of ways in which to structure production programs. Community participation, alternative credit programs, and technical assistance methods will be needed to make site- or event-conditioned recommendations effective in the farm community.

NATIONAL CROPPING SYSTEMS RESEARCH PROGRAM

As shown earlier, the generation of environment-conditioned production technology requires capabilities in land classification, climatic analyses, crop protection, crop improvement, agronomy and farm management, economics, and, at times, irrigation management. But these capabilities are scattered over several institutions that have to satisfy other tasks in addition to those associated with technology development. The disciplines can be brought together in two ways:

1. The institution responsible for the generation of new production technology acquires capabilities in the disciplines not normally represented among their staff. This method avoids the need for complex interinstitutional arrangements. Another advantage is that once the organization learns to provide the needed support, there will be more recombination of knowledge within the institution, which is a prerequisite to the development of an interdisciplinary research method.
2. Several institutions combine efforts to provide the disciplinary mix required for cropping systems research. This means that interinstitutional teams are structured at the site and at regional or national support levels. Greater staffing flexibility and a consensus on policies for rural research and development are achieved. A disadvantage is that a lead agency that manages individuals seconded from other agencies is not familiar with their support needs and work methods. In addition, the institutions may have different reward structures, which can lead to conflicts in the research teams.

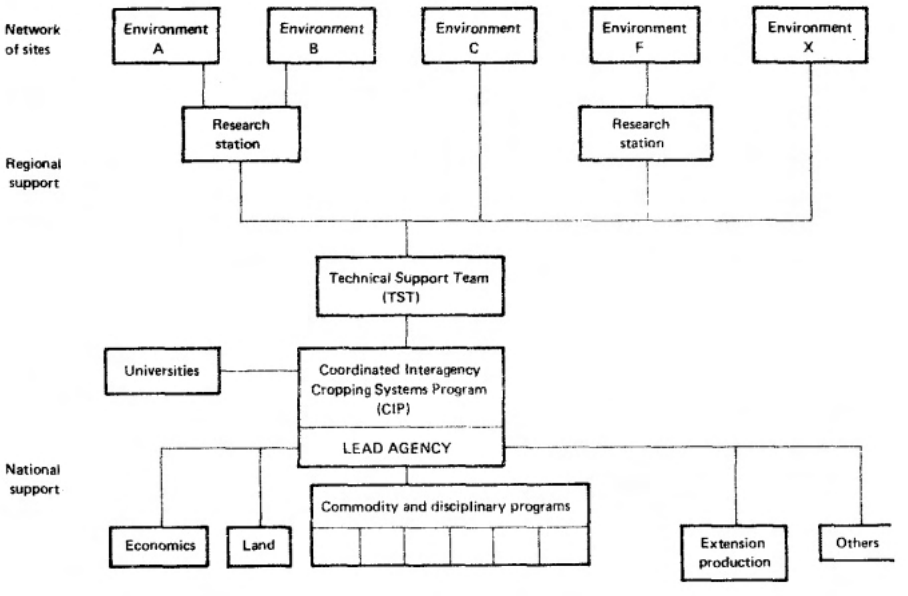
In spite of these problems, cropping systems research should not be independent of the present national research structure. The organizational setup should ensure that discipline and commodity experts at regional and central research locations participate in the structuring (design) and evaluation of site-related research. Conversely cropping systems research must communicate to commodity programs their

observations on priorities for on-station research.

An organizational scheme for a national cropping systems program is shown in Figure 7. A national coordinating committee (CIP) has representatives from all institutions involved in cropping systems research and development. It is chaired by a representative of the lead agency. At the national or regional level the CIP appoints a technical support team (TST)—a group of specialists with advanced training and experience in on-farm research composed of, where possible, a production agronomist, an economist, a land classification specialist, and an entomologist. The team provides operational and technical support to the researchers at test sites in the important production environments. It will also ensure feedback of technical and operational problems tu the CIP. The cropping systems test sites may be associated with a research station nearby. Staff from commodity and disciplinary programs at such stations can provide the associated test sites the results of component technology research. Researchers from the stations should be encouraged to visit the trials and conduct some of their own research at the site.

The site team can be composed of staff entirely from the lead agency, or it can combine staff from a number of agencies. One team member is appointed site coordinator and is responsible for operational supervision of staff. Technical supervision comes from the TST. The TST can also have a staff recruited from several agencies or from just the lead agency. This team should be located near the operational center of the cropping systems program and must be able to visit sites regularly.

On-site research teams should have adequate support from discipline and com-



7. Organizational setup of a national cropping systems program.

Table 1. Division of responsibilities among components of a national cropping systems program.

Program component	Responsibility
Network of test sites	Site description, design of improved patterns, testing. Formulation of recommendations, with support from TST.
Regional research stations (commodity and disciplinary programs)	Component technology research, varietal screening, long-term cropping pattern trials, performance of agricultural chemicals, operational support for nearby sites.
Technical support teams (TST)	Full-time team. Visits test sites to provide support in research design, experimental design, and analyses and interpretation; ensures feedback on technical and operational problems to the Cropping Systems Program Committee (CIP); identifies trainees, serves as trainer, organizes workshops, combines site results.
Coordinated interagency Cropping Systems Program Committee (CIP)	Sets policy, selects sites, structures staff complements at sites and in technical support teams, monitors methodology used, ensures feedback to commodity and disciplinary programs or departments, identifies training needs.
Commodity and disciplinary programs or departments	Conducts research on aspects of component technology, environmental classification, research methods and problems identified in on-farm test sites.

modity programs. But the success of cropping systems research depends also on the extent to which site teams can become effective, independent, analytical instruments. A major effort is required to train these researchers in farmer-participant research methods. Through decentralization of research decisions, the site teams must become increasingly instrumental in the formulation of their research. They must be responsible for the initial analyses and interpretation of their results. This often involves a change in institutional traditions: supervisors become supporters and advisors and administrators become providers and protectors.

Table 1 describes the responsibilities of the components of a national cropping systems program.

SUMMARY AND CONCLUSIONS

There has been a rapid increase in the availability of improved — often short-duration — crop varieties, early crop establishment techniques, pest management alternatives, farm machinery, and supplemental irrigation. To be useful to rice farmers these technological components must be carefully combined to fit the prevailing production environment. This requires a holistic approach to agricultural research that is oriented toward the combination of crop enterprises encountered on, or suitable for, the different land types in rice-growing regions.

In the formulation of such an approach, more manageable methods of summarization and evaluation of research results were required for the research teams.

The consideration of the farmer and his environment at an early stage in agricultural research has led to a multidisciplinary research method that places different demands on research management and institutions. Cooperation with representatives from national research organizations in South and Southeast Asia (Cropping Systems Working Group 1973 led to the formulation of a site-related cropping systems research methodology that focuses on the description and classification of the environment, on the design of improved cropping systems and their on-farm testing, and on methods for the formulation of production programs. Small multidisciplinary teams are now applying this methodology in more than 50 research sites in South and Southeast Asia.

A remaining challenge is that of providing institutional and technical support for site-related on-farm research. It is important because of the rapidly expanding number of cropping systems research sites.

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ESTABLISHMENT OF UPLAND CROPS BEFORE AND AFTER RICE

Tillage practices and methods of seeding upland crops after wetland rice

A. Syarifuddin K.

The importance of growing upland crops after flooded rice is indicated by the facts that:

- 54% of the total world's cropland area is in the developing countries, which have about 85% of the total world population (Framji and Mahajan 1969);
- two-thirds of the world's rice area is rainfed (Barker and Herdt 1978); and due to the rainfall pattern and the water needs of a flooded rice system, a single flooded rice crop is common practice in the rainfed areas.

Upland crops need high nutrient availability under oxidized soil conditions. a friable granular soil structure, and adequate soil moisture. Puddling for flooded rice, however, breaks down the soil aggregates; flooding changes the soil except for a few millimeters of the surface from an oxidized to a reduced condition. Because of puddling and flooding, the soil is very wet right after rice harvest and remains reduced for some time (Melhuish et al 1976). Upon drying the puddled soil becomes hard and has a high bulk density (Sanchez 1976). Phosphate is less available in a dried puddled soil than it was before puddling and flooding (Melhuish et al 1976. Willet et al 1977).

The conditions of a dried puddled soil are not favorable for growing upland crops (Bradfield 1970) and methods must be found to eradicate the contradictive requirements. The solutions could include cultural practices and crop adaptation and varietal approaches. In this paper I cover only tillage practices and method of seeding.

TILLAGE PRACTICES

Tillage improves soil aeration (Jensen et al 1964, Cooper 1971) and provides a good physical seedbed condition for plant germination and growth (Cooper 1971). But when it coincides with the onset of the dry season, it accelerates soil moisture loss (Sanchez 1976). which may be detrimental in the system of growing an upland crop after wetland rice. Many studies have shown a long turnaround period (TAP) in establishing upland crops after wetland rice. A long TAP may reduce the yield of an

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upland crop as a result of drought in the late growth stages. In Iloilo, Philippines, a 40-50 day TAP has been recorded (Magbanua et al 1977). A long TAP also occurs in other regions or countries (E. C. Price, IRRI pers. comm.).

There are several reasons for a long TAP. One is the lack of suitable soil moisture for tillage to achieve a good seedbed condition. In many cases this entails delays from 3 weeks to more than a month. During that period weeds grow and increase the cost of tillage.

A study by the Central Research Institute for Agriculture (CRIA) (1973-74, unpubl.) on a heavy alluvial clay soil in Indramayu, West Java, Indonesia, showed that zero tillage was promising for maize and soybean following wetland rice, although the yield of crops on zero-tillage plots was slightly lower than that on complete-tillage plots. The economic return from zero-tillage plots, however, was almost twice that from complete tillage. Another study showed that digging small drainage canals at 4-m spacings improved crop growth and production considerably on zero tillage.

An IRRI study (Syarifuddin 1979) with zero-tillage soybean showed a significant relationship between the percentage of established plants *(Y)* and soil moisture content (% oven-dry-weight basis) in the 0-5 cm layer at planting *(X)*.

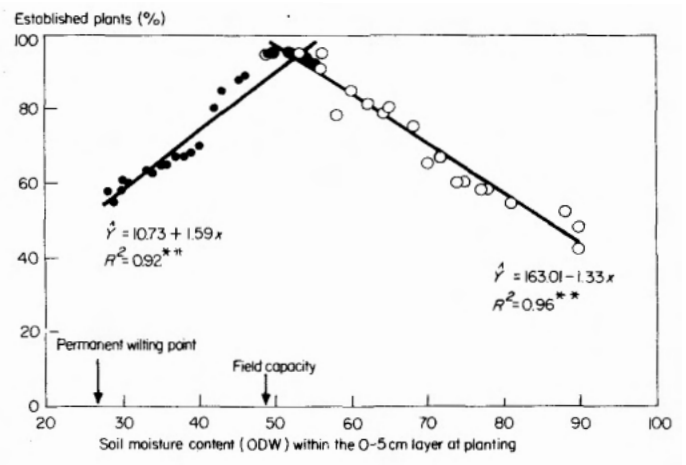
$$\hat{Y} = 163.01 - 1.33\ X \qquad (1)$$
$$R^2 = 0.96^{**}$$

for X ranging from 90 to 48%, and

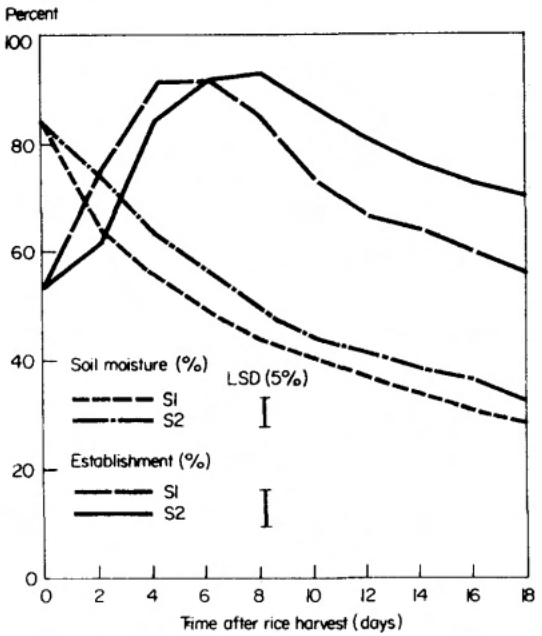
$$\hat{Y} = 10.73 + 1.59\ X \qquad (2)$$
$$R^2 = 0.92^{**}$$

for X ranging from 56 to 28 % (Fig. 1).

In the IRRI experiment the maximum stand for zero-tillage soybean was obtained when the soil moisture content (oven-dry weight) of the 0-5 layer at planting was 50-56%. This condition was obtained 4-6 days after rice harvest when rice straw was removed at harvest and 6-8 days after rice harvest when the rice straw



1. Relationship between soil moisture content and soybean establishment on no-tillage plots after flooded rice. IRRI, 1976 dry season. ODW = oven-dry wt (Syarifuddin 1979).



2. Relationship of soil moisture content of the 0-5 cm layer at planting and percentage of established soybean. S1 = straw removed at rice harvest, S2 = straw removed at soybean planting. IRRI, 1978 dry season (Syarifuddin 1979).

was removed at the soybean planting date (Fig. 2).

The results of this study and the 1973-74 study at Indramayu are similar. The problems arising from the zero-tillage method are:

- *Weed infestation.* The data for soybean showed that the dry weight of weeds on the zero-tillage plot was much higher than that on plots rototilled three times (Table 1).
- *Tillage requirements.* More tillage is required for the following rainy season

Table 1. Dry weight of weeds and time required for hand weeding at 27 days after seeding of soybean, as influenced by drainage and tillage treatments IRRI, 1978 dry season.

Tillage	Time from drainage to rice harvest[a]		
	21 d	11 d (control)	1 d
	Dry wt of weed (g/m²)		
No tillage (control	88.5 a	128.7 a	196.7 a
Furrow tillage	36.4 b	92.8 b	108.6 b
Bed tillage	32.7 b	81.6 b	121.9 b
One rototilling	12.5 c	17.7 c	23.6 c
Three rototillings	2.7 c	2.5 d	12.9 c
	Hand weeding time[b] (h/ha)		
No tillage (control	448 a	676 a	643 a
Furrow tillage	248 b	462 b	505 b
Bed tillage	248 b	486 b	500 b
One rototilling	148 c	176 c	195 c
Three rototillings	86 d	86 d	105 d

[a] In a column of the respective characters, means followed by a common letter are not significantly different at the 5% level. [b] Observation was done in minutes/ 35 m^2.

crop. Tillage is less for the rototilled soil because it forms a dry soil mulch on the surface and keeps the lower layer relatively wetter than in the zero-tillage plots (Bolton and De Datta 1977, Syarifuddin 1979).

The rainfed soybean crop stand was lower in the rototilled plot than in the zero-tillage plot (Table 2). The mean yield of the three-rototilling plot was lower than that of the zero-tillage plot; that of the one-rototilling plot was highest (Table 3).

The poor crop stand in the rototilled plots was due to low moisture in the soil surface, which affected germination (Fig. 3). The good individual crop performance

Table 2. Soybean plants/m^2 at 2 periods as influenced by drainage and tillage treatments. IRRI, 1978 dry season.

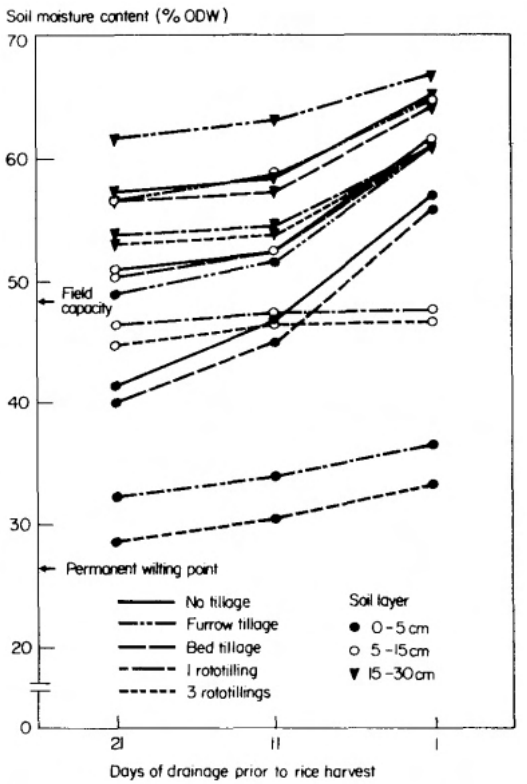
Tillage	Soybean plants (no., m^2) at indicated days from drainage to rice harvest[a]		
	21 d	11 d (control)	1 d
	10 days after seeding		
No tillage (control)	53 b	60 a	60 a
Furrow tillage	49 c	48 d	48 c
Bed tillage	53 b	52 c	51 bcd
One rototilling	38 a	56 b	52 b
Three rototillings	32 d	33 e	33 d
	2 days before harvest		
No tillage (control)	46 ab	58 a	58 a
Furrow tillage	42 b	40 b	40 c
Bed tillage	49 a	48 h	48 b
One rototilling	51 a	51 a	51 b
Three rototillings	26 c	28 c	28 d

[a]In a column of the respective observation dates means followed by a common letter are not significantly different at the 5% level.

Table 3. Grain yield and grain weight of soybean as influenced by drainage and tillage treatments. IRRI dry season, 1978.'

Tillage	Time from drainage to rice harvest			Mean
	21 d	11 d (control)	1d	
	Grain yield (kg/ha)			
No tillage	1,004 ab	1,157 a	1,247 b	1,136 b
Furrow tillage	463 c	470 c	559 d	497 e
Bed tillage	530 c	663 c	634 d	595 d
One rototilling	1,099 a	1,199 a	1,396 a	1,231 a
Three rototillings	903 b	886 b	1,076 c	955 c
Mean	800 ns	865	982	
	Grain weight (g/100 grains)			
No tillage	11.63 c	12.83 c	14.12 c	
Furrow tillage	11.04 c	12.62 c	13.47 c	
Bed tillage	12.93 b	13.66 bc	15.72 b	
One rototilling	13.50 b	14.76 b	15.98 b	
Three rototillings	15.11 a	16.09 a	17.45 a	

[a]In a column of the respective characteristics, means followed by a common letter are not significantly different at the 5% level.



3. Soil moisture content at soybean planting, as influenced by tillage treatments and times of drainage prior to rice harvest. IRRI, 1978 dry season. ODW = oven-dry wt (Syarifuddin 1979).

in rototilled plots was due to sufficient soil moisture in the lower soil layer, which was conserved by the pulverized, dry-mulched surface soil. Weed infestation was low in the rototilled plots.

The weaknesses of rototilling (complete tillage) are:

- the generally long TAP between rice harvest and crop establishment, which reduces crop intensity;
- the high cost for tillage; and
- because of the long TAP, the danger that extremely dry weather at the late crop stage may drastically reduce crop yield.

METHOD OF SEEDING

The best method of seeding an upland crop following wetland rice depends on the crop, soil, and weather conditions at planting time. If the soil is too wet, dibbling seed into the soil should not be done because most upland crops will not germinate in a reduced soil. Drilling seeds onto the soil surface provides sufficient water through seed contact with the soil. As the soil surface dries the crop roots penetrate to the

lower layer where the moisture is still high and the oxygen concentration has gradually increased. Surface drilling, however, usually results in a poor stand and the method is not recommended as a general practice.

Broadcasting soybean into a standing rice crop 2-4 days before harvest is a common practice in Java, Indonesia. In Pangasinan, Philippines, farmers broadcast mungbean into rice stubble soon after harvest. In Burma and Thailand mungbean is broadcast into standing rice 1-2 weeks before harvest. This method is simple and inexpensive, but it is not applicable to all conditions. If the rice crop lodges or the paddy soil surface is too dry, the upland crop will fail.

Even under suitable conditions, as much as 25-30% of the seeds do not germinate. The soybean stand was slightly increased when seeds were drilled in between rice rows instead of being broadcast, and by soaking them about 24 hours before sowing (Table 4). The stand was greatly increased by doubling the amount of seeds. In plots where soaking, drilling, and doubling the amount of seeds were practiced, the stand was significantly better than that in plots where the three methods were not practiced. However, drilling the seed between standing rice rows is not a simple practice.

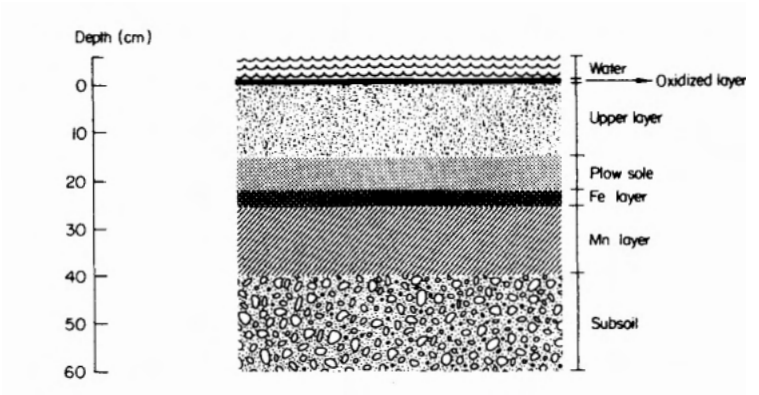
Dibbling seeds of field crops into the soil is practiced in many places. If the soil is too wet, dibbling is delayed until the soil moisture conditions are suitable. On the other hand, if the soil is too dry, small furrows are made to reach the wetter soil layer. With the latter, however, nutrient uptake imbalance may occur.

Koenigs (1950) described high Fe- and Mn- layers in wetland rice soil at about the 22-40-cm depth (Fig. 4) and dibbling in furrows places the seed close to those layers. In the study at IRRI, manganese deficiency occurred in soybean planted in a furrow (Table 5) (Syarifuddin 1979). Knezek and Greinert (1971) reported on soils high in manganese and iron, manganese deficiency or iron toxicity may depend on soil pH. For soil with pH <6 iron toxicity may occur; for soil with pH >6 manganese deficiency may occur.

Table 4. The stand at 10 DS and 2 days before harvest and yield of soybean relay planted into puddled flooded rice as influenced by seeding methods, seed soaking, and seeding rates. IRRI, 1978 dry season.[a]

Seeding methods and seeding rates	Stand (plants/m^2) at 10 DS	Stand (plants/m^2) at 2 DBH	Expected stand (plants/m^2)	Mean yield (t/ha)
Broadcast, unsoaked				
60 kg/ha	43 g	42 g	60	1.31 f
120 kg/ha	61 cd	61 cd	120	2.12 bc
Broadcast, soaked				
60 kg/ha	48 f	47 f	60	1.55 e
120 kg/ha	65 bc	64 bc	120	2.22 b
Drill, unsoaked				
60 kg/ha	53 e	53 e	60	1.77 d
120 kg/ha	68 b	67 b	120	2.24 b
Drill, soaked				
60 kg/ha	58 d	58 d	60	2.02 c
120 kg/ha	88 a	88 a	120	2.61 a

[a] In a column, means followed by a common letter are not significantly different at the 5% level. DS = days after seeding, DBH = days before harvest.



4. Puddled flooded rice soil profile, near Bogor, Indonesia (Koenigs 1950).

Dibbling seeds into a loose rototilled soil often results in a poor stand (Table 2) because the soil moisture in the top soil layer is low. Many experiments have shown this phenomenon (Chaudhary and Prihar 1974). The crop stand can be increased by light compaction around the seed (Hadas and Russo 1974, Dasberg et al 1966).

CONCLUSION

Based on the tillage and seeding method discussed a recommended practice can be proposed. The upland crop is planted with zero tillage. If the soil is too wet at planting time, small drainage canals spaced 4–5 m can shorten TAP. Rice straw is used as mulch between crop rows to reduce moisture loss and reduce weed infesta-

Table 5. Nitrogen, phosphorus, potassium, iron, manganese, and zinc contents at 63 days after seeding of soybean grown after wetland rice as affected by mulching and planting methods.[a] IRRI, 1978 dry season.

Planting method and mulching	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Iron (ppm)	Manganese (ppm)
Drill-relay					
No mulch	3.43 a	0.32 b	1.97 a	138 c	140 a
Mulched	3.38 a	0.32 b	1.94 a	138 c	133 ab
No tillage					
No mulch	3.37 a	0.33 b	1.96 a	145 c	129 ab
Mulched	3.49 a	0.32 b	1.94 a	138 c	127 b
Funow-tillage					
No mulch	3.01 b	0.44 a	1.64 b	491 a	66 c
Mulched	3.12 b	0.46 a	1.60 b	421 b	65 c
One rototilling					
No mulch	3.42 a	0.31 b	1.97 a	125 c	125 b
Mulched	3.45 a	0.32 b	1.96 a	130 c	122 b

[a]In a column, means followed by a common letter are not significantly different from each other at the 5% level.

tion. A supplemental recommendation is shallow interrow cultivation or rototilling — at the right soil moisture content —after establishment with zero tillage. Mulch can be applied after the interrow cultivation.

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DISCUSSION

Upasena: Zero tillage has given the best method of stand establishment. In Sri Lanka, in on-station trials where legumes were grown after rice, the method of establishment was zero tillage.

But when you try to extrapolate this information to bigger and wider production complexes, other environmental factors interact. Topography, and the drainage characteristics of the soil type, play the most significant role. Sudden showers cause accumulation of water on rice paddies on plains and create a perched water table that makes conditions unfavorable for good stand establishment. Therefore the decision on which type of land preparation to use for establishment should be linked with the topography and drainage characteristics of the soil type. Zero tillage may be best for the upper areas of the plateau but full tillage or the bed and furrow system may be best for the plains.

Syarifuddin: I agree. We had some experiments on plains where drainage was poor and the bed or furrow system seemed appropriate. We found that it was best to dig small furrows and dibble the seed between the furrows. When the temporary flooding was deep, we piled the soil from the furrows on the bed and dibbled the seed into the bed.

Hobbs: Did you try seeding soybean directly into rice stubble rather than in the soil? Any results?

Syarifuddin: The seeds were dibbled into the soil, not into the rice stubble. I am not sure if there is much difference between the two. Our experiment in Indonesia did not show a significant difference, but seeding into the stubble gave slightly better results than seeding into the soil.

Chatterjee: In the Gangetic plains of most of Bengal (India) at 23 °N latitude with short and mild winters, experiments carried out for 3 years on silty loam showed that wheat, rape and mustard, safflower, sunflower, winter maize, and lentil can be drilled without tillage into rice fields (when soil is wet to field capacity) and the crop yields are as good as when the crop is sown after conventional tillage. That helped in early and timely sowing of the crop in the mild and short winter of W. Bengal.

Pretreatment of seeds with water (6 hours) or Na_2HPO_4 solutions (358 ppm for 6 hours) and drying them to normal seed moisture (10-14%) before sowing helped in increasing better stand establishment. The seedling growth was vigorous.

Placement of fertilizers showed advantage over broadcasting.

In unirrigated fields, utilization of stored soil moisture was better in minimum tillage than in normal tillage. In normal tillage the topsoil (0-15 cm) dried earlier.

Effect of soil moisture and texture on the growth of upland crops after wetland rice

H. G. Zandstra

Upland crops after wetland rice are often either damaged by excessive moisture at the critical period of crop establishment, or hurt by drought at the equally critical period of flowering and grain filling. Fortunately, a wide range of crops are available for production after rice, and maturity ranges are from 60 to more than 120 days. In several countries, some of these crops offer a potential value product that approaches that of a wet-season rice crop. From the point of view of the researcher and the farmer, this should provide a strong rationale for tracing back through the previous crops in the cropping pattern and to make adjustments that allow the more favorable "location" of the postmonsoon upland crop.

This paper describes the soil moisture conditions that prevail at the end of the monsoon period, and the climate and soil factors that influence them. It also discusses the effects of these conditions on upland crops produced after wetland rice and the management methods that can be considered to favor upland crop production. At times, the discussion is based on speculation about mechanisms associated with soil water or crop behavior, primarily to indicate future research needs.

THE POSTMONSOON GROWING CONDITION

Rice-based cropping systems differentiate into three major groups: dryland, rainfed-wetland, and irrigated wetland. Wetland rice culture encourages accumulation of water on the soil. It uses land, the rooting zone of which can be kept saturated for a substantial part of the rice-growing season.

The rainfed-wetland growing season can be divided into the dry season, the premonsoon moist period, the wet period, and the postmonsoon moist period (Fig. 1). The transition between the wet period and the postmonsoon moist period and the duration of the postmonsoon moist period are critical to upland crop production.

Regions vary in the rate at which the monsoon period ceases (Fig. 2). A slow rate of termination leads to a long postmonsoon moist period. In the tropics, the rate of termination generally increases as the location is further removed from the equator. Between 10° N and 10° S the dry season may be absent, so that the postmonsoon

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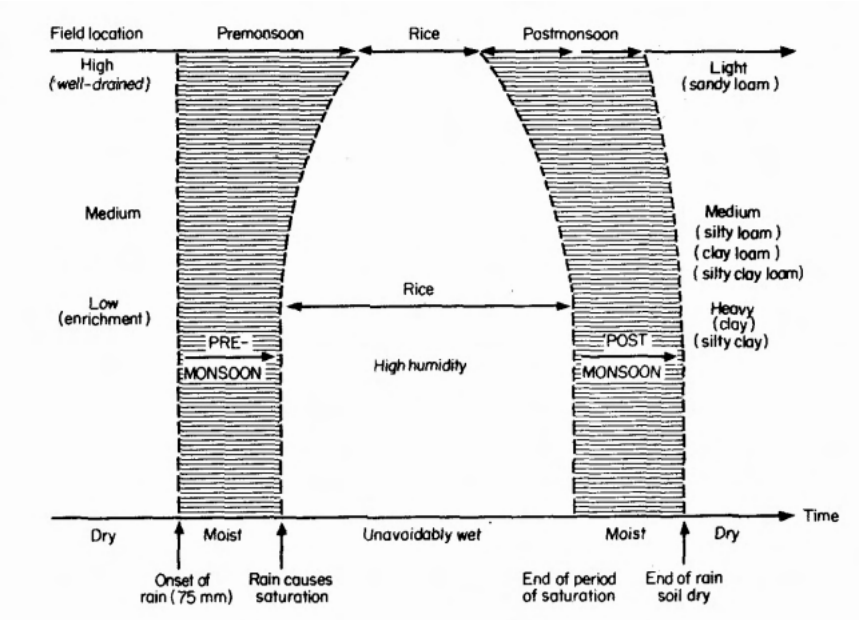
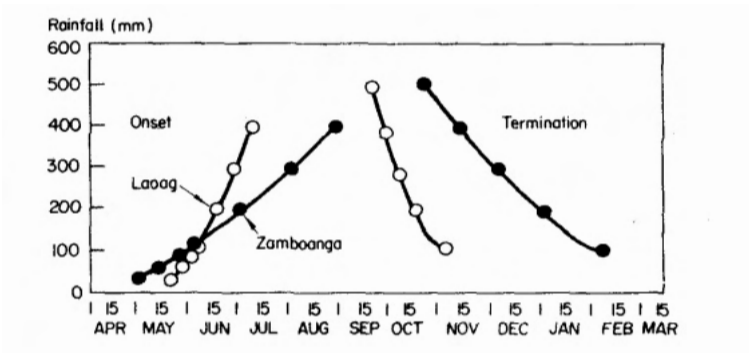


1. The growing season components of wetland rice-based cropping systems.



2. Rainfall accumulated after 1 April (onset) and rainfall still to occur before 1 April (termination) at different dates for northern (Laoag) and southern (Zamboanga), Philippines (*P* = 0.70).

moist period runs into the premonsoon moist period.

For a given rainfall regime, the termination of the wet period varies according to field characteristics. The wet period ends when lack of water addition allows the topsoil (30 cm) to drain. This can be substantially influenced by management. If farmers open paddy dikes early and provide within-field drainage by peripheral ditches, the onset of the postmonsoon dry period will be hastened. This assumes that the groundwater level is below the field surface. In some river basins, continued high river discharge may maintain groundwater levels above the surface (flooding), well past the end of the rainy season. If rains are still substantial, however, they will

exceed the ability of heavy-textured (clay, clay loam, and silty clay loam) soils to dispose of water in excess of field capacity through percolation. Periods of 4 to 10 days when most of the root zone is saturated will occur with consequent damage to upland crops.

During the postmonsoon period, the soil water content reduces from above field capacity to the point where all extractable water has been used by the crop and the topsoil water reduces toward the hygroscopic moisture content. The duration of this period greatly influences the possibility for upland crop production after rice. In areas where rains drop abruptly from more than 200 mm, month to less than 75 mm, month, upland crops depend primarily on water stored in the soil profile or that provided by a shallow water table.

THE RAINFED POSTMONSOON UPLAND CROP

Water supply in wetland fields

In the absence of irrigation, postmonsoon upland crops have access to three sources of water: water stored in the part of the soil profile to which roots have access, water provided to the rooting zone from a lower-lying water table, and water from rainfall or dew.

Stored water within the rooting zone depends on depth of rooting (30 to 150 cm) and the amount of available water held per unit depth of soil. The available water varies according to soil texture and organic matter content. Water held between field capacity and wilting point (available water) ranges from 40 (sands) to 250 mm (clays) per 100 cm soil depth. In addition, wetland soils can hold substantial water between field capacity and saturation just after surface drainage. This amount varies from 300 mm (light-textured soils) to 100 mm (clay) per meter soil depth.

Groundwater contribution depends on the depth of groundwater over time and on soil texture (Doorenbos and Pruitt 1975). It is useful to contrast ‘‘true’’ groundwater and perched groundwater. True groundwater is continuous to great depths and does not disappear in the dry season. Its fluctuation is controlled by contributions from adjacent hills and mountains through rivers and subsoil strata as well as that from rain received in situ. The withdrawal of the true groundwater table is generally not as rapid as that of the perched water table. Perched groundwater occurs in higher-lying landscapes, is generally separated from true groundwater by unsaturated soil, and generally disappears during the dry season. The perched water table fluctuates more rapidly than the groundwater table because it depends on in situ rainfall and on localized lateral water movement in the shallow subsoil.

Groundwater can recede at different rates. The measured recession of perched groundwater has been in the order of 3 to 6 cm day during rainless periods and is generally greater in higher-lying fields. At a groundwater depth of 1 m below the root zone, contribution to the root zone can be greater than 1 mm/day only for fine sandy loams. With groundwater at 50 cm below the root zone, contributions range from 1 to 5 mm for most wetland rice soils, but can satisfy evaporative demands above 10 mm/day in the case offinesandy loams (Doorenbos and Pruitt 1975). Groundwater contribution to the root zone, therefore, takes place during 5 to 15 days when groundwater recedes through the soil layers up to a depth of about I m below the

root zone (for some very fine sandy loams, contribution continues from groundwater depth up to 3 m). For most wetland soils, this contribution is about 25 mm of total water in about 10 days for each ground water recession, but in some soils it may well reach 100 mm in 15 days.

Direct measurements of groundwater contribution in undisturbed soils are lacking. Substantial effects from textural discontinuities and traffic pans undoubtedly exist, but are also poorly documented.

Rainfall is essential for non-irrigated postmonsoon upland crop production on light-textured wetland soils with a deep or rapidly receding water table. In these soils, groundwater contribution is minimal and little water is held in the profile. At the other extreme on heavy-textured soils, rainfall can lead to damage due to excess water. In addition, soil water stored in the upper 80 cm of the soil can be as high as 250 mm just after surface drainage, so that the crop becomes less dependent on rainfall or groundwater contributions. The estimates presented in Table 1 demonstrate the range in contributions from stored profile water (just after drainage of rice fields) and groundwater and the amount of rainfall required to meet the 375-mm water requirement of a crop such as mungbean.

Water demand of a rainfed postmonsoon upland crop

The evaporative demand is one of the most important factors determining crop water requirements and water loss from the soil surface. In rainfed wetland regions of the tropics, evaporative demand as measured by class A pan evaporation increases from 4 to 6 mm/day during the period in which most fields have standing water to 8-1 2 mm/day during the peak of the dry season. Where temperatures drop during the postmonsoon period, evaporative demands may be lower, e.g. 6-7 mm/day.

Table 1. Estimated rainfall requirement and the contribution of other sources of water for growing a postmonsoon upland crop planted immediately after drainage of the rice field in different land types. Crop water requirement is assumed as 375 mm.

Soil texture	Estimated contribution of water sources[a] (mm)								
	Deep water table								
	Fast receding perched water table			Slowly receding perched water table			Shallow water table[b]		
	R	SW	GW	R	SW	GW	R	SW	GW
Heavy (clay, clay loam, silty clay loam)	100	250	25	15	250	50	50	250	75
Medium (sandy clay, sandy clay loam, loam, silty loam, silty)	200	I50	25	I50	I50	75	100	I25	I50
Light (sandy loam, loamy sand, sandy)	300	15	0	200	15	100	< 50	15	> 250

[a] R = rainfall required to complete the 375-mm crop requirement, SW = available soil water in 80 cm of the profile at planting time, GW = water contributed by capillary rise to the actual root zone. [b] Within 2 m of soil surface for 30 days after upland crop planting.

Potential evapotranspiration of the crop varies throughout the growing period. Assuming an evaporative demand of 7 mm/ day, it increases from about 3 mm/day during crop establishment to 8 mm/day during maximum growth, and decreases to 2 mm at the final ripening stage.

The growing-period water requirements of upland crops range from 300 to more than 1,000 mm (Doorenbos and Kassam 1979), depending on growth duration, evaporative demands of the atmosphere, and crop characteristics. For a 70-day mungbean crop, total water requirements (in the absence of stress) would be about 375 mm. On the basis of soil water extraction, Angus et al (1979) found acceptable mungbean, cowpea, and sorghum yields on a dryland soil at IRRI with only 238-306 mm of water (Table 2). These measures were obtained when the class A pan evaporation averaged 6 mm/day and do not include water loss incurred during plowing and harrowing (probably about 20 mm).

Crops with longer growth duration require more water as shown by estimates published (Doorenbos and Kassam 1979) for soybean (100 days, ~ 450 mm), maize (100 days, ~500 mm), sorghum (100 days, ~450 mm) and peanut (90 days, ~500 mm). Short-duration varieties such as a 75-day maize variety will, therefore, require less water (probably 400 mm) and have greater probability of success as a postmonsoon crop. A comparison of these water requirements with the estimated groundwater and soil moisture contributions in Table 1 indicates that crops with growth durations longer than 100 days would need much rainfall during their growing season. In wetland fields, this can only be achieved without flooding on light-textured soils where the rainfall slowly recedes at the end of the monsoon (e.g. Zamboanga in Fig. 2).

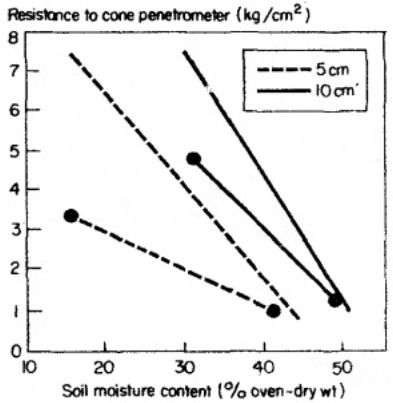
Rooting depth of upland crops in wetland fields

In most recently drained fields, soil moisture contents will be high enough to keep mechanical impedance to levels that will not inhibit root growth. Maximum soil densities occur in lighter-textured soils and medium-textured soils that lack swelling clays. Upon drying, previously puddled clay soils also rapidly become impenetrable to roots (Tayloret al 1964). Syarifuddin and Zandstra (1978a) showed that puddling of wetland soils increased mechanical impedance at 5- and 10-cm depths, particularly at low soil moisture contents (Fig. 3). It is, therefore, important to ensure that

Table 2. Production and water use of eight crops under rainfed dryland conditions (Angus et al 1979).

Crop	Yield (t/ha)		Total crop[b] water use (mm)
	Dry matter	Grain[a]	
Mungbean	2.1	1.2	238
Cowpea	2.8	1.3	268
Soybean	1.7	0.6	198
Peanut	3.7	1.0	364
Sorghum	6.8	3.6	306
Maize	7.6	1.6	258
IR36 rice	1.6	0	203
C-171 rice	2.3	0	200

[a] At 12% moisture. [b] Estimated from soil water depletion from sowing to harvest plus rainfall (98 mm) and irrigation (30 mm) at sowing.



3. Relationship between soil moisture content and penetrometer resistance in puddled and unpuddled (with dots) Lipa clay loam at 5-and 10-cm depth.

crop roots can reach lower layers of the soil profile before a reduction in soil moisture content increases soil impedance to an extent that limits root growth.

Oxygen contents can also limit root growth. Previously puddled clay soils have little coarse pore space. At higher soil moisture contents, root growth may, therefore, be reduced or prevented (Gill and Miller 1956). Oxygen contents will normally not be limiting in medium- and light-textured soils. Syarifuddin (1979) found that maize planted on a recently drained previously puddled clay loam with a water table at 65 cm still had active roots down to the 50-cm depth.

Little is known about the precise conditions around the roots of upland crops that penetrate a drying, shrinking, originally reduced clay soil. At high moisture contents, lack of oxygen may reduce root growth; but once the moisture content of the root zone drops, low hydraulic conductivities may prevent the plant from satisfying its moisture requirements. In addition, increased soil strength may reduce root penetration. The extent to which plow pans reduce rooting depth and thereby subsoil water use also needs more research.

Effects of crop management on water use

Establishment of upland crops. Upland crops after wetland rice can be established in several ways, each of which loses different amounts of water. After surface drainage of rice fields, water loss from the soil is rapid, satisfying evaporative demands (7 mm/day) during the first 2 days and losing water at $6/\sqrt{t}$ for every day (t) after that (based on Syarifuddin 1979). Thus, water loss was 41 mm after 5 days and 48 mm after 10 days. Maintenance of standing rice straw in the field reduced water loss in the 0-5 cm and 5-15 cm layers. After 10 days, plots in which 20 cm of straw was kept standing had lost 6 mm less water than fields in which straw was cut at the level of the soil.

Tillage operations can substantially reduce topsoil moisture contents. A single rototillage of a field at field capacity led to a loss of 12 mm water, mostly from the 0-5 cm layer, and brought it close to the wilting point. Plowing followed by rototillage led to a loss of 20 mm water from the soil profile (Syarifuddin and Zandstra 1978a).

Crop establishment without tillage can therefore lead to considerable water savings in medium- and heavy-textured soils. By allowing immediate crop establishment, water loss from the field during the first 5 days (some 40 mm) is avoided; and by not disturbing the soil, a water saving of 15 to 20 mm is achieved. Most of this water is from the top 15 cm of the soil and is necessary to ensure germination and early crop growth in plantings that cannot depend on rainfall for crop establishment. Under these conditions, rice fields should not be drained until just before (1-2 days) rice harvest.

Relay cropping can further ensure the early establishment of upland crops and root penetration to lower layers before soil moisture is depleted. Relay broadcasting is particularly suitable for legumes, but it should be practiced only when topsoil moisture contents are close to saturation.

Mulching. Mulching decreases soil temperatures and reduces evaporation from the soil, particularly at the 0-15 cm depth (Benoit and Kirkham 1963). Mulching can reduce soil temperatures as much as 15° C at the surface or 5° C at 15 cm. Reduced evaporation substantially increased the water use efficiency of maize in dryland soils (Harold et al 1959). In wetland soils, Lantican (1977) grew 20 soybean and mungbean varieties after rice with zero tillage. These yielded 0.78 t/ha and 0.55 t/ha without mulch, but 1.57 t/ha and 0.99 t/ha with mulch.

Syarifuddin and Zandstra (1978a) found similar yield increases in maize (Table 3) and soybean (Table 4) grown after wetland rice. The effect of the mulch was greater in zero-tilled than in rototilled plots, because rototillage already reduced water loss from lower soil layers (at the cost of drying up the 0-5 cm layer). The use of mulch on the maize plots substantially improved fertilizer availability and, thus, root growth

Table 3. Effect of fertilizer rates, mulching, and fertilizer placement (5- and 20-cm depths) on the yield of maize grown after puddled wetland rice.

Fertilizer (NPK) rate (kg/ha)	Maize grain[a] (t/ha)			
	No mulch		Mulched	
	5 cm	20 cm	5 cm	20 cm
0-25-50	0.38 f	0.63 f	0.55 f	1.02 e
60-25-50	1.14 e	2.05 e	1.84 cd	2.82 b
120- 0-50	1.03 e	1.99 cd	2.00 cd	2.05 c
120-25-50	1.74 d	2.85 b	2.64 b	3.15 a

[a] In a column, means followed by the same letter are not significantly different at the 5% level.

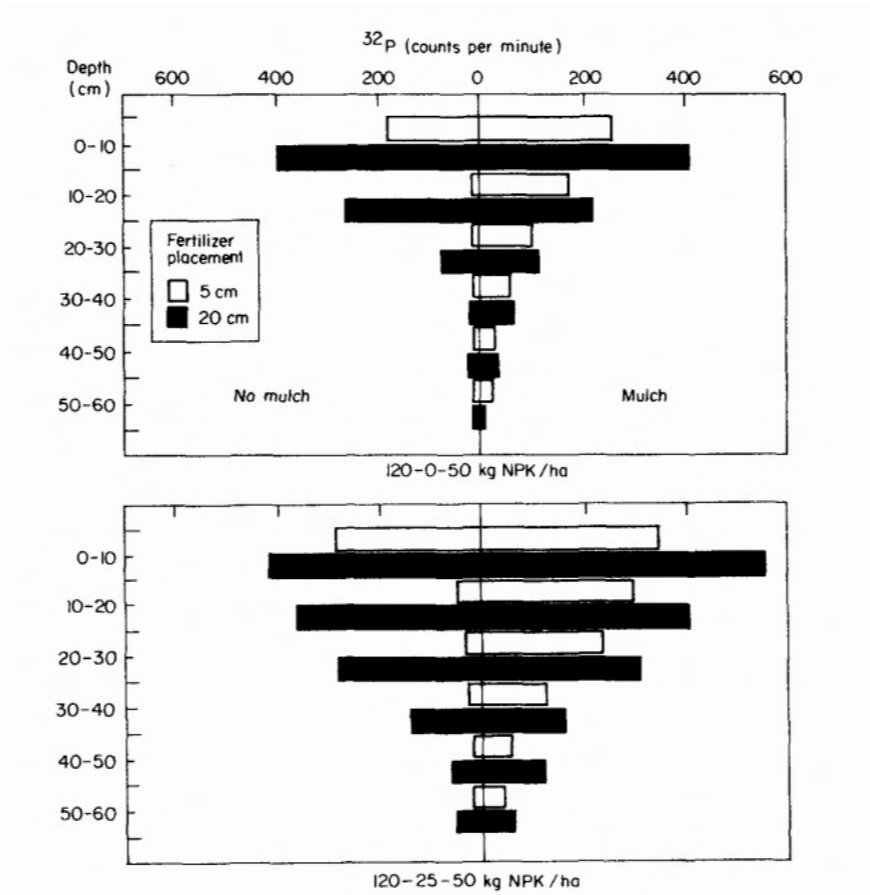
Table 4. Grain yield of soybean as influenced by planting methods and mulching.

Planting methods	Grain yield[a] (t/ha)	
	No mulch	Mulched
Drill, relay planting	0.52 e	1.09 c
Dibbling, no tillage	1.38 b	1.90 a
Seeding in furrow, tillage	0.38 f	0.77 d
Row drilling, 1 rototilling	1.64 ab	1.97 a

[a] In a column means followed by the same letter are not significantly different at the 5% level.

(Table 3, Fig. 4). Mulching also reduced soil cracks and the associated moisture loss by evaporation from the lower layers. In unmulched plots, the topsoil rapidly dried out. The added fertilizer became unavailable and plants grew so poorly that they did not extend their roots to the moist subsoil.

Fertilization. It is known that crops grown with adequate nutrient supply have a higher water use efficiency than those suffering from nutrient deficiencies. During the postmonsoon growing season, rainfed wetland soils change from a reduced state to an oxidized state. This leads to lower phosphorus availability. In wetland fields that remain reduced for a long time after upland crop planting, zinc deficiency may be a problem, particularly in fields with water of high pH. In addition, the several wetting and drying cycles that rainfed wetlands often pass through at the end of the rice-growing season reduce nitrogen fertility. Nonleguminous crops, therefore, generally require a basal application of nitrogen and phosphorus fertilizer, and leguminous crops will generally benefit from basal phosphorus fertilizer.



4. Root distribution, indicated by ^{32}P counts at different depths, as influenced by fertilizer rates, mulching, and depths of fertilizer placement.

Because the topsoil dries rapidly, fertilizer should be placed deep where the soil stays moist well into the rapid growth phase. Syarifuddin and Zandstra (1978b) found substantial responses, in terms of nutrient uptake and yield, to deep (20 cm) placement of fertilizer for maize, particularly in the absence of a straw mulch (Table 3). This response was associated with greater rooting activity (Fig. 4) and water absorption in the subsoil.

Deep placement of fertilizers poses severe operational problems, particularly in areas where labor is scarce. Special machinery for this purpose may need to be developed.

Effects of flooding. Upland crop production is limited during the wet period of the growing season (Fig. 1) because of intermittent flooding and high atmospheric humidity. The transition of the wet period to the postmonsoon dry period is difficult to predict so that short periods in which the topsoil is saturated can recur several times after the initial drainage of wetland fields.

The frequency of these flooding periods in heavy-textured low-lying fields will be low. These fields have low percolation rates and accumulate drainage water from higher-lying fields. They tend to stay wet until the probability of high-rainfall storms is low. The lighter-textured, higher-lying fields will drain earlier in the season when substantial rain is still expected. These fields are susceptible to short periods of topsoil saturation. A given amount of rainfall, e.g. 100 mm in 2 days, however, leads to much longer periods of flooding or topsoil saturation in the heavy textured, low-lying fields or in fields with a shallow water table.

Results from a well-drained dryland field of IRRI showed that flooding for more than 4 days in the early growth stages substantially reduces yields of maize and soybean (Table 5). On previously puddled heavy-textured soils, internal drainage is poor and the soil may still be substantially reduced so that effects of flooding are prone to be more severe than those described in Table 5. Mungbean and peanut have shown greater susceptibility to flooding than soybean, whereas sorghum is comparatively tolerant (Herrera and Zandstra 1979). Observations from screening trials showed that considerable variation exists between the tolerance of different cowpea varieties for short-duration flooding in the early establishment phase. In many cases, damping-off caused loss of stand and early vigor.

Planting times

Aside from considerations relating to the schedule of previous crops in a pattern, the best planting time should assure sufficient water to the crop and avoid severe crop

Table 5. Effect of flooding duration at 15 days after seeding on yields of maize and soybean.

Flooding duration (days)	Grain yield[a] (t/ha)	
	Maize	Soybean
0	4.68 a	1.15a
4	3.91 ab	1.06 ab
8	3.04 b	0.81 b
12	1.95 b	0.84 b

[a] In a column means followed by the same letter are not significantly different at the 5% level.

damage or loss due to excessive moisture. Because rainfall requirements for upland crop production (Table 1) and drainage characteristics vary widely for different land types, the best planting time will also vary.

On light-textured soils in land types that have no shallow water table during the dry season (most common), upland crops should be planted early so that at least 300 mm of rainfall can still be expected. With normal drainage precautions, the risk of flooding on these soils will be minimal as topsoils will not remain saturated for a long time, even after heavy rains. The remaining rainfall allows complete land preparation as long as this does not lead to excessive turnaround times.

On heavier soils, short-duration upland crops depend less on rainfall, as long as the soil profile is fully recharged at planting time. In lower landscape positions, these fields will maintain standing water until the remaining rainfall for that growing season is quite low. Upland crops should then be planted only where substantial soil moisture remains after rice harvest. When such fields had no standing water for more than 15 days before rice harvest, germination and crop establishment will depend on rainfall. In regions with an abrupt end to the monsoon rains, it may be better to plow the fields shortly after the end of the rains to make early premonsoon crop establishment possible, rather than try to produce a postmonsoon upland crop. When fields have been saturated up to rice harvest, zero-tillage dibbled or row-drilled upland crops of short duration can be planted if precautions are taken to ensure surface drainage (peripheral ditches) in case of heavy rains.

Fields that maintain a water table near the surface will also remain saturated until late in the season, when little additional rain is expected. Chances of flooding at this time are less. Light- and medium-textured soils can generally be rapidly prepared and seeded to upland crops. Land preparation may be difficult in heavy clay soils, which will also be strongly reduced and difficult to drain. Zero tillage planting on these soils is also hazardous because crops in the fields are very susceptible to flood damage if rainwater accumulates. Ridging has been attempted, but may be too costly. Permanent land modifications, such as poldering or the sorjan method, may be successful under certain socioeconomic conditions.

CONCLUSIONS

The scheduling of postmonsoon upland crops in the design of wetland rice-based cropping patterns must consider the expected contribution of soil water, to allow estimation of the rainfall required after planting time. This scheduling should also evaluate the possibility of unexpected intensive rains (greater than 50 mm) and ensure at least good surface drainage where such rains are expected.

Crop access to soil water, loss by evaporation, and water use efficiency can be substantially varied by crop choice and management methods. In rainfed areas with less than 200 mm rain after rice harvest, the best postmonsoon dryland crops are short-duration, drought-tolerant low-profile crops, such as grain legumes. These crops can often be planted with lower fertilizer inputs than those needed for cereals or oilseed crops.

Substantial water can be saved by planting upland crops into rice stubble immediately after the harvest of rice fields that were drained a day before harvest. The use

of special equipment for zero tillage planting and deep placement of fertilizer can greatly contribute to the success of upland crops grown after wetland rice. Planting upland crops directly after rice in a wet soil predisposes the stand to soil-borne diseases such as damping-off and sheath blight. Cultural or chemical control methods should be used to prevent crop loss from these pathogens.

Straw mulches and, to a lesser extent, shallow interrow cultivation after emergence of upland crops planted in the stubble will reduce water loss by evaporation from the soil surface and deep cracks. In the absence of regrowth, standing straw also reduces water loss, but no comparisons have been made between this method and straw or soil mulches.

There is a need to further evaluate the effect of soil water use, root growth, soil density, and low oxygen concentration on the performance of upland crops after wetland rice.

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DISCUSSION

Price: Yours and other research concern establishment of crops after rice and the results reflect yield gains over that which farmers achieve. The problem of establishment is a formidable one and clearly it has been largely solved. However, the yield ranges in experimental work are still modest compared to the potentials of upland crops. Experimental yields of mungbean, cowpea, and soybean of about 1 t/ha are half or a third that realized on the same crop on well-drained upland soils. Maize and sorghum yields of 3 or 4 t/ha are half that on well-managed upland soils.

Do upland crops after rice ultimately have the potential of those crops under ideal conditons? What remain to be investigated — variety? soil moisture management? tilth for better root growth?

It would appear that since considerable effort and sensitive management by farmers are required to achieve the gains shown so far, it is particularly important to exploit the investment by aiming at achieving yields nearer the potential.

Zandstra: I emphasize the relationship between production potential for upland crops after wetland rice and different land qualities. We have achieved soybean (2.5 t/ha), cowpea (2 t/ha), and mungbean (1.7 t/ha) yields that approach those achieved in more ideal dryland conditions. The argument is, however, that upland crop production after wetland rice can exploit land and water resources that are presently not or are poorly utilized. Comparison with upland crop production on different land types in different seasons and different irrigation regimes is of doubtful relevance.

I agree that we need to continue our research to identify management methods for upland crops after wetland rice that provide acceptable returns to farmers' labor and cash, and do not demand excessive inputs.

Methods of applying fertilizer on upland crops after wetland rice

Diosdado A. Carandang

The method of fertilizer application for upland crops after wetland rice will depend on the crop, the method of land preparation and planting, and the type of fertilizer nutrient applied. Research on methods of fertilizer application for upland crops after wetland rice has been negligible. This is not surprising, however, because the practices recommended for an upland-upland crop pattern are generally adopted.

GENERAL METHODS OF FERTILIZER APPLICATION

Fertilizer is generally applied by broadcasting, banding, or foliar spraying. Farmers often modify these methods to meet special needs.

Broadcast

Broadcast fertilizer is uniformly applied on the soil surface before planting (basal) or after the crop has been established (topdressed). If applied basally, the fertilizer may later be incorporated into the soil.

Broadcasting has some disadvantages. Because the entire field is covered, broadcasting requires a greater quantity of fertilizer material than do other methods where the plant nutrients are localized. Thus, the same amount of fertilizer applied as broadcast has a lower effective rate than that applied in band. Broadcast fertilizer also enhances weed growth, and weed competition with the crop.

The availability of nutrients can also be affected. Volatilization may occur if urea or ammonium sulfate is applied at the surface without incorporation. If the soil has a high phosphorus-fixing capacity, broadcasting phosphorus fertilizer increases the percentage of phosphorus fixed.

Banding

Banded fertilizer is applied by hand or machine in bands on one or two sides of the seed or plant. Special equipment is used to place the band of fertilizer 5-7.5 cm to the side and 2.5-5 cm below the seed or transplant. Band application puts fertilizer near

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the germinating seed and provides nutrients to the young plants soon after germination. Where nutrient fixation is high, as for phosphorus, fixation can be minimized. Band application results in high fertilizer concentration, which can be an advantage and a disadvantage. A high concentration means that a lower rate is needed, but a high concentration in solution can damage the germinating seed.

Foliar application

In recent years, foliar application of liquid fertilizer has become popular. Foliar application is especially suitable for micronutrients, which are applied in small quantities. Nitrogen in the form of urea has also been applied to foliage. The main disadvantages of the method are that the concentration has to be kept low to avoid damage to the foliage and several applications are needed to apply the recommended rate.

Farmers modifications

Farmers apply fertilizer by modifications of the above methods. Some farmers mix a small amount of fertilizer with the seed before planting. Others drop the fertilizer in a hole near the seed. To sidedress fertilizer, farmers place it on each hill or at the base of the plants, as with maize. In some cases, farmers add a small amount of fertilizer to irrigation water.

FERTILIZER MOVEMENT

Movement of fertilizer is important to make it available to the plants. Soluble salts dissolve in the soil solution surrounding the zone of fertilizer application. The rate of movement and distance of the salts from the point of application depend on the nature of the salts for fertilizer, the property of the soil, and climatic conditions.

- Phosphorus moves slowly from the point of placement. Although water-soluble phosphorus sources move short distances, for all practical purposes the amount of phosphates in salt movement are nil.
- Nitrogen salts move in the soil solution depending on the direction of water movement. The nitrate form of nitrogen is especially mobile, and NH_4^+ can also be converted into nitrate.
- Potassium is restricted in its movement as a salt because of its positive charge.

With zero or minimum tillage, nutrient movement is seriously affected. Pink and Wesley (1974) showed that with no tillage, the downward movement of phosphorus was reduced more than that of potassium.

CHEMICAL AND PHYSICAL CONDITIONS OF THE SOIL AFTER WETLAND RICE

The lack of research on fertilizer for upland crops after wetland rice is understandable. Fertilization of upland crops in an upland-upland crop pattern or in a wetland rice-upland crop pattern should be the same as long as the field preparation for the upland crop is the same.

In rainfed areas, where wetland rice is transplanted in a puddled soil, the physical properties of the soil may be unfavorable to the succeeding upland crops. The

moisture content in the lower root zone may be high and oxygen concentration low. Melhuish et al (1976) reported a lower oxygen concentration at the lower depth, which increases the possibility of anaerobic microzones able to restrict root extension. They also reported that the available phosphate concentration in the soil was lower after wetland rice than after an upland crop (wheat). This is related to the active iron ratio (ratio of easily reducible iron to total iron in the soil), which is higher after wetland rice than after upland crops. Thus, upland crops after wetland rice are expected to respond to phosphorus. Melhuish et al (1976) suggested that banding of phosphorus and nitrogen should enhance phosphorus uptake.

In another study, Willet et al (1977) reported the phosphorus sorption characteristics of soils sampled before and after flooding. The results showed that a previously flooded soil had greater phosphorus sorption than their nonflooded soil counterparts. It was indicated that soils previously grown to wetland rice required more phosphorus for an upland crop than upland crop soils do. Phosphorus sorption was significantly and positively correlated with active iron.

Generally, much rice stubble is left in the field after wetland rice. A thorough land preparation incorporates residues of high C:N, which can immobilize nitrogen during decomposition. The conditions in wetland rice fields are such that nitrogen, and probably phosphorus, could be limiting nutrients for the upland crops that follow rice.

RESEARCH ON METHODS OF APPLYING FERTILIZER

Research results and recommendations on the methods of fertilizer application for upland crops after wetland rice are scanty. Some studies do not even report the method of application. Where land preparation or planting methods or both are not conventional for the upland crops, as in zero tillage, the method of fertilizer application is important.

In field studies, Martin et al (1971) found that poor growth of safflower after years of rice is associated with acute phosphorus deficiency. The application of 90 kg of an 11-48-0 or 10-50-0 formulation in the seed row was found to be safe and effective. Greenhouse tests showed a striking response to fertilizer phosphorus if it was placed with or near the seed, but little or no benefit if it was mixed thoroughly with the soil. Coating safflower seed with phosphate fertilizer was effective but toxic to seedlings in some cases. The field experiment showed that ammonium phosphate treatments were more profitable than those with superphosphate.

Another study in California (Petersen et al 1972) showed that sorghum production after rice was improved by phosphorus banded near the seed. Phosphorus addition advanced maturity by 2-3 weeks. The study also showed that the effect of wetland rice cropping was more evident where wetland rice had been grown continuously for 4 years or longer.

The results of Muirhead et al (1976) in Australia showed an initial advantage of banded phosphorus fertilizer over phosphorus fertilizer mixed with the soil. Four weeks after emergence of maize the dry matter yield was 8 times higher where 30 kg P/ha was banded than where it was mixed with the soil. At 10 days after emergence,

when no appreciable difference in growth was observed, the phosphorus content of maize where phosphorus was banded was 40 times higher than that of phosphorus mixed with the soil. At a later growth period, however, the effect of phosphorus was much lower. The recovery of added phosphorus was 3.5% on the soil-mixed treatment and 7.7% on the banded treatment. The method of phosphorus application did not affect yield, however, because nitrogen was lacking — ammonium nitrate had been used — and waterlogging occurred during the early growth stage of maize.

In another experiment, 30 kg P/ha banded with the seed (2 cm or 10 cm below the soil surface) increased the grain yield of maize and sunflower significantly. Depth of placement did not significantly affect grain yield. Maize tasseled 7-10 days earlier in the banded treatment than the mixed or the control; no difference in maturity was observed in sunflower.

Asandhi (1979) did not observe any phosphorus effect on yield of Maahas soil in the Philippines, but the method of nitrogen fertilizer application affected the yield of zero-tillage sorghum after transplanted rice. Dibbling the basal fertilizer beside the seed resulted in a high yield comparable to that with band application, It also resulted in long panicles, high phosphorus content of the plant, and increased magnesium uptake. The labor requirement for fertilizer application was, however, very high.

Syarifuddin and Zandstra (1978) compared band application of complete fertilizer beside the seed and placement 20 cm below the soil surface — or 15 cm below the seed — with and without mulch. Yields were highest in mulched plots with 120-60-60 NPK fertilizer applied 20 cm below the soil surface. The plants had more roots, hence, greater nutrient uptake and ultimately higher yields.

Recommended fertilizer practices for upland crops in a wetland rice-upland crop system in Taiwan were reported by Cheng (1972). For soybean a basal application of the whole amount of phosphorus and potassium and half the nitrogen fertilizer are broadcast immediately after planting and then covered with straw mulch. The other half of nitrogen fertilizer is broadcast 8-10 days after germination. For sweet potato, where the field is thoroughly cultivated and the cuttings planted on a ridge, ammonium sulfate, superphosphate, muriate of potash, and compost are banded at the time of ridging. Additional ammonium sulfate and muriate of potash are sidedressed 1 month after planting by making furrows along the sides of the rows 1-2 days before nitrogen and potassium sidedressing and reridging. The first fertilizer application on sugarcane following rice is done by punching a hole beside each seedling and filling the hole with a small quantity of fertilizer.

In Thailand, farmers apply urea to a no-tillage soybean crop by dropping the fertilizer in each hill.

In the Philippines, compost and inorganic fertilizers are mixed together in the planting hole for watermelon or squash. Additional fertilizers dissolved in water are applied. Pelleting of fertilizer with seed was reported by Paterno and Espiritu (1977) in connection with legumes inoculated with rhizobia. Pelleting with the seed may be another approach where the upland crop is planted with no tillage. Liquid fertilizer applied to the soil or through the leaves can supplement the basal application (Paner 1976).

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Desirable characteristics of upland crops for planting before or after wetland rice

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Numerous studies and reports on the management of rainfed wetland rice systems under varying climatic conditions in the Asian region have shown the important role of upland crops in further increasing the intensity of land use and productivity (IRRI [1975], 1976a, b, 1977, 1978a; Tijam and Gomez 1979). The upland crop species that have been grown successfully before or after a wetland rice crop are mungbean, soybean, peanut, cowpea, yard-long bean, adzuki bean, rice bean, sweet potato, grain and green maize, sorghum, millets, sesame, cucurbits, and root, leafy, and fruit vegetables.

In the temperate and subtemperate climates of Asia, wheat, rye, rape, barley, white potato, and cabbage have been used as complementary crops (Singh and Modgal 1976, Hwa 1978).

PRERICE AND POSTRICE CROPPING AND ATTENDANT FACTORS

Planting of upland crops before wetland rice has been done in areas where a bimodal rainfall pattern occurs, such as in Northeast Thailand and Burma, or where there is an early and gradually increasing monsoonal rainfall.

Crops like yard-long bean, green maize, mungbean, cowpea, cucumber, and peanuts have been tried with success in the Philippines and Thailand (UPLB 1979, Chandrapanya 1978). Sesamum and jute before wetland rice have been experimented with in Burma (Saing et al 1978).

The important climatological factors during the prerice growing period are:

- longer photoperiod;
- prevailing cloudiness; and
- excessive wetness during the flowering to maturity stage.

Under these conditions, the crops are prone to produce more stover in relation to seed yield (Lantican and Garaza 1977).

Cultivars that produce reduced vegetative development, such as the determinate types of cowpea and other grain legumes, as opposed to those with the indeterminate growth habit, have been observed to adapt better to cropping before wetland rice.

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Early maturity of crops or harvesting them as a green vegetable instead of as grain is a key to success.

Rhizoctonia and sclerotium diseases are usually prevalent in the prerice upland crop and genetic resistance to them is required.

Planting of upland crops after rice is widely practiced because the risk of delayed planting of the rice crop is removed. The upland crops after rice rely on residual moisture and minimal tillage and are constrained to produce less vegetative cover. Mulching has improved yields considerably (Lantican and Catedral 1977, Catedral and Lantican 1977).

The important stress factors in the upland crop after rice are drought, high temperature in the tropics, cold temperature in the temperate zone, poor soil granulation, and soil compaction. Occasional flooding due to excessive rains may also be experienced during the early stages of upland crop establishment.

BREEDING IMPLICATIONS

The success of multiple cropping in the rainfed wetland rice system is contingent on the availability of upland crop varieties that will suit the system. The issues involved are twofold:

1. What essential varietal characteristics should be sought and used as selection indices in the screening and evaluation processes so as to ensure cultivar adaptation?
2. What type of a breeding and evaluation program can be designed so that the specific requirements of the system are appropriately addressed?

Desirable characteristics of upland crops

During the second 1977 meeting of workers on multiple cropping in Sri Lanka (IRRI 1977), a checklist of required plant characteristics for individual plant species was drawn. However, the list was considered too inclusive because it had characters of universal significance, i.e. yields, nutritional quality, resistance to pests and diseases. In another joint meeting in Los Baños (IRRI 1978b), the committee on varietal screening and testing made a more judicious choice of varietal characteristics, emphasizing only those that are unique to the requirements of intensive farming. These were short maturity, shade tolerance (for intercropping purposes), vigorous seedling growth, and drought tolerance.

In view of the varied conditions in the rice-based system, the following characteristics deserve consideration.

Drought tolerance

The most important adaptive feature in crops grown on residual moisture is drought tolerance. Characters or manifestations associated with drought tolerance, as reviewed by Rasco (1974), are:

- high root-shoot ratio or extent of root development (Villareal 1976, Parao et al 1976),
- high percentage of undamaged leaves and branches after drought,
- low mean number of veinlets in the leaves, and

- low plant height reduction during stress.

Rasco (1974) also listed the following associated morphological and physiological characters:

- small stomatal opening during stress,
- high germination at low osmotic medium,
- high moisture-retaining capacity of the leaves,
- high cell sap concentration, and
- low transpiration rate under water stress.

The biochemical characters associated with drought tolerance include high polyphenol oxidase activity during water stress, and high ascorbic acid and ascorbigen content in the leaves (Rasco 1974). High free-proline accumulation during water stress has been noted in a number of crops (Palfi 1971, Singh et a1 1972, Blum and Ebercon 1976). Free-proline accumulation has been commonly used as a biochemical measure of drought tolerance.

Techniques for evaluating drought tolerance in field conditions have been described (IRRI 1976a, Loresto et al 1976).

Tolerance for waterlogging

As mentioned earlier, waterlogging is a problem in prerice planting or in early seedling establishment in postrice cropping. Upland crop species vary in degree of tolerance for waterlogging. For example, sorghum (Gomez and Evangelista 1977), jute, and soybean are less sensitive than the readily affected crops like maize, mungbean, and sweet potato (Villareal and Lai 1976). It is not known if within the species there is adequate genetic variability in tolerance for waterlogging to capitalize on in selection.

Early maturity

Early maturity is universally acknowledged as the key to increased cropping intensity. Earliness also minimizes the exposure of crops to acute stresses late in the growing season. Earliness is highly heritable and plants can be bred for it with ease.

Photoperiod insensitivity

Reaction to photoperiod is important in some leguminous species. Photoperiod reaction is a particular problem of soybean establishment after rice when planting occurs in December. The reproductive phase sets in at an early stage, limiting bean production. At AVRDC (1977, 1978), attempts are made to produce day-neutral varieties of soybean.

The rice bean, on the other hand, undergoes a protracted vegetative phase during the long days of summer.

Early seedling development

Early seedling development enables the crop to remain competitive with weed growth (IRRI 1972, Catedral and Lantican 1977) and provides adequate ground cover to minimize moisture evaporation and excessive heating of the soil. A fast rate of seedling growth gives the plant a head start in development before any adverse effect of stress factors sets in. There is usually a substantial amount of genetic variability in rate of seedling growth among and within upland species.

Tolerance for low temperatures

In areas in Burma, Bangladesh, the Himalayan countries, and Korea, where the second cropping coincides with the winter season. tolerance for low temperature is important. Cropping is limited to temperate vegetables and cereal crops. The tropical species have limited potential for adaptation.

Because of the need to extend the range of adaptation of some of the tropical crop species, the Mae Jo Field Crop Experiment Station in Chiang Mai, Thailand, which has a mild winter climate, has been designated as the lead station in the extensive initial screening of tropical crops for subtemperate adaptation.

Selection indices for paddy adaptation

In addition to the earlier mentioned characters, others that have to do with adaptation and high yields need to be identified. Literature on the subject is limited and available information is conjectural or, at best, based on circumstantial evidence.

The selection criteria for the prerice and the postrice planting are expected to differ because of the contrasting nature of the growing conditions during the two periods.

The requirements of crops for prerice planting would invariably follow those for the regular monsoonal upland culture. The following selection indices may be useful: short plant stature, low leaf area index (LAI) value, and high harvest index (HI). As mentioned earlier, the determinate types of legumes appear to yield better than the indeterminate ones, which usually produce a low-seed stover ratio.

As for postrice cropping, certain plant characters have been observed to be highly influenced by stress factors and may serve as selection indices for adaptation and yield ability in the paddy. In soybean, Catedral and Lantican (1977) found that yield components such as pod number per plant and seed weight were markedly affected by moisture and soil stresses. Thus, selection for those two characters may be worthwhile. Buajarern (1978) found that a fast rate of seed filling was important and varieties of soybeans that had deposited more than 3.5 mg dry matter/day per seed and attained maximum seed weight in 40 days gave the highest seed yields. Varieties that were poor yielders had a seed-filling rate of as low as 2.2 mg, and a maximum bean weight attained late in 52 days. A faster rate of seed filling obviously conferred an advantage — the plant avoided the critical period of moisture stress late in the season.

In mungbean, LAI, total dry matter weight, and plant height correlated with bean yield under paddy conditions (Lantican and Catedral 1977). This indicated the importance of a rapid rate of plant growth and attainment of vegetative development before the reproductive phase sets in. In cowpea, the indeterminate varieties are more adapted to dry paddy conditions. The short-statured, highly determinate types have limited yield potential.

Sweet potato varieties that characteristically produced roundish tubers and which developed at the upper layer of compacted paddy soils produced tubers of better market quality (Lantican 1976) than cultivars with elongated tubers which burrowed deeper into the ground. Villareal (1976) noted that genotypes that inherently produced a low top-root ratio were the best yielders in the paddy.

Crops suffering from moisture stress also manifested physiologic and nutrient

deficiency disorders in the form of general yellowing and purple pigmentation of the base of stems, petioles, and leaf tissues (Lantican 1976). Some genotypes seemed to be less affected than others and produced normal green leaves.

Design of breeding and varietal testing programs

During the initial upsurge of interests in multiple cropping work, a breeding and selection program exclusively for dryland crops for paddy cultivation was thought necessary. This concept arose primarily out of a common observation of the occurrence of variety × cropping systems interactions in most experimental data analyzed (Francis et al 1976, Lantican 1976).

More recently, detailed monitoring of yields of selected varieties of upland crops common across monoculture and mixed cropping systems has indicated consistency in relative yields and ranking (Francis et al 1978a,b; Francis 1979). Results of extensive experiments at the University of the Philippines at Los Baños have shown that elite varieties of different upland crop species developed under ideal dryland conditions likewise gave very satisfactory yields when grown under paddy conditions (UPLB 1978, 1979).

In view of these recent observations, the concept of breeding and selection work exclusively for paddy adaptation loses its validity. Even if the idea is to exploit to the maximum genotype × cropping systems interaction and specificity of certain genotypes for adaptation to paddy cultivation, the probable benefits and justification will be offset by the high costs of maintaining a breeding program, limitation in research personnel, and low level of application of technology to exploit the yield potential of new varieties by the average Asian farmer. Francis et al (1978b) further argued that genotypic selection under stress conditions would be subject to environmental error influences as to render it less effective in promoting genetic advance.

Instead, a unified, multistage breeding and evaluation program for all cropping situations is suggested.

The first stage is the hybridization and selection phase among early segregating populations (F_2 to F_6), to be done in an ideal dryland environment. Selection should exploit known varietal features that relate to general fitness and greater yield stability over a range of cropping systems and seasonal patterns. Disease and pest resistance should be a major consideration.

In soybean, a crop known for its erratic behavior, a number of important selection indices for wide adaptation and their respective range of acceptability are as follows:

- early maturity period of 80 to 95 days,
- moderate vegetative development at LAI values of 3 to 5,
- high HI of 30% and higher, and
- high seed weight of 150 g/1,000 seeds and higher.

Wide fluctuations in values beyond the above range are due to seasonal influences, mostly moisture and photoperiod differences. Values beyond those ranges—especially late maturity of up to 130 days, high LAI values of 9 or 10, and low HI—will make for erratic behavior of varieties over changing environments. The same selection criteria can well apply to other crop species. Numerical index values may change, but the acceptable limits in the scale may be the same.

The second stage constitutes the evaluation of first-stage selections of genetically

stable genotypes, together with selected cultivars in the germplasm collection, in each cropping situation. The idea is to exploit further unique specialties for adaptiveness or tolerance for stress complexes such as drought and soil compaction in the case of postrice cultivation.

The second stage will take a series of testing starting from the nonreplicated observational nurseries of a large number of entries to the two-replicated preliminary trials of a smaller number of entries. This will be succeeded by the general trials of selected lines at more precise designs, larger plots, and at various sites.

The third or last stage will be the advanced trials to be conducted at strategic sites in rainfed rice areas in the country. The results will form the basis for a national variety recommendation. In the Philippines, we now have a multilocational advanced trial of varieties conducted under paddy conditions.

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Economics of upland crops in rice-based cropping systems

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In many parts of Asia, farmers commonly grow upland crops in wetland rice paddies during the drier periods of the year. The growing season is extended and land is used for a longer period. The nature and importance of upland crops in these farming systems vary, but such crops have considerable potential for raising the output and incomes of small farmers in many areas.

We examine some of the economic factors involved in upland crop production in rainfed, rice-based systems. Our examples are largely drawn from the Philippines and relate especially to mungbean.

ROLE OF UPLAND CROPS IN RICE-BASED SYSTEMS

Upland crops grown in rice paddies range from food crops (cereals, vegetables, root crops, and grain legumes) to commercial crops such as tobacco, cotton, and oilseeds. They are commonly grown with low input and management levels and have correspondingly low yields. Nevertheless, their economic importance to the small farmer can be high.

A study of farming systems in the Cagayan Valley, Philippines, showed that many farmers obtained almost all their cash income from sale of mungbean, yet the average yield of mungbean grown after rice was less than 300 kg/ha (Flinn et al 1981). Another study showed that garlic and tobacco grown after rice were the main source of cash incomes for farmers in Ilocos Norte province, Philippines (Paris and Price 1979). Similar situations have been observed elsewhere in the Philippines.

Upland crops are often important sources of dietary nutrients, particularly proteins. Grain legumes (mungbean, chickpea, cowpea) are a major source of proteins in many countries of Asia; in parts of the Indian subcontinent they are the major source. Cereals, such as maize and wheat, grown in rice-based patterns are often substitutes for rice as staple foods and the recent extensive adoption of wheat as a winter crop in rice paddies in Bangladesh, North India, and Nepal has significantly enhanced overall food availability.

Certain upland crops, such as some of the grain legumes, may also have contributed to the maintenance of soil fertility in the traditional farming systems.

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ECONOMIC POTENTIAL OF UPLAND CROPS

The introduction, or intensification, of upland crops in rice-based cropping patterns does not lead to major resource conflicts within the farming system. Competition for land between rice and upland crops is minimal. Labor demands for major operations for wetland rice and upland crops usually do not coincide, although some overlap can occur. Positive interactions between crops with beneficial effects on weed populations and soil fertility can, indeed, lead to better overall pattern performance.

Major economic gains appear possible through improved upland crop components; however, a number of constraints can be identified.

The low yields of upland crops in rice-based patterns generally reflect low levels of inputs and of management. They are also related to the absence of suitable varieties. Mungbean, for example, is widely grown in rice-based patterns in many countries but average yields are well below 500 kg/ha. Only in Thailand are farmers obtaining yields close to 1,000 kg/ha (Calkins 1978).

For many upland crops, particularly grain legumes, little research information is available in most countries to evaluate the impact of large-scale output increases on prices. But if the relative prices that have prevailed over the last few years were to continue, substantial improvements in farm incomes would be possible with relatively small yield increases. In the Philippines, farming systems studies in Iloilo, Pangasinan, and Cagayan provinces have indicated that raising mungbean yields by 200-300 kg/ha could have a major impact on farm incomes. Indeed, the impact would be greater than raising rice yields by 1 t/ha (Barlow et al 1981, Flinn et al 1981).

It is quite likely that the importance of grain legume crops as sources of protein will grow. Table 1 shows the relative costs of protein from a number of food sources in the Philippines. The cheapest noncereal sources of proteins are the grain legumes. This is true for other countries in the region and changes in relative prices are likely to enhance this cost advantage.

Table 1. Estimated average cost of protein at farm level for selected food items in the Philippines.

Year	US$/kg Protein					
	Pork	Beef	Fish[a]	Mungbean	Cowpea	Soybean
1969[b]	3.87	3.01	1.83	0.56	*c*	0.39
1970	4.37	3.41	1.97	0.64	*c*	0.49
1971	5.85	4.29	2.58	0.99	0.78	0.52
1972	6.48	4.85	2.99	1.16	0.94	0.63
1973	6.65	4.95	3.15	1.25	1.09	1.09
1974[d]	10.23	7.73	4.46	1.99	1.84	1.31
1975	10.91	8.76	4.94	2.19	1.87	1.36
1976	10.83	9.02	5.12	2.29	2.11	1.67
1977	12.13	9.81	5.68	2.41	2.16	1.80
1978	13.25	10.81	5.81	2.46	*c*	2.01
1979	14.47[e]	12.11[e]	6.78[e]	2.53[f]	*c*	2.19[g]

[a]Milkfish, fresh. [b]1969-73 yellow type. [c]No data. [d]1974-79 green type. [e]Av of first 5 months. [f]Av of first 4 months. [g]Av of first 10 months.

Table 2. Performance of selected upland crops from cropping systems network sites.

Crop	Site	Pattern[a]	Yield (t/ha) 1st crop	Yield (t/ha) 2d crop	Yield (t/ha) 3d crop	US$/ha Gross return	US$/ha Total cash cost	US$/ha Total labor cost	US$/ha Total variable cost	US$/ha Return above variable cost	US$/US$ Return to labor	US$/US$ Return to cash	Gross return: total variable cost
Mung	Pangasinan, Philippines	R-M EP	4.17	0.82		513	154	98	252	261	3.66	3.33	2.04
		R-M FP	1.65	0.22		133	26	47	73	60	2.28	5.11	1.82
		R-M FPZT	1.65	0.22		132	27	34	61	71	3.09	4.89	2.16
		R-M FPLT	1.65	0.25		152	27	45	72	80	2.78	5.63	2.11
		R-M FPMT	1.65	0.25		152	33	49	82	70	2.43	4.61	1.85
		R-M FPHT	1.65	0.18		112	27	58	85	27	1.47	4.15	1.32
	Iloilo, Philippines	R-M EP	5.30	0.60		426	124	90	214	212	3.36	2.01	1.99
		R-M FP	2.10	0.06		59	15	9	24	35	4.89	3.93	2.46
		R-R-M EPZT	5.48	3.44	0.30			20		85			
		R-R-M EPHT	5.48	3.44	0.20			50		9			
Cowpea	Pangasinan, Philippines	R-C EP	4.27	0.70		502	190	110	300	202	2.84	2.64	1.67
		R-C FP	2.05	5.38[i]		663	36	232	268	395	2.70	18.42	2.47
	Iloilo, Philippines	R-C EP	5.30	0.75		232	87	48	135	97	3.02	2.67	1.72
		R-C FP	2.10	0.21		71	9	9	18	53	6.89	7.89	3.94
		R-C EPZT	5.03	1.03				13		233			
		R-C EPHT	5.03	0.82				74		13			
		R-R-C EPZT	5.48	3.44	0.29			8		13			
		R-R-C EPHT	5.48	3.44	0.14			43		-40			
	Indramayu. Indonesia	R-R-C-5 mo EP	4.68[b]	4.98	0.63	254	63	115	178	76	1.66	4.03	1.43
		R-R-C-5 mo EP	5.06[c]	5.12	0.62	251	63	116	179	72	1.62	3.98	1.40
		R-R-C-7 mo EP	6.04	4.72	0.73	293	65	112	177	116	2.04	4.51	I.65
Sorghum	Iloilo, Philippines	R-S EP	4.70	2.57		291	85	75	160	131	2.75	3.42	1.82
		R-S EPZT	5.03	8.33				19		952			
		R-S EPHT	5.03	4.34				63		471			
	Pangasinan, Philippines	R-S EP	4.27	1.40		242	111	62	173	69	2.11	2.18	1.40

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TABLE 2 CONTINUED

Crop	Site	Pattern[a]	Yield (t/ha)			US$/ ha				US$/US$			
			1st crop	2d crop	3d crop	Gross return	Total cash cost	Total labor cost	Total variable cost	Return above variable cost	Return to labor	Return to cash	Gross return: total variable cost
Bush sitao	Pangasinan, Philippines	R-BS EP	4.27	0.08		37	81	30	111	−74		0.46	0.33
Peanut	Pangasinan, Philippines	R-P EP	4.27	0.70		424	177	156	333	91	1.58	2.40	1.27
Cassava	Lampung, Indonesia	R-Ca EP	5.55	10.17		98	45	30	75	23	1.77	2.18	1.3l
Maize	Lampung, Indonesia	R-Ma EP	5.55	1.42		115	46	94	140	−25	0.73	2.50	0.82

[a] R = rice, M = mung, C = cowpea, S = sorghum, BS = bush sitao, P = peanut, Ca = cassava, Ma = maize, EP = experimental pattern, FP = farmer's pattern, ZT = zero tillage, LT = low tillage, MT = minimum tillage, HT = high tillage. [b] IR20. [c] IR26.

The future may also bring changes in government policies and market prices, which can significantly, and favorably, alter the present economic status of certain upland crops. The Philippines, for instance, imports large quantities of sorghum as animal feed. Research has established that sorghum can fit well into rice-based cropping patterns. A shift toward less dependency on imported food grains and improvements in the marketing mechanisms can lead to sorghum cultivation on a much wider scale.

CROP PERFORMANCE

Table 2 presents some data on performance of upland crops included in rice-based cropping patterns tested at a number of cropping systems network sites. Environmental differences across the sites impose limits on the types of comparisons that can be made but it is seen that:

- The yields of upland crops in farmers' and experimental patterns are generally low;
- Where data on farmers' patterns are available, farmers' input costs are seen to be significantly lower than the experimental; and
- In many instances, upland crops have responded significantly to higher input levels.

Given the higher levels of investment farmers have to make to adopt the experimental patterns, stability of crop performance will be important. This is particularly true in the case of upland crops that are established at the beginning or the end of the rainy season. Risk can, of course, arise from both yield and price variability; however, farmers can often anticipate seasonal price fluctuations. It can be argued that in most upland crops, yield variability arising from moisture (too little or too much) and insects and diseases are more likely to be considered as the sources of risk by farmers. Indeed, farmers' preference for low input technologies for upland crops is probably related to the high variability in returns from such crops. It is important that this be taken into consideration in evaluation of cropping patterns leading to recommendations.

FUTURE RESEARCH NEEDS

Improved upland crop varieties that are better suited to the postrice or prerice environment in rice paddies can contribute significantly to farm output and incomes. Widespread adoption and increased production of such crops can, however, alter existing price structures. Market research in such crops would be important. With rising fertilizer prices, the contribution of nitrogen-fixing legumes and green manure crops to improving soil fertility will have greater economic value and will need to be incorporated explicitly in economic analysis of upland crops.

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DISCUSSION

Pookpakdi: You have emphasized the need to consider the nutrient status and protein status of the crop that will be used in rice-based cropping systems. What would be a good approach to introduce a cropping system that contains certain upland crops that people do not consume in their present diet?

Jayasuriya: It is usually difficult to persuade people to change their food habits. If the new crop is different from what the farmers are used to, then this can be a major problem. I cannot suggest a solution that will work in all situations. However, if processing and marketing facilities are available, farmers may grow a new crop for sale at first and then gradually start using it in their diets.

Weed control in dryland crops after rice

Keith Moody

In nonirrigated areas, the dryland crop grown after rice has to grow mainly on residual soil moisture. Therefore, it must be relatively drought tolerant or of short growth duration, or both. Dryland crops after rice often are damaged by excessive moisture at the critical period of crop establishment and hurt by drought at the equally critical period of flowering and grain filling (Zandstra and Price 1977).

In some areas, farmers relay plant the dryland crop into the standing rice crop or sow it into the rice stubble with little or no land preparation so that full use can be made of the available moisture. They realize that substantial moisture loss will result if traditional methods of land preparation such as plowing and harrowing are used. With such water loss, it may not be possible to grow a dryland crop after rice.

YIELD LOSSES DUE TO WEEDS IN DRYLAND CROPS AFTER WETLAND RICE

Conflicting results on the importance of weeding in the dryland crop grown after wetland rice have been reported.

Yield losses due to weeds depend on factors such as the crop, the cultivar selected, plant density, the spatial arrangement of the crop, the weed species and their density, and the fertility and moisture status of the soil. Yield reduction due to weeds may be more for crops growing in the rainy season than for crops growing in the dry season or on irrigated land. Kim (1979) observed this for irrigated transplanted rice.

Mungbean

Losses of 60% in mungbean yield due to weeds occurred in Taiwan in the spring of 1975, but in summer of the same year, only 27% loss occurred (AVRDC 1976). In the Philippines, a 95% yield loss occurred in mungbean in the wet season in 1970. In the dry season of 1971 when the crop was irrigated and weed growth was less, a 77% loss was recorded (Madrid and Vega 1971).

A positive response to weeding of mungbean planted after rice has been reported (Responso 1980, Watanabe et al 1980). Responso reported that yields of mungbean from plots that were hand weeded twice, 15 and 30 days after crop emergence, were

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significantly greater than those from plots that were hand weeded once or received an interrow cultivation followed by a hand weeding. All the weeded plots yielded significantly higher than the unweeded check.

But trials in the Philippines (IRRI, 1978, 1979; Moody 1979) indicated no significant yield response due to weeding for mungbean planted after rice. However, Herrera et al (1978) reported that a significant response to weeding in mungbean was observed after yield losses due to insects had been eliminated.

No significant differences in grain yields were observed between weeding treatments when mungbean was planted with zero tillage after maize (Ahmed 1979).

In irrigated fields in Thailand, Watanabe et al (1980) observed an average of 31% mungbean yield loss due to weeds. Yield losses were less when the soil moisture content was high. For optimum yields, weed control was necessary for 4 weeks after crop emergence.

Maize

Under dryland conditions, the number and fresh weight of cobs of maize planted after rice did not significantly differ between plots weeded twice and the unweeded check plots, even though weed weight was significantly lower in the weeded plots (Ahmed 1979). In a bunded field with a low ponding potential, weeding did not significantly increase the yield of maize planted in a zero-tillage field (Ahmed 1979).

In Batangas Province, Philippines, most farmers weed the maize crop only once by passing a plow between the rows 30-40days after planting. Even though the maize fields appeared very weedy at that time, previous additional weeding did not result in a significant increase in yield (Garrity et a1 1975). The farmer's weed control method was adequate for the yield levels that he obtained. Higher levels of weed control would not have been economically justified.

Responso (1980), however, reported that interrow cultivation significantly increased the yield of maize grown in the dry season in Bukidnon, Mindanao, Philippines. One interrow cultivation 14 days after crop emergence was adequate to obtain optimum yields.

Sorghum

Samiano and Motooka (1979) reported the work of San Gabriel and Motooka (unpubl.) who found that atrazine and linuron gave good weed control in sorghum in the dry season; however, yield differences between the herbicide-treated and unweeded plots were not significant. The sorghum crop with its deeper root system perhaps did not have competition from the shallow-rooted weeds, which suffered water stress between irrigations.

Wheat and barley

As a rule, Nepalese farmers do little early-season weeding in wheat or barley. Weed removal is delayed until weeds are well-developed so that they can be used for livestock feed. Malla et al (1979) observed no significant difference in yield between plots that had been hand weeded or treated with herbicides and those that had not been weeded for both crops.

In the Punjab, India, traditional methods are unsuccessful in controlling such

weeds in wheat as *Phalaris minor* L. and *Avena fatua* L. (Gill and Brar 1972). However, herbicides that will control these weeds are available.

Choi (1979) reported that in Korea, competition of weeds with barley in the early stages of growth was more harmful to grain yield than competition in the late stages of growth. For optimum yields, barley should be weeded twice in the first month of growth (Choi 1979).

Yield losses due to weeds varied from 2 to 82% (av 27.8%) over a 5-year period in trials conducted at various sites in Korea (Kim et al 1975). A proprietary mixture of thiobencarb and simetryn was particularly effective in controlling *Alpeculus amurensis* Ohwi, the major weed in barley fields.

POSSIBLE REASONS FOR CONFLICTING RESULTS

In cropping systems the effect of weed control on a particular crop is usually more pronounced when weed control in the previous crop is poor than when it is good. Good weed control reduces weed seed reserves (Harwood and Bantilan 1974).

Crop rotation

Each crop has its own characteristic weeds; growing the same crop on the same piece of land increases the number of these weeds. Rotating the crops greatly reduces the possibility of a buildup ofcertain weed species. Rotations should be planned so that no group of weeds is allowed to develop undisturbed.

Rotation of crops having drastically dissimilar life cycles or cultural conditions is among the most effective and practical of all weed control methods. For example, when land rotation is practiced, as in the rotation of wetland rice with dryland crops, rice weeds are greatly reduced or eliminated under dryland conditions and vice-versa.

Moody and De Datta (1977) observed that difficult-to-control weeds tend to build up less in a crop rotation involving both wetland and dryland crops than in continuous wetland or dryland culture. Without weeding, yield losses are less when dryland and wetland crops are rotated than when they are grown continuously.

Harwood and Bantilan (1974) reported that both weed weightsand numbers for a wetland ricedryland crop rotation showed a downward trend in successive cropping seasons. After 4 crops, puddling had reduced weed numbers in the dryland crop by an average of 76%. The same authors also noted that *Eleusine indica* (L.) Gaertn., *Digitaria sanguinalis* (L.) Scop., *Amaranthus spinosus* L., and *Cyperus rotundus* L. were most sensitive to puddling, *Echinochloa colona* (L.) Link and *Portulaca oleracea* L. were moderately sensitive, and *Cyperus iria* L. was least sensitive. In the tenth crop (peanut) the weight of *C. rotundus* was reduced to an average of 50% by puddling in previous crops (Moody 1977b). According to William (1979) flooding fields during the fallow season or growing wetland rice in rotation with vegetables can reduce some weed infestations, especially of perennial weeds in the vegetable crops. For example, Taiwanese vegetable growers rarely have a problem with *C. rotundus* in areas where wetland rice is grown regularly in rotation with vegetables.

Flooding had a major suppressive effect on stand establishment and growth and development when applied during the early growth stages of *C. iria* (Civico and

Moody 1979). Once *C. iria* had become established, flooding had less effect on it. Delayed flooding must be deeper to affect the weed's growth.

When soybean is grown using zero tillage after wetland rice, the few weeds found at rice harvest died when the soil was no longer flooded (William and Chiang 1976). Moody (1979) reported no carryover effect on the subsequent dryland crops of weed control treatments applied to a transplanted rice crop. Choi (1979) also observed little similarity between the weed flora growing in association with barley and that growing in association with transplanted rice.

Mercado (1976) observed that *E. colona* and volunteer rice can be major problems in dryland crops planted after wetland rice, and Moody (1977a) reported that if weeds such as *E. colona* are present in the rice crop, they continue to grow during the dryland crop when this is seeded either before rice harvest or int the rice stubble. William (1979) noted that weeds such as *Echinochloa crus-galli* (L.) Beauv. or *E. colona* can become more serious if allowed to grow and produce seeds under variable flooding conditions.

Intensification of agriculture coupled with the dwarf wheat cultivars has created a weed problem, which did not exist when tall traditional wheat cultivars were grown. In the Punjab in India, the introduction of dwarf improved cultivars of wheat accompanied by increased fertilizer rates and irrigation has changed the microclimate in favor of certain grassy weeds particularly *P. minor* and *A. fatua* (Gill and Brar 1972). In an endeavor to increase crop production in the area, transplanted rice followed by wheat is becoming an important crop rotation, particularly on heavy soils. With that rotation *P. minor* thrives and is increasing at alarming rates.

Land preparation

The method of land preparation used depends greatly on the available rainfall. When no rain follows planting, complete tillage can be disastrous because it causes loss of residual moisture (Zandstra and Price 1977). However, it can be the best choice if rainfall occurs or irrigation is available after planting. In Taiwan, the selection of the type of land preparation depended on factors such as the supply of labor, conditions of irrigation and drainage, harvest date of the previous rice crop, transplanting date of the following rice crop, and, for wheat, the incidence of rust during past years (Cheng 1977b).

The degree of land preparation for crops such as mungbean, soybean, and wheat varies from none to thorough. Lavapiez et al (1978) identified four levels of tillage ranging from none to two or more plowings and harrowings for mungbean after wetland rice in Manaoag, Pangasinan. Eighty-eight percent of the farmers surveyed by Navarez and Moody (1979) reported that they plowed their fields once before planting mungbean, but some broadcast mungbean on an unplowed field and may make one pass with a harrow after broadcasting to ensure that the seeds are in contact with the soil.

In Indonesia (Dharo 1953, Ismunadji 1975) and Taiwan (Cheng 1977a), soybean is often broadcast on the field before wetland rice harvest or into the rice stubble after rice harvest without any land preparation. Planting at the base of the rice hills without additional land preparation is also common in Taiwan (William and Chiang 1976, Cheng 1977a).

Wheat grown after wetland rice in Taiwan is either relay interplanted with rice before rice harvest, sown without land preparation after rice harvest, or sown after the field has been plowed and ridged (Cheng 1977b).

The degree of land preparation for the dryland crop affects the weeds that are present (Moody 1977b). Weeds would be more of a problem in fields that have been poorly prepared than in those that have been thoroughly prepared before planting. Moody (1977a) observed that in no-tillage plots, the weeds were predominantly grasses; in tilled plots the weeds were almost exclusively sedges, primarily *C. rotundus.* Moody (1977%) reported that *Trianthema portulacastrum* L. grew primarily in the furrow that was opened for seeding the dryland crop while in the remainder of the field, grasses predominated.

The method of primary tillage (moldboard plowing, chisel plowing or rototilling) had little effect on weed growth in maize planted after wetland rice (Hundal, IRRI, 1980, pers. comm.). However, differences were observed between secondary tillage treatments. Rototilling was superior to disk harrowing in suppressing weeds. Weeds were controlled poorly when no tillage was used and paraquat was applied before planting.

In trials conducted in Pangasinan (IRRI 1978, 1979) and at IRRI (1979) method of land preparation (no tillage but paraquat application versus one plowing plus one harrowing or two rototillings) after rice harvest had no or little effect on weed weight. In most of those trials, the yields of sorghum, soybean, cowpea, mungbean, and vegetable cowpea (*V. unguiculata* ssp. *sesquipedalis*) were unaffected by tillage method or by degree of weeding. At IRRI (1979), however, mungbean yielded significantly more in a no-tillage field than in a field that had been plowed and rototilled. Weeding resulted in a significant increase in yield for sorghum in Pangasinan (IRRI 1978) regardless of the method of land preparation.

In no-tillage fields, I have observed little advantage from the use of paraquat before planting. Weed weights in the dryland crop after paraquat use are similar to those where no paraquat is used.

Time of planting

The importance of weed control in the dryland crop planted after wetland rice appears to be dependent on the moisture available in the soil at the time of planting the dryland crop and the degree of weed control in the previous rice crop (Moody 1977a). The growth of weeds, volunteer rice, and ratoon rice is much greater when the surface soil is wet at the time of dryland crop establishment than when it is dry (Moody 1977a). At IRRI, weed and volunteer rice growth was far greater when dryland crops were established in September than when they were planted in November (Janiya and Moody, unpubl.). *Ludwigia octovalvis* ssp. *sessiliflora* (Mich.) Raven, one of the major weeds in wetland rice (the other was *Echinochloa glabrescens* Munro ex Hook f.), was the dominant weed in the September planting when conditions were suitable for its germination and growth. It had virtually disappeared from the weed flora at the other planting times because of unsuitable conditions for germination and growth. *C. rotundus,* never a major weed, increased in importance from September to December reflecting the changing environmental conditions.

If the surface soil is dry and the crop seed is placed in contact with the moist soil layer, the crop will germinate and grow whereas the weed seeds, which may be in an unfavorable moisture zone, will not germinate. Moody (1977b) speculated that if no weeding was done in the dryland crop, yield losses would be less when moisture was limiting than when it was adequate. However, Watanabe et al (1980) reported that yield losses due to weeds were greater in both soybean and mungbean when the crops were irrigated 6 times between 7 February and 30 April than when they were irrigated 12 times between 7 February and 2 May.

Method and time of irrigation

Irrigation can be managed to control or reduce weeds in the dry season. For example, water placement, as in dry or trickle irrigation, confined weed problems to the places irrigated (Shoji 1977).

Samiano and Motooka (1979) reported that weed seed germination with irrigation in the dry season was about one-third that occurring in the rainy season. According to them, continuous moisture (low moisture tension over a period of time) is necessary for profuse weed seed germination. When irrigation was applied at 6- or 12-day intervals, weed density was significantly greater than that in the unirrigated check, but was significantly lower than (only about one-third) that when the plots were irrigated at 3-day intervals. Irrigations at frequent intervals during the dry season were needed to promote profuse weed seed germination.

In the Philippines, some melon and tomato producers water individual plants by hand. Weed problems are avoided in the unirrigated areas between plants, and weeding, if done at all, is confined to the areas adjacent to the watered plants.

Mulching

Rice straw is common as a mulch in crops planted after rice. In soybean cultivation in western, central and Eastern Java, the straw may be scattered on the field before the soybean is planted. In other cases, soybean is broadcast into the rice before it is harvested. The soybean crop receives little or no cultivation before it is harvested (Ismunadji 1975). The practice of mulching soybean with rice straw significantly increases crop yields. Dahro (1953) and Ismunadji (1975) attribute the increase to lower soil temperature, increased moisture availability, and decreased weed growth.

Lantican (1977) reported an average yield increase of 79% for 20 mungbean cultivars when they were mulched.

In the autumn-sown soybean crop in Taiwan, the crop is planted in the rice stubble without land preparation. Rice straw is spread over the field after the seeds have been sown in shallow holes beside each rice hill (Cheng 1977b).

Some farmers burn rice straw after seeding. The fire destroys weeds and weed seeds, and the ashes are said to improve drainage (Cheng 1977b). William and Chiang (1976) reported that both the rice straw mulch and burning of rice straw provided better weed control than a no-mulch check when no herbicides were applied. The use of herbicides improved the control of annual grasses in both the mulched and unmulched plots, but did not substantially improve weed control in the burned-straw treatment. Further trials (AVRDC 1976) confirmed that the burning of rice straw after sowing significantly controlled both broadleaf and grassy weeds.

Mulching by itself gave no disadvantage with respect to weed control.

In a trial at IRRI in the 1978-79 dry season, using rice straw as a mulch or burning it before planting sorghum had no effect on the weed population. Yields from the plots that were mulched or where the rice straw was burned were significantly higher than those from the unmulched plots. In another trial (IRRI 1979), rice straw mulch ranging from 1.5 to 4.5 t/ha had no suppressive effect on weeds. Mulching led to a significant increase in sorghum yield but had no effect on the yield of soybean and mungbean.

In Pangasinan Province, Philippines (IRRI 1978), cowpea, mungbean, and sorghum did not yield significantly higher when they were mulched. Mulching caused a significant depression in weed weight only in zero-tillage mungbean plots.

Moody (1978) reported a significant decline in weed weight in mulched mungbean plots compared to unmulched plots; there was no corresponding increase in mungbean yield.

It would appear that the advantage of rice straw as a mulch for weed control in the dry season is limited. Yield increases obtained by using a mulch are more likely to be due to moisture conservation than to weed suppression.

METHODS OF WEED CONTROL

In rainfed areas, farmers rarely weed, or they devote little time, effort, and money to weeding their dryland crops planted after wetland rice. Moody (1978) speculated that farmers are unwilling to risk their limited resources on weeding considering the low yields and the low return to weeding. If other factors such as moisture become limiting, the potential increase in yield probably will not be high enough to justify the expenditure of much labor on weeding (Harwood 1979).

In rainfed areas, hand weeding, or interrow cultivation especially on light soils, will have to be used to control weeds in the dryland crop after wetland rice. However, hand weeding is slower than in the wet season because of the difficulty in uprooting the weeds.

Interrow cultivation should be possible on all soil types provided that plowing and harrowing or rototilling were used for land preparation. However, if no tillage is used for crop establishment, the chances for use of interrow cultivation are greatly reduced. The rapid drying of the soil after the end of the rains creates conditions where it is impossible for the cultivating implement to penetrate, particularly on heavy soils.

Preemergence herbicides cannot be used if the crop is grown entirely on residual moisture, as there is no water to activate them (Moody 1979). The possibility of using selective postemergence herbicides needs to be explored further. Moody (1979) noted that herbicides are expensive and the yield levels presently being obtained in nonirrigated dryland crops grown after wetland rice probably do not warrant their use. Herbicides are most likely to be used in areas where irrigation is available (Moody 1977d).

Although yield depressions due to weeds in the dryland crop may be slight, Moody (1977b) recommended that some weed control be done to prevent weed seeding and to help prepare the soil for the crop to be planted at the start of the rains.

Without weed control and with the continued growing of the same cropping pattern, weeds in the dryland crop may build up to levels where they will have to be controlled to avoid yield losses.

William and Chiang (1976) reported that in Taiwan, farmers repeatedly weed soybean to eliminate *E. colona* when no apparent economic or biological response is expected in the soybean. The farmers try to maintain a low population level of this weed in soybean so as to reduce its population in rice where it is considered a serious problem.

SUMMARY

Weeds are usually not a major problem in dryland crops grown after rice when such crops are grown rainfed.

Crop rotations involving wetland and dryland crops generally result in reduced weed growth in the dryland crops. Method of land preparation affects the weed population, but not yield losses caused by weeds. Time of planting the dryland crop and time and method of irrigation affect weed growth, but mulching has little effect. Mulching appears to be more important in reducing moisture losses than in weed control.

The level of weed control in dryland crops is low because of the potentially low yields and low return to weeding from crops growing on residual moisture. Even though no economic or biological response to weeding is expected in the dryland crop, some weed control is recommended to prevent weed seeding and thus avoid problems in subsequent years.

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DISCUSSION

Malla: If weeds are a problem in upland crops after irrigated rice, is this also true in groundwater irrigated systems?

Moody: It appears that the degree of competition between weeds and crops planted after rice depends on the amount of irrigation applied. The more irrigation, the shallower the crop roots and the greater the competition. With less irrigation, the crop roots appear to go deeper than the roots of the weeds and therefore less competition for water occurs.

Malla: Can we reduce the weed population in upland crops by screening weed seeds from the canal water?

Moody: Yes.

Effect of rice stubble and tillage methods on the preflowering insect pests of grain legumes

Ruhendi and J. A. Litsinger

Soybean, cowpea, and mungbean are the most commonly grown grain legumes following wetland rice in the tropical zones of Asia. In wetland rice areas, farmers normally establish legumes by reduced tillage techniques to take advantage of the residual soil moisture for seed germination. The practice saves time, capital, and soil moisture.

Several reduced tillage methods are used for establishing legume crops following flooded rice (Somaatmadja 1972; Haque 1975; AVRDC 1976, 1977; Rahman et al 1976; Saxena 1976; Sambuichi and Watanabe 1976; Tongdee 1976; IRRI 1978):

- broadcasting seed into recently harvested rice fields with erect stubble;
- cutting rice straw and using it as a mulch after broadcasting seeds;
- spreading straw over planted fields, then burning it, presumably for better weed control and as a source of nutrients; and
- placing seeds in a wedge made with a hand tool at the base of the stubble after harvest.

PREFLOWERING INSECT PESTS OF GRAIN LEGUMES

Insect pests are reported to be the single most important constraint limiting grain legume yields in the tropics (Singh and van Emden 1979). An extensive array of pest species attack all parts of the plant at all stages of growth.

Bean flies, leafhoppers, aphids, leaf miners, leaf folders and leaf rollers, armyworms and cutworms, thrips, and leaf-feeding beetles are the major preflowering pests of soybean, cowpea, and mungbean in South and Southeast Asia (Arunin 1978, Kabir 1978, Litsinger et al 1978, Rose et al 1978, Saxena 1978, Subasinghe and Fellowes 1978).

Several researchers have shown that reduced tillage has a beneficial effect or insect control (CIAT 1977, 1978; Ruhendi 1976; Somaatmadja and Guhardja 1976; All et a1 1977, 1979; IRRI 1978), but others report that reduced tillage increased insect damage (Musick and Petty 1978, All et a1 1977).

The farmers' cultural practice of growing cowpea in zero-tillage rice stubble

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culture has a beneficial effect on control of the bean fly *Ophiomyia phaseoli.* In Iloilo, Philippines, the bean fly on cowpea was reduced in the presence of tall rice stubble compared with no stubble. Bean flies on each plant were 0.3 with zero tillage (rice stubble) and 3.1 with high tillage (no stubble) (IRRI 1978). A study at IRRI confirmed that the bean fly population per 30-m crop row with high tillage was higher (42 adults) than that with minimum (20 adults) and zero tillage (16 adults) (Table 1).

RICE STRAW MULCH

In Java, Indonesia, sowing soybean seeds on well-prepared land results in serious stand reduction from the bean fly *Melanagromyza sojae* at the seedling stage, but seeds sown on tilled land covered with rice straw escaped bean fly attack (Somaatmadja 1972). At Brebes, in Central Java, the number of bean fly adults, infested soybean plants, and dead plants were lower with rice straw mulch than without mulch (Table 2). But in an IRRI study, the number of adults in the high tillage

Table 1. Effect of 5 rice stubble heights, straw mulch, and 3 tillage methods on the adult bean fly population (counted visually) colonizing cowpea sown after flooded rice. IRRI, 1978 dry season.

Rice stubble	Tillage method[a]	Bean fly adults[b] (no./30-m crop row) 5-14 DE		
		No insecticide	With insecticide[c]	$\bar{c}$
None	High	38 ab	46 a	42 ab
Mulch	High	45 ab	47 a	46 a
2-cm high	Minimum	32 b	35 b	34 b
2-cm high	Zero	21 c	20 bc	21 c
15-cm high	Minimum	19 cd	27 bc	23 cd
15-cm high	Zero	20 cd	23 cd	21 de
30-cm high	Minimum	17 cd	16 de	17 def
30-cm high	Zero	12 cde	12 e	12 f
45-cm high	Minimum	14 e	16 de	15 ef
45-cm high	Zero	10 de	11 e	11 f
60-cm high	Minimum	13 e	16 de	15 ef
60-cm high	Zero	9 e	13 de	11 f

[a] 50-cm rows, high tillage (plowed once, harrowed twice), minimum tillage (furrows plowed between alternate rice rows), zero tillage (seeds dibbled in alternate rice rows). [b] In a column, means followed by a common letter are not significantly different at the 5% level. Analysis based on $\sqrt{x + 0.5}$ transformation. DE = days after crop emergence. [c] 2% wt/wt carbofuran (Furadan 50 DB) seed treatment.

Table 2. Effect of rice straw mulch on the soybean bean fly *Melanagromyza sojae.* 1975 dry season, Brebes, Central Java, Indonesia.[a]

	Bean fly adults 5 DE (no./40 hills)	Bean fly-infested plants at 10 DE (%)	Dead plants at 20 DE (%)
With rice straw mulch	1 a	27 a	38 a
Without rice straw mulch	7 b	54 b	59 b

[a] Av of 6 replications; untreated with insecticides. Means in a column followed by a common letter are not significantly different at the 5% level DE = days after emergence.

cowpea plots with no rice straw mulch and with rice straw mulch were equally high (42 and 46 adults per 30-m row), indicating that rice straw mulch had no bean fly-suppressing effect (Table 1). Thedifferent effects may be attributed to differences in behavior of the bean fly species *M. sojae* on soybean and *O. phaseoli* on cowpea.

Studies by other workers have also demonstrated the importance of rice straw mulch in insect control (CIAT 1977, 1978). Leafhopper *Empoasca fabae* populations colonizing common bean in mulched plots were lower (1 nymph/leaf) than those in unmulched plots (4 nymphs/leaf).

A study at IRRI showed that thrips *Thrips palmi* populations in cowpea were suppressed in plots with rice straw mulch (9 thrips/ 15 plants compared with 87 thrips/ 15 plants in high-tillage plots with bare soil) (Table 3). Smith et al (1972) showed that mulches repelled the gladiolus thrips. The effect was confirmed by Walker (1974) who studied the effects of different colored backgrounds on thrips colonizing crops.

RICE STUBBLE HEIGHT

The presence of stubble greatly depressed the colonizing bean fly adult population at IRRI (Table 1). The relationships between the adult and subsequent larval and pupal bean fly populations, and stubble height at 13 days after emergence (DE) were quadratic (Fig. 1, 2). Bean fly populations were minimum 13 DE in the 5l-cm-and 4l-cm-high stubble.

Thrips numbers were significantly suppressed in the plots with 30- to 60-cm erect stubble (2-8 nymphs + adults/ 15 plants) compared to that in the high-tillage plot with bare soil (87 nymphs + adults/ 15 plants) (Table 3). The 2-cm-high stubble did not suppress the thrips population (61-63 nymphs + adults/ 15 plants). The effect of the 15-cm rice stubble (30-32 nymphs + adults/ 15 plants) was intermediate. The relationship between the thrips population and stubble height (2-60 cm) was quadratic; the population was minimum 10 DE in the 54-cm stubble (Fig. 3).

Ten or 20 DE, the leafhopper *Amrasca biguttula* populations were lower in plots with 30- to 60-cm stubble (0-13 nymphs/ 15 plants) than in high-tillage plots with bare soil (23-26 nymphs/ 15 plants) (Table 4). A negative linear relationship was found between leafhopper number and stubble height in the 2- to 60-cm range at 10 DE. But at 20 DE, the relationship was quadratic and minimum leafhopper numbers occurred in the 44-cm stubble (Fig. 4).

At 30 DE, the black bean aphid *Aphis craccivora* infesting cowpea after rice in Iloilo were fewer in plots with rice stubble (grade 2) than in high-tillage plots with bare soil (grade 5), on a 1-9 scale of increasing severity (Table 5).

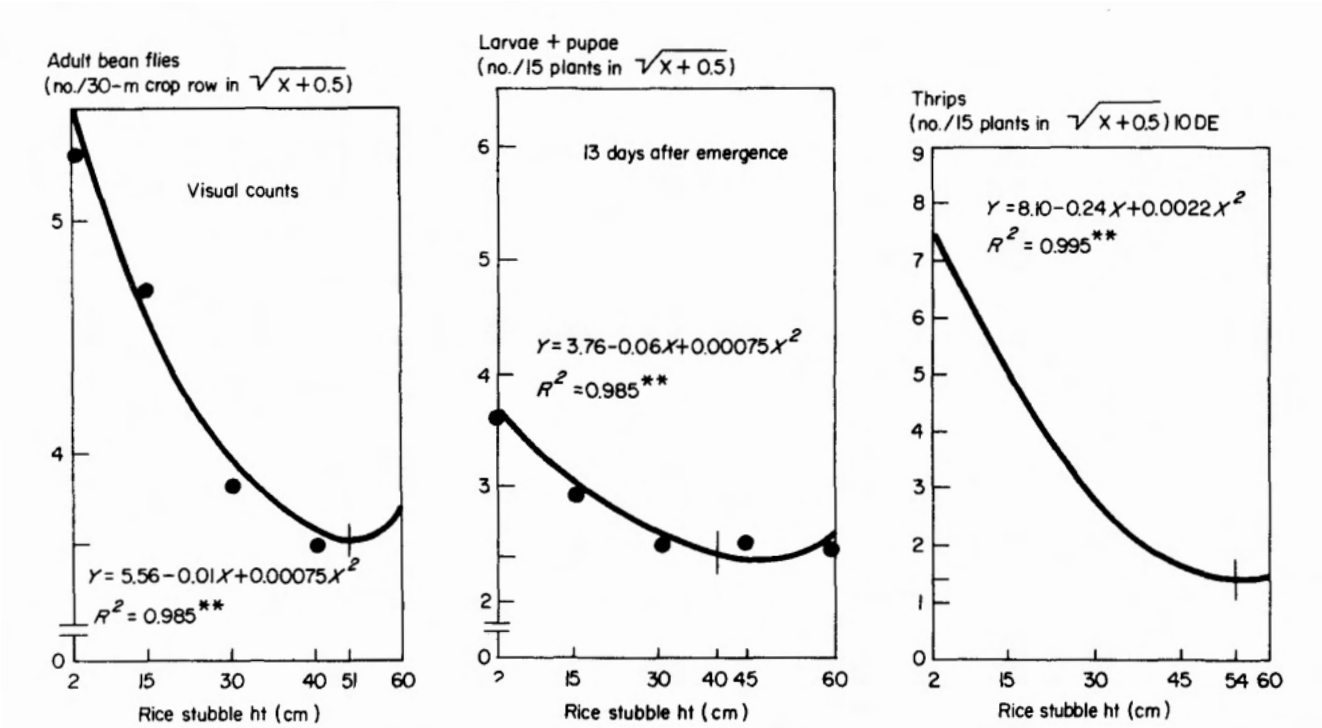
Erect rice stubble did not affect flea beetles, orthopterans, or leaf-feeding worms. At IRRI, the population of the leaf miner *Stomopteryx subsecivella* increased in tall rice stubble (Fig. 5), but in Iloilo, it was depressed (Table 5).

The spider populations at 13 DE were significantly higher on 30-cm to 60-cm tall stubble (5-9 spiders/30-m row crop) than in high tillage with bare soil or rice straw mulch, or on 2- to 15-m stubble height (1-2 spiders/ 30-m crop row) (Table 6). The relationship between the spider numbers and stubble height was quadratic, and maximum spider numbers occurred at 13 DE (6.3 spiders/ 30-m crop row) in 5l-cm

Table 3. Effect of 5 rice stubble heights, straw mulch, and 3 tillage methods on thrips infesting cowpea sown after flooded rice. IRRI, 1978 dry season.

Rice stubble	Tillage method[a]	Thrips[b] (no./15 plants)					
		10 DE			30 DE		
		No insecticide	With insecticide[c]	$\bar{c}$	No insecticide	With insecticide[c]	$\bar{c}$
None	High	87 a	27 ab	57 ab	5 a	9 a	7 a
Mulch	High	9 c	9 bc	9 d	1 a	1 a	1 a
2-cm high	Minimum	67 ab	58 a	63 a	7 a	5 a	6 a
2-cm high	Zero	60 ab	62 a	61 ab	9 a	3 a	6 a
15-cm high	Minimum	33 b	17 bc	25 c	6 a	2 a	6 a
15-cm high	Zero	33 b	31 ab	32 bc	5 a	0 a	3 a
30-cm high	Minimum	8 c	7 bc	8 d	5 a	6 a	6 a
30-cm high	Zero	5 c	5 bc	10 d	2 a	1 a	2 a
45-cm high	Minimum	8 c	1 c	5 d	0 a	1 a	1 a
45-cm high	Zero	4 c	2 c	3 d	1 a	0 a	1 a
60-cm high	Minimum	3 c	2 c	3 d	4 a	2 a	3 a
60-cm high	Zero	2 c	1 c	2 d	3 a	1 a	2 a

[a]50-cm rows, high tillage (plowed once, harrowed twice), minimum tillage (furrows plowed between alternate rice rows), zero tillage (seeds dibbled in alternate rice rows). [b]In a column, means followed by a common letter are not significantly different at the 5% level. DE = days after crop emergence. [c]2% wt/wt carbofuran (Furadan 50 DB) seed treatment.



1. Relationship between adult bean fly population and rice stubble height on cowpea sown after flooded rice. IRRI, 1978 dry season.

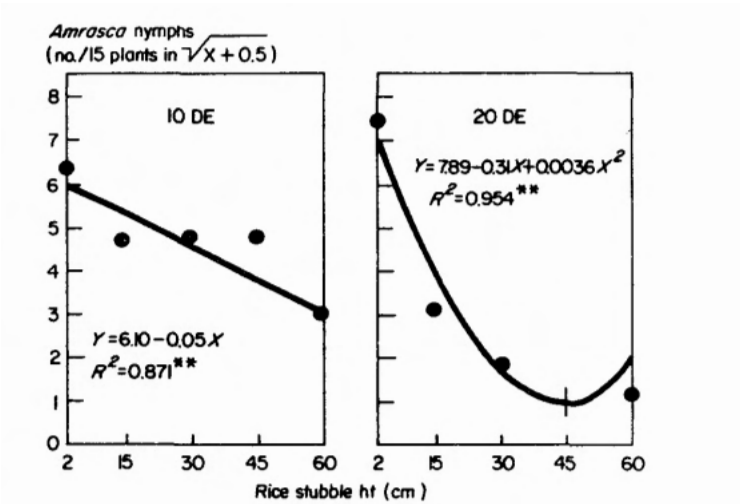
2. Relationship between bean fly larval and pupal population and rice stubble height on cowpea sown after flooded rice. IRRI, 1978 dry season.

3. Relationship between thrips and rice stubble. height on cowpea sown after flooded rice. IRRI, 1978 dry season. DE = days after crop emergence

Table 4. Effect of 5 rice stubble heights, straw mulch, and 3 tillage methods on *Amrasca* leafhoppers infesting cowpea sown after flooded rice. IRRI 1978 dry season.

Rice stubble	Tillage method[a]	*Amrasca* leafhopper nymphs[b] (no./15 plants)								
		10 DE			20 DE			30 DE		
		No insec-ticide	With insee ticide[c]	$\bar{x}$	No insec-ticide	With insec-ticide[c]	$\bar{x}$	No insec-ticide	With insec-ticide[c]	$\bar{x}$
None	High	23 ab	7 a	15 ab	36 b	22 a	29 a	21 abc	31 a	32 ab
Mulch	High	5 cde	2 ab	4 bcd	13 c	4 bcd	9 b	20 abc	3 c	12 bcd
2-cm high	Minimum	31 a	12 a	22 a	83 a	14 abc	54 a	53 a	23 abc	38 a
2-cm high	Zero	12 bc	16 a	14 abc	53 ab	23 ab	38 b	50 a	26 ab	38 a
15-cm high	Minimum	9 bcd	3 ab	6 bcd	13 b	5 abcd	9 b	31 ab	10 abc	21 abcd
15-cm high	Zero	11 cde	4 ab	9 abcd	9 c	10 abcd	10 b	27 abc	9 ab	18 abc
30-cm high	Minimum	5 cde	4 ab	5 bcd	6 c	2 cd	4 b	20 abc	13 abc	17 abcd
30-cm high	Zero	2 cde	l b	2 d	2 c	2 cd	2 b	17 abc	4 bc	11 abcd
45-cm high	Minimum	4 cde	2 ab	3 cd	2 c	2 cd	2 b	8 bc	4 bc	6 cd
45-cm high	Zero	4 cde	l b	3 cd	2 c	3 cd	3 b	9 bc	2 c	6 cd
60-cm high	Minimum	0 e	l b	1 d	2 c	1 d	2 b	21 abc	7 bc	14 abcd
60-cm high	Zero	1 de	l b	1 d	3 c	2 cd	3 b	6 c	2 c	4 d

[a] 50-cm rows, high tillage (plowed once, harrowed twice), minimum tillage (furrows plowed between alternate rice rows), zero tillage (seeds dibbled in alternate rice rows). [b] In a column, means followed by a common letter are not significantly different at the 5% level. DE = days after crop emergence. [c] 2% wt/wt carbofuran (Furadan 50 DB) seed treatment.



4. Relationship between *Amrasca* nymphs sampled on 2 dates and rice stubble height on cowpea sown after flooded rice. IRRI, 1978 dry season. DE = days after crop emergence.

stubble.

The population of the bean fly parasite in the 2-cm stubble was the highest (7 adults/30-m crop row). The population in the tall (45- to 6km) stubble was 2 adults/30-m crop row (Table 7). The relationship between the bean fly parasite population and stubble height within the 2- to 60-cm range was negatively linear. The parasite population decreased as the stubble height increased (Table 8, Fig. 6).

MECHANISMS TO EXPLAIN RICE STUBBLE OR STRAW MULCH INFLUENCE ON PREFLOWERING INSECT PESTS OF GRAIN LEGUMES

Tahvanainen and Root (1972) have coined a term for crop diversity effects — *associational resistance,* in which nonhost plants act as a defense in breaking or nullifying insect behavioral responses during crop colonization and subsequent population buildup. Risch (1979) found that associational resistance may be achieved in two ways: 1) by resource concentration, and 2) by natural enemies.

Resource concentration

The resource concentration theory is concerned with the changes in insect behavioral responses due to olfactory stimuli, visual cues, physical barriers or microclimate effects on insect colonization, reproduction, and survival.

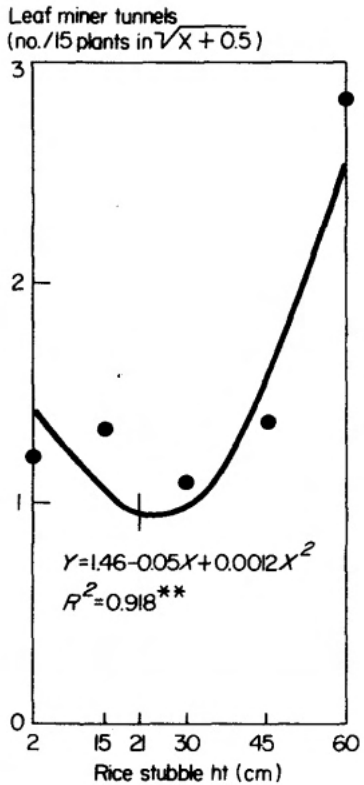
Olfactory stimuli. Herbivorous insects are affected by chemical stimuli from host and nonhost plants and these stimuli affect both the rate at which the insects colonize fields and their behavior once they have selected a suitable environment (Kennedy et al 1959a, 1961; Perrin 1977; Altierri et al 1977). It is unlikely that the dead rice straw or rice stubble emitted masking chemicals: therefore, olfactory stimuli would be an unlikely cause of the insect-suppressing effect in the rice stubble-cowpea association.

Visual cues. Bean fly vision was probably not influenced by crop background; the

Table 5. Effect of rice stubble on preflowering insect pests of cowpea.[a] Iloilo, Philippines, 1978.

Variety	Bean fly 10 DE		Aphid rating[b] (grade) 30 DE	Pests (no./20 plants) 30 DE	
	Larvae + pupae (no./20 plants)	Infested plants (%)		*Amrasca*	Leaf miner
EG 2					
With rice stubble	1 a	9 a	2 a	1 a	2 a
Without rice stubble	24 b	68 b	5 b	18 b	8 b
Camaros					
With rice stubble	la	6 a	2 a	0.3 a	1 a
Without rice stubble	16 b	59 b	6 b	15 b	21 b

[a]Av of 4 fields; untreated with insecticides. DE = days after emergence. Means in a column followed by a common letter are not significantly different at the 5% level. [b]1-9 scale: 1 = no aphids, 3 = adults only, 5 = several colonies, 7 = many distinct colonies, 9 = many colonies coalesced and indistinct.



5. Relationship between leaf miner tunnels and rice stubble height on cowpea sown after flooded rice. IRRI, 1978 dry season.

Table 6. Effect of 5 rice stubble heights, straw mulch, and 3 tillage methods on spiders sampled by D-VAC on cowpea sown after flooded rice. IRRI, 1978 dry season.

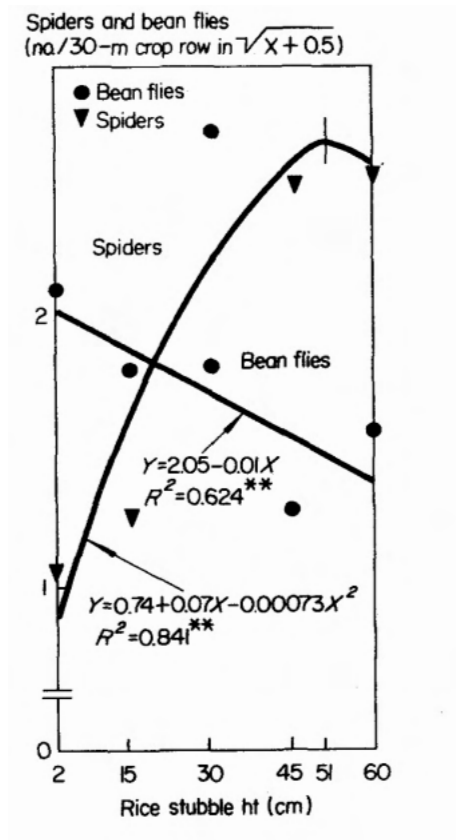
Rice stubble	Tillage method[a]	Spiders (no./30-m crop row)[b]	
		13 DE	26 DE
None	High	1 a	3 a
Mulch	High	1 a	2 a
2-cm high	Minimum	1 a	2 a
2-cm high	Zero	1 a	3 a
15-cm high	Minimum	2 ab	5 a
15-cm high	Zero	2 ab	4 a
30-cm high	Minimum	9 c	3 a
30-cm high	Zero	9 c	3 a
45-cm high	Minimum	7 bc	3 a
45-cm high	Zero	7 bc	3 a
60-cm high	Minimum	5 ab	3 a
60-cm high	Zero	8 c	5 a

[a]50-cm rows, high tillage (plowed once, harrowed twice), minimum tillage (fur-rows plowed between alternate rice rows), zero tillage (seeds dibbled in alternate rice rows). [b]In a column, means followed by a common letter are not significantly different at the 5% level. DE = days after crop emergence.

Table 7. Effect of 5 rice stubble heights, straw mulch, and 3 tillage methods on bean fly parasites[a] on cowpea sown after flooded rice. IRRI, 1978 dry season.

Rice stubble	Tillage method[b]	Bean fly parasites[c] (no./30-m crop row)	
		13 DE	26 DE
None	High	5 ab	2a
Mulch	High	3 ab	4a
2-cm high	Minimum	la	3a
2-cm high	Zero	4 ab	4a
15-cm high	Minimum	4 ab	5a
15-cm high	Zero	4 ab	2a
30-cm high	Minimum	5 ab	2a
30-cm high	Zero	3 ab	3a
45-cm high	Minimum	2b	la
45-cm high	Zero	2b	4a
60-cm high	Minimum	2b	4a
60-cm high	Zero	2b	4a

[a]Caught with a D-VAC suction sampler. [b]50-cm rows, high tillage (plowed once, harrowed twice), minimum tillage (furrows plowed between alternate rice rows), zero tillage (seed dibbled in alternate rice rows). [c]In a column, means followed by a common letter are not significantly different at the 5% level, DE = days after crop emergence.



6. Relationship between bean flies and spiders and rice stubble height on cowpea sown after flooded rice. IRRI, 1978 dry season.

Table 8. Relationship of stubble height and spiders and bean fly parasites on cowpea sown after flooded rice. IRRI, 1978 dry season.

Rice stubble ht (cm)	Pests [a] (no./30-m row at 13 DE)	
	Spiders	Bean fly parasites
2	1	4
15	1	3
30	7	3
45	6	1
60	6	2

[a] Three replications averaged over 2 tillage methods (zero and minimum) and 2 insecticide treatments (with and without preflowering protection). DE = days after crop emergence. D-VAC insect sweep-net sampling.

rice straw mulch did not interfere with adults colonizing cowpea plants. The rice straw mulch or tall rice stubble had low numbers of adult leafhoppers, thrips, and aphids. A CIAT study (1978) showed that light reflection was the principal factor involved in reducing leafhopper populations — reflected light intensity was higher for rice straw (20%) than for bare soil (5%). Gonzales and Rawlins (1968) and IRRI (1978) reported that more aphids were attracted to plants set against bare soil than to plants that were densely spaced. Since thrips and leafhopper gave the same responses to rice straw mulch and tall stubble, possibly the visual crop background (high light reflection) nullified the host-seeking visual stimuli of colonizing adults.

Physical barrier effect. Insect ability to locate a host in a particular habitat is affected by the presence in plant associations of nonhosts that act as physical barriers to obstruct an immigrating pest. The fact that the taller rice stubble had proportionally fewer insects (bean fly, thrips, leafhoppers, and aphids) supports the camouflage physical barrier theory. In the case of thrips, leafhoppers, and aphid, the rice stubble may have acted as a filter. Tillage method also had an effect on the bean fly population. Minimum tillage was significantly less effective than zero tillage, but significantly more effective than high tillage. The different responses to zero tillage and minimum tillage may be due to the plow furrows in minimum tillage, which reduced stubble density by opening bare soil. The result again supports the camouflage theory. However, the nonhost that acts as a barrier to obstruct an immigrating insect pest is probably more important to small insects that have little control over the direction of their fight.

Microclimate effect. It is postulated that the abundance of spiders was differentially affected by the microclimate in the various straw and stubble treatments, which then led to differential pest mortality between tillage treatments. High-tillage plots with bare soil, or plots with 2-cm stubble may create a hot and dry habitat that repels spiders, while the cooler and humid microenvironment in the tall stubble may have been more attractive to spiders.

Natural enemies

The spider population was higher in the erect rice stubble than in the plot with high tillage. A beneficial effect of rice stubble was reported by Raros (1974) who showed that decaying rice straw mulch supported collembolans, which are the primary food

of first-instar spiderlings. Because the tall rice stubble lodged sooner, it may have provided more decayed stubble than either the short stubble or rice straw mulch. This could have resulted in high collembolan populations that, in turn, supported more spiders. As shown in the erect stubble-cowpea association, the two previously mentioned mechanisms possibly contributed to high spider populations at 13 DE: the tall stubble served as shelter and provided an alternate food source (collembolans).

The bean fly parasites need hosts on which to deposit eggs. The highest numbers of bean flies and of their parasites were recorded in the high-tillage plots.

Nonhost anti-arrestant effect

Risch (1979) developed the nonhost anti-arrestant theory to explain leaf beetles' behavior when they alight on nonhost plants. He found that the greater the proportion of nonhosts in a polyculture for each *Diabrotica* species, the fewer the beetles that remained in the field. Nonhost plants interfered with beetle behavior. The beetles apparently did not discriminate hosts from nonhosts before they alighted on plants. If they landed on a nonhost, they flew off again out of the plot, but if they landed on a host, their flight behavior was arrested and they fed on the plant.

Rice straw mulch did not suppress the bean fly. It is probable that a bean fly coming into a field will choose to alight on taller objects rather than the prostrate straw at ground level. In the rice stubble-cowpea association (rice stubble is a nonhost), however, a bean fly may seek out the tall rice stubble rather than a cowpea plant. Instead of flying down to a cowpea plant below the rice stubble, the adults probably fly off again. This process may occur repeatedly until the insects find a host or are blown off the field by wind. Therefore, the nonhost, anti-arrestant theory could explain the bean fly response in the rice stubble-cowpea association and the proportionally fewer leafhoppers, thrips, and aphids in taller stubble.

CONCLUSION

Trials at IRRI and Iloilo in the Philippines demonstrated that straw and stubble from the previous flooded rice crop suppressed certain preflowering insect pests of cowpea. Straw mulch negatively affected thrips *T. palmi* and the leafhopper *A. biguttula,* and stubble suppressed the bean fly *O. phaseoli,* black bean aphid *A. craccivora,* thrips, and leafhopper.

The effect of straw mulch was probably due to increased light reflection that interfered with the visual host-seeking responses of colonizing thrips and leafhopper. This phenomenon is documented in the literature on similar species.

The rice stubble may also have expressed negative visual stimuli to colonizing thrips and leafhoppers, but stubble taller than 2 cm was required. Population suppression was maximum at 54- and 44-cm-high stubble for thrips and leafhopper.

Erect rice stubble 15-60 cm significantly reduced bean fly and aphid populations. The maximum suppressing effects on bean fly occurred in the 41- to 51-cm-high stubble.

Stubble density was also important for bean fly suppression. Minimum tillage, which opened up plow furrows, reduced the effective stubble density and was less

effective than zero tillage where cowpea was dibbled without disturbing the stubble.

Bean fly suppression in stubble may have occurred from any of the following factors: 1) crop camouflage, 2) nonhost, anti-arrestant effect due to crop diversity, and 3) conditions favoring more predatory spiders.

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Disease problems in upland crops grown before and after wetland rice

T. W. Mew and F. A. Elazegui

Multiple cropping systems involve crop diversity in the same field during a single cropping season or year. The rice-based cropping systems always have a rice crop in the rainy season for 4 to 5 months, and the upland crops are planted either before or after rice. The distinct characteristic of wetland cropping systems is field flooding or submergence during certain periods of the year. The disease complex of all crop species of the cropping systems is, no doubt, affected by the flooding. It has been said, and often taken for granted, that continuous flooding reduces the inocula of certain well-established and destructive pathogens — especially soil-borne ones — of the component upland crops of a cropping system. In dryland fields, flood irrigation is often applied to minimize a disease problem, such as bacterial wilt of solanaceous crops (Mew and Ho 1976, Seneviratne 1976) and southern blight of grain legumes (Stoner and Moore 1953).

In China, Kelman and Cook (1977) and Williams (1979) observed fewer soil-borne diseases caused either by fungi, bacteria, or nematodes on upland crops. They attributed it to extensive paddy-based cropping systems and the use of compost. But much effort has been devoted to research on and impact of monoculture on diseases (Shipton 1977) and the beneficial effects of crop rotation on management of some diseases of upland crops (Zentmyer and Bald 1977).

Analysis of a disease ecosystem within a rice-based cropping system has not caught the attention of many pathologists. On Asian small farms, *traditional agriculture* lessens the opportunity for disease to establish and to spread (Glass and Thurston 1978) because the field is small and crop species or varieties are of diverse genetic types. Such *mixed cultural system* does not allow endemic plant diseases to be serious to the point of causing crop failure. A significant feature of Asian *traditional agriculture* is submergence or flooding of the rice field for several months.

The pathological component of multiple cropping systems research seeks to analyze the impact of the natural interactions between the rice crop and upland crops established either before or after the rice crop, on diseases. Attention is directed to the disease complex or the ecosystem of plant disease within a rice-based cropping system. The general ecosystem of plant disease is a triangle (Van der Plank

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1972) representing the host, the pathogen, and the environment. The host, with rice as the base crop, includes the upland crop species or varieties across the cropping systems. The pathogen can be soil-borne or airborne, and can be fungi, bacteria, nematodes, or viruses. The environment could be rainfall, temperatures, and soil moisture. Pathological component research involves the management of either one, two, or all angles of the disease triangle.

We report our initial observations and approaches. No attempt is made to provide a complete literature review of the disease problems of the crops planted before and after rice.

DISEASE SURVEY

Disease survey has the following objectives: to determine disease problems and to assess the damage caused by each disease. Diagnosis is descriptive and confirmative of problems relative to the cause. Assessment of damage relates to either qualitative or quantitative yield losses. Quantifying of yield loss caused by disease, however, is not easy and sometimes is not possible unless a disease epidemic occurs. Disease assessment could be based on its incidence (the number of plant units infected in a given area or field during a given period) and on its severity (the amount or degree of infection). Correlation between these two parameters and actual yield loss is not always evident nor predictable. Experiments for this purpose are needed. This survey is concerned primarily with the diagnosis of the disease and estimation of its incidence and severity.

James (1974) defined *disease incidence* as the number of plant units infected expressed as percentage of the total number of units assessed, and *disease severity* as the amount of plant tissues affected by disease expressed as percentage of the total tissues. In a disease survey, the following should be considered.

Determining the fields to be surveyed

For convenience, it is a common practice to include only fields near the road or those known to extension workers. Ideally, randomly selected fields that are representative of a site should be used. A more sophisticated approach is to list the number of fields in a site or farm, then select randomly the particular fields to be surveyed using a table of sampling numbers (James 1969).

Disease assessment

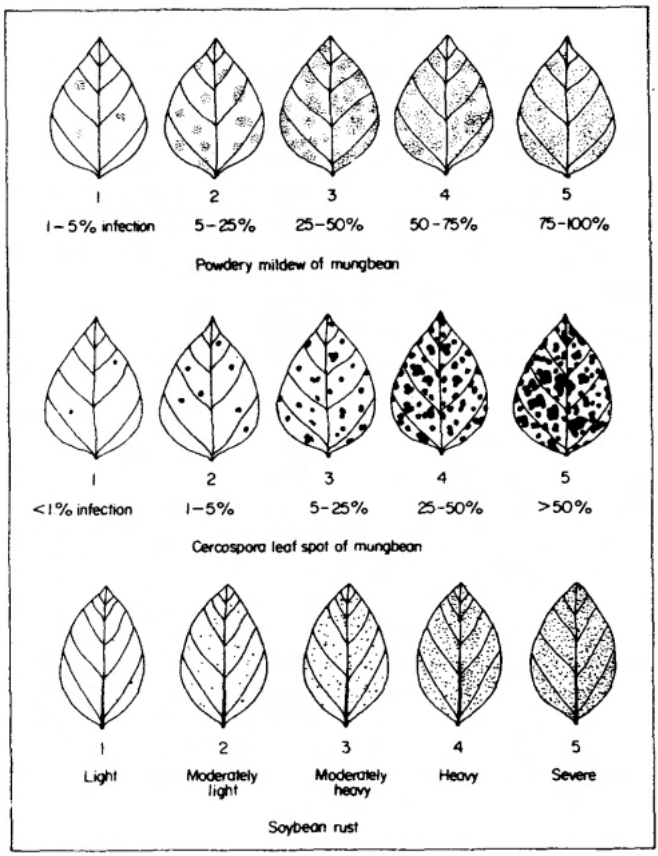
For an objective assessment of incidence and severity, diseases are classified on the basis of type of infection.

1. Those which affect the whole plant (systemic infection), e.g. downy mildew of maize, bacterial wilt of solanaceous crops, or some virus diseases.
2. Those which kill the whole plant as a result of infection on the stem and roots, e.g. root and stem rot and damping-off.
3. Those which affect only plant parts (local infection), e.g. leaf spot.

Ability to diagnose plant disease is of great value. For diseases in categories 1 and 2, incidence is closely related to severity. Crop reduction or crop density loss in a single field may be estimated. Diseases in category 2 may not always lead to plant mortality.

Assessment of diseases in category 3 is not easy. Lower or older leaves may have more infection than the upper or younger ones. The number of lesions or infected leaf areas also varies from leaf to leaf and from plant to plant. In the field, diseases other than the target one may also be present. Therefore, the survey may have to consider the disease complex.

Disease incidence, however, can be accurately estimated for individual diseases or disease complex. The Asian Vegetable Research and Development Center has developed rating systems, which serve as convenient guides to determine the seventy of Cercospora leaf spot and powdery mildew of mungbean, and rust of soybean. The rating systems are similar to IRRI's *Standard Evaluation System for Rice.* A more comprehensive guide for diseases (esp. foliage diseases) of diverse crop species has been devised by James (1971). Figure 1 shows our modifications for mungbean powdery mildew and powdery Cercospora leaf spot and soybean rust.



1. Diagram showing severity and suggested score of some foliar diseases of legumes.

One important requirement is to state the crop growth stage at the time of the survey.

DISEASES OF COMPONENT UPLAND CROPS

In most of the rice-based cropping systems in tropical Asia, the following upland crops are planted either before or after rice: cereals (maize, sorghum), legumes (soybean, cowpea, mungbean, peanut), root crops (sweet potato, potato, cassava), and vegetables (tomato, eggplant). Some of the important diseases of the component upland crops in a cropping systems also threaten crops in a monoculture system.

Our initial 3-year survey of diseases on component upland crops of the cropping systems in the Philippine outreach sites showed 2 major groups: airborne and soil-borne (Table 1). The airborne diseases are ubiquitous and spread easily; the source of inoculum may be in areas outside of a specific cropping pattern's field, or in neighboring fields, thus, nullifying our studies on the effect of the cropping systems on disease establishment and severity. On the other hand, soil-borne diseases spread only endemically and, hence, could sometimes be correlated with previous crops.

The soil-borne diseases were further divided into two major categories (Garrett 1970): those caused by unspecialized pathogens and those caused by specialized ones. Unspecialized pathogens usually have a wide host range conferring the advantages of abundance and wide distribution. Specialized pathogens have a relatively limited host range and distribution. Their infection is specific to not only certain crop

Table 1. Common diseases recorded at the Philippine outreach sites of the IRRI Cropping Systems Program during 1977-79.

Crop	Disease	Pathogen	Nature
Cereal			
Rice	Leaf blast	*Pyricularia oryzae*	Airborne
	Brown spot	*Helminthosporium oryzae*	Airborne
	Sheath blight	*Corticium sasukii*	Soil-borne
	Bacterial leaf blight	*Xanthomonas oryzae*	Soil-borne
Sorghum	Downy mildew	*Sclerospora philippinensis*	Airborne
	Sheath blight	*Rhizoctonia solani*	Soil-borne
	Zonate spot	*Gleocercospora sorghi*	Airborne
Legume			
Mungbean	Damping-off	*Sclerotium rolfsii*	Soil-borne
	Powdery mildew	*Erysiphe polygoni*	Airborne
	Cercospora leaf spot	*Cercospora* spp.	Airborne
Cowpea	Damping-off	*S. rolfsii*	Soil-borne
	Cercospora leaf spot	*Cercospora canescens*	Airborne
	Leaf rust	*Uromyces phaseoli*	Airborne
Soybean	Damping-off	*S. rolfsii*	Soil-borne
	Rust	*Phakopsora pachyrhizi*	Airborne
Peanut	Black spot	*Cercospora spp.*	Airborne
	Leaf rust	*Puccinia arachidis*	Airborne
	Mottle	*Peanut mottle virus*	Seedborne
Bush sitao	Stem and root rot	*Fusarium solani* f. sp. *phaseoli*	Soil-borne

species but also plant tissues. Therefore, cropping patterns may have a significant effect on this type of pathogens.

The common and major diseases of the component upland crops are described.

Foliage diseases

Downy mildew. Downy mildew is perhaps the most important biological constraint threatening maize in tropical Asia (Frederiksen and Renfro 1977). There are nearly 21 species of the fungal pathogens causing downy mildew in the tropics. In the Philippines, the maize downy mildew pathogen is *Sclerospora philippinensis* Weston. It is an airborne disease normally transmitted by inoculum generated in the field. The pathogen infects young leaves through conidia, and as the leaves unfold, various symptoms appear. The infected leaves show lighter green or yellow discoloration. When infection occurs at the seedling stage, the growth of the entire plant is arrested.

Recent surveys indicate losses of 15-40% (Exconde and Raymundo 1974) in monoculture planting in farmers' fields.

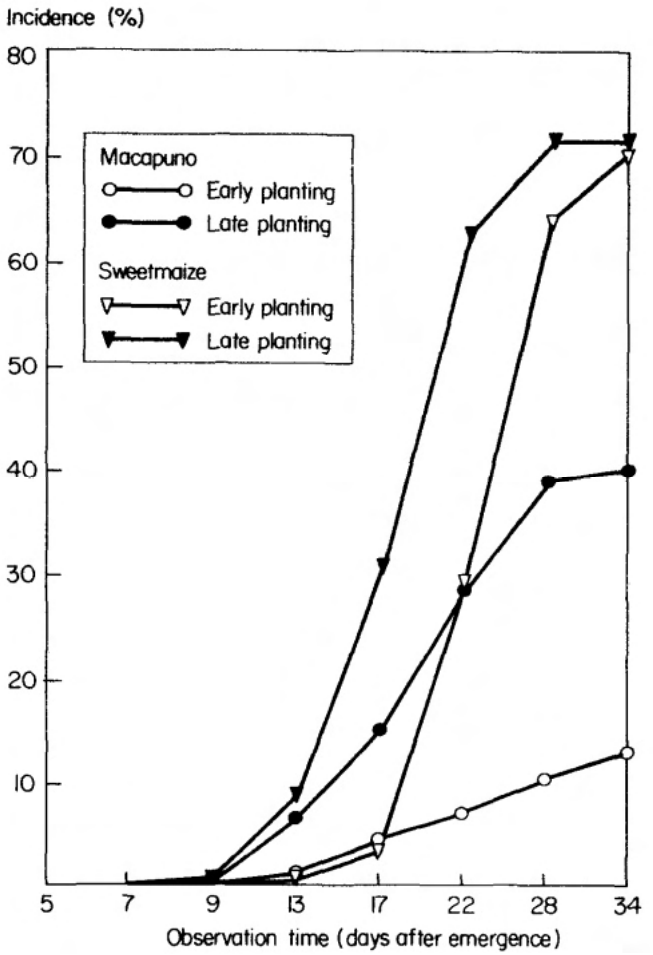
In rice-based systems, maize is usually planted before rice. The disease was observed at various levels of incidence and severity. In 1978, at the Pangasinan outreach site of the Philippines, the buildup of inoculum from diseased plants in early planting caused the higher disease incidence of later planting (Fig. 2). This suggests that the varied cropping patterns in a site may affect the spread of the disease of this nature. Planting resistant varieties may control the disease.

Several chemicals have kept the disease in check. The most effective one is Ridomil applied as seed treatment.

Powdery mildew of legumes. Powdery mildew of legumes is one of the most important foliage diseases attacking mungbean planted in the dry season, a period of the year when there is little rainfall but the relative humidity may still be high. In the Philippines, Thailand, and other Southeast Asian countries, the disease occurs mostly from November through April. Initial infection of powdery mildew of mungbean, caused by *Erysiphe polygoni,* can be observed at the cotyledon leaf stage, but the most severe infections usually occur from flowering to harvest. The fungus attacks mungbean at all growth stages. All parts, except the roots, are vulnerable. When infection occurs at the seedling stage, the plants never recover. Severe infection can result in premature defoliation.

Cercospora leaf spot of legumes. In tropical Asia, Cercospora leaf spot of legumes is prevalent and is particularly damaging on legumes planted during the wet season. Many species of the fungus attack legumes. On mungbean, the causal fungus is *Cercospora canescens,* and its close relative infects cowpea, peanut, and soybean. Infection on the leaves usually results in necrotic lesions characterized by a brown halo and white center. *C. canescens* also infects pods, petioles, and stems. The fungus was readily isolated from seeds (T.W. Mew, unpubl. data).

In Southeast Asia, Cercospora leaf spot constitutes a major threat to mungbean cultivation in the wet season. The disease on susceptible cultivars generally causes complete defoliation and yield losses often reaching 50%. The disease tends to taper off during the dry season. In the wet season, infection initiated on very young seedlings becomes more severe during flowering. Cercospora leaf spot of peanuts is



2. Maize downy mildew on 2 maize varieties with early and late plantings before the rice Crop in Pangasinan, Philippines, 1979.

caused by two species: *C. personata* at early growth, or *C. arachidicola* at later growth stage. The former is very common and destructive wherever peanuts are grown intensively (Chupp 1953).

Other foliage diseases. In tropical Asia, soybean rust caused by *Phakopsora pachyrhizi* is the most destructive foliage disease of the crop. In Southeast Asia, other hosts of the fungal pathogen include common bean (*Phaseolus vulgaris*), the wild soybean (*Glycine soja*), and the yam bean (*Pachyrhizus erosus*) (AVRDC 1975).

Other important foliage diseases of the component upland crops often observed in the Philippines are corn rust (*Puccinia polysora*), Helminthosporium leaf spot of sorghum (*Helminthosporium sorghicola*), peanut leaf rust (*Puccinia arachidis*), and bacterial blight of legumes (*Xanthomonas phaseoli*).

Soil-borne diseases

Damping-off. Damping-off of legumes following rice is one major constraint in establishing legume crops. The disease usually starts 1 week after planting and continues until the first or second trifoliate leaf stage. The disease affects seedling emergence even with seeds of high germinative capacity. Seedlings that have emerged often show water-soaking and browning or shriveling of the stem tissues at soil level, and die as a result. The disease at those two stages are known to plant pathologists as preemergence and postemergence damping-off. All legume crops — soybean, mungbean, cowpea, peanuts, etc. — involved in the component upland crops of the cropping systems in the Philippines are vulnerable to the disease.

Of the many individual fungi associated with damping-off, *Sclerotium rolfsii* Sacc. is perhaps the most common as far as the Philippine outreach sites are concerned. *S. rolfsii* is distributed in tropical and subtropical countries where high temperatures prevail during the rainy season. Although the fungus is best known as a parasite of stems of older plants, it can infect any parts of a susceptible plant under favorable environmental conditions. Once the plants are infected, sclerotia are formed. The white mass of mycelium *superficially* growing on the stem becomes visible.

Other fungi have been identified as causes of damping-off of legumes at IRRI and also at the different outreach sites. They include *Rhizoctonia solani, Fusarium* spp., and *Pythium* spp. However, they are sometimes location specific.

Damping-off is caused by unspecialized pathogens and, therefore, the host range is fairly broad. Any crop, including rice, may be affected. Crops grown in unfavorable conditions that affect their growth vigor or germination are vulnerable.

Root and stem diseases. Root and stem diseases may be caused by various fungi. Legume root rot caused by *Fusarium solani* is common. Progressive rotting of the root system often involves the basal portion of the stem, and the plant cannot obtain the water and nutrients it needs. Shoot growth is checked and the plant becomes stunted, the leaves yellow and some drop off; eventually the plant wilts and dies. The syndrome and final mortality of a plant depend not only on the progress of rotting but also on the ability of the host to undertake defense mechanisms such as producing new roots in unaffected parts and withstanding the water shortage that results from the loss of roots.

S. rolfsii infection on adult plants results in yellowing of the leaves followed by wilting; finally, the plant dies. The mycelium often appears as a white mass at the stem bases of dying plants. Sclerotia are formed on the affected portions. Disease development is favored by high soil moisture and by high soil temperature. *S. rolfsii* is an unspecialized pathogen; hence, its host range is fairly broad.

Fusarium root rot of legumes is another common disease of legumes in cropping patterns. It is caused by *Fusarium solani.* Like other root rot diseases, the infection occurs on adult plants. Ingress of the pathogen is apparently through lateral roots or through the tip of the main roots. The infection results in gradual drying out of the tissues of the stem bases. The fungus has a relatively narrow host range and belongs to the specialized group of soil-borne pathogens. One distinct feature of the disease is the reddish discoloration often associated with the taproot.

The rice sheath blight fungus *R. solani* infects many crops other than rice. Maize

and sorghum in dryland rice fields are especially vulnerable. The symptoms on these cereals are leaf sheath lesions becoming necrotic and giving the infected tissues a banded appearance. That is why the disease is sometimes known as banded blight. The pathogen also affects soybean and mungbean (Table 2).

EFFECT OF FLOODING ON DISEASES OF COMPONENT UPLAND CROPS

Flooding is generally believed to have some significant effect on the elimination of pathogens, particularly the soil-borne ones (Cook 1977). Because most of the soil-borne fungal, bacterial, and nematode pathogens are aerobic, flooding the fields for 3 to 5 months would affect their survival.

Flooding or irrigation has suppressed inocula. Flooding has been used to get rid of the sclerotia of *Sclerotinia sclerotiorum* (Stoner and Moore 1953). It is presumed that the anaerobic conditions weaken the propagules and predispose them to decay. Smith (1972) provided further evidence on decaying of sclerotia of *S. rolfsii.* He found that a period of dry fallow followed by irrigation or rain reduced the populations of the pathogen because drying and then rewetting caused the sclerotia to lose reserved nutrients. Rewetting caused the sclerotia to germinate, but they

Table 2. Incidence and severity of diseases caused by various host isolates of *Rhizoctonia solani* on different crops. 1979.

Isolate from	Disease incidence or severity[a]					
	Rice		Maize	Sorghum	Mungbean	Cowpea
	Dryland	Wetland				
	Preemergence damping-off[b] (%)					
Rice, wetland	28.0 a		29.7 a	58.7 a	100.0 a	100.0 a
Rice, dryland	13.3 a		22.7 a	27.0 c	59.7 c	38.3 b
Maize	25.3 a		19.7 a	42.0 abc	98.0 ab	98.0 b
Sorghum	14.0 a		20.3 a	37.7 bc	84.7 bc	60.3 b
Mungbean	15.3 a		19.7 a	72.3 a	87.0 b	98.7 a
Cowpea	42.3 a		37.7 a	69.7 ab	100.0 a	100.0 a
	Postemergence damping-off[c] (%)					
Rice, wetland	65.4 a		51.7 ab	80.0 ab	90.8 a	76.7 b
Rice, dryland	17.1 b		35.0 bc	68.3 b	46.7 bc	51.7 bc
Maize	72.5 a		76.7 a	95.8 a	25.8 c	43.3 c
Sorghum	47.9 a		56.7 ab	96.8 a	61.8 b	46.7 bc
Mungbean	40.8 ab		60.0 a	96.8 a	38.3 bc	8.3 d
Cowpea	0 c		10.0 c	27.5 c	100.0 a	95.0 a
	Lesion length (cm)[c]					
Rice, wetland	17.6 a	19.9 a	27.7 a	28.6 a	1.9 a	6.8 b
Rice, dryland	11.9 bc	12.4 b	24.4 a	25.1 ab	2.8 a	12.6 a
Maize	15.4 ab	13.8 b	26.8 a	27.0 a	6.7 a	8.2 ab
Sorghum	12.6 bc	12.4 b	24.4 a	21.9 b	2.1 a	8.9 ab
Mungbean	19.1 a	9.6 a	23.9 a	24.8 ab	4.4 a	6.0 b
Cowpea	8.2 c	6.3 c	8.8 b	16.2 c	6.5 a	9.6 ab

[a]Each figure represents mean of 3 replications; analysis for preemergence and postemergence damping-off based on values transformed to arcsin; means followed by a common letter are not significantly different at the 5% level. [b]Data taken 7 days after sowing. [c]Data taken 7 days after inoculation.

eventually rotted because of colonization by other saprophytes. On the other hand, Tanaka et al (1975) demonstrated that *S. rolfsii* maintained in soil (dryland soil) under submerged conditions at a temperature range of 10-35° C could survive for 60 days at 10° C, 30 days at 30°C, and a few days at 30-35° C. *Pseudomonas solanacearum* in solanaceous crops under the same conditions showed a similar trend of survival. Nematodes are no exception under submerged soil.

Castillo et al (1976) monitored the parasitic nematode populations of certain upland crops after rice and found the highest populations of *Meloidogyne* spp. and *Rotylenchus* spp. in nonflooded upland fields. Isolated paddies in drainageways among the dryland fields had low populations. They indicated that 1 crop of paddy rice, which undergoes 2 to 3 months of flooding, is sufficient to reduce the nematode populations in these fields.

There is however, controversial information on this field. In the Welimada and Kandy Districts of Sri Lanka, solanaceous crops including potato and tomato are grown in rice fields during the dry season, when the supply of water is inadequate to sustain a crop of rice. Although *Pseudomonas solanacearum* is an aerobic organism, flooding of fields for several weeks during the rice growing season did not control the disease (Seneviratne 1976). It is believed that the pathogenic bacteria were present in the soils and survived despite cultural practices that accompanied rice cultivation.

Mew and Ho (1976) observed bacterial wilt in tomato transplanted in paddy fields shortly after rice harvest. The inoculum could have originated from the nursery where tomato seedlings were raised.

In the Philippine outreach sites of IRRI's Cropping Systems Program, damping-off caused by *S. rolfsii, Phythium* sp., or *R. solani* and root rot of legumes were major threats to the establishment of legumes after rice. Whether the inoculum of these diseases could survive flooding and submerged conditions, or whether the source of inoculum was brought in from outside is not known. The host range of these pathogens is, however, fairly broad.

DISEASE MANAGEMENT AND CONTROL

For a pathogen to cause disease in a cropping system involving more than one crop species, inoculum must be indigenous on one of the crops, or become introduced during cultivation of particular crops. In either case, the cropping pattern influences the time and rate of development of the disease.

The general strategy of disease management or control is either to reduce the amount of inoculum from which the disease starts or reduce the rate at which it increases after it has started, or both (Vander Plank 1963). Inoculum management is especially relevant with disease problems identified as important to the component crops. The inoculum of a disease can be reduced or eliminated from the fields by chemical control, cultural practices, or by planting resistant varieties.

Resistant varieties are a good means of minimizing the inoculum and eventually the infection, but very often resistant varieties of the component dryland crops are neither available to, nor acceptable to the farmers. For unspecialized soil-borne parasites, there may be no resistant varieties; for some airborne diseases, resistant varieties may be available but nonfunctional in specific locations because of differ-

ence in virulence or pathogenicity of the organisms. Stem rot or damping-off caused by *S. rolfsii* is a good example of the former, while mungbean varieties resistant to powdery mildew are examples of the latter. We, therefore, concentrate on cultural practice and chemical control.

Cultural practice

Tillage. Both farmer's and researcher's levels of tillage affect the incidence of plant diseases. Certain plant pathogens can survive and even build up in crop residues left on the ground, or on weeds or volunteer plants of previous crops when zero tillage or low tillage is practiced. In temperate regions under monoculture, however, crops such as wheat, sorghum, or maize tend to be grown under zero- or low-tillage conditions. The available information suggests that the zero- or reduced-tillage management may preserve a well-balanced situation among the pathogen and some antagonists (Shipton 1977, Brooks and Dawson 1968). Therefore, the buildup ofthe pathogen may suppress the saprophytes. This appears to be very prominent in the case of the specialized soil-borne pathogen *Gaeumannomyces graminis* var. *tritici* on wheat. For unspecialized pathogens such *S. rolfsii,* the effect may be the opposite.

In mungbean planted after rice, damping-off caused by *S. rolfsii* appears to occur usually on zero- and low-tillage fields. *S. rolfsii* produces sclerotia that germinate near the soil surface. When legumes are planted immediately after rice under levels of tillage that presumably conserve soil moisture (Cook 1977), infection is difficult to avoid unless some preventive measures are taken. We have assumed, based on our observation in farmers' fields, that increasing the level of tillage could have reduced disease incidence. Tillage, however, accelerates drying and redistribution of substrates (plant debris) for the pathogen. Plowing, specifically, buries the plant residues used as food base by the pathogen. It, therefore, places the pathogen in a relatively disadvantageous position as decomposer of plant debris in the soil (Garren and Duke 1957). Reduced or zero tillage is emphasized in planting another type of crop directly into the residues of the previous crop because such practice assumes reduction of the disease (Doupnik and Boosalis 1980). The effect, is apparently stressed on pathogens of specialized nature rather than on pathogens such as *S. rolfsii* and *R. solani* affecting a wide variety of crops.

If in the management of such diseases the tillage level is unlikely to be increased substantially, some practices could be designed to promote seedling vigor to prevent infection, which usually occurs very early at the stage of crop growth. Once the plant reaches the second or third trifoliolate-leaf stage, it becomes less vulnerable.

Cropping systems. In principle, any soil-borne pathogen specific to a particular crop should continue to cause fairly widespread and severe disease in that crop as long as monoculture continues (Garrett 1970). Recent evidence, however, shows exceptions even though the mechanism is still not known (Shipton 1975, 1977). Crop rotation will break the niche of what monoculture has or is known to establish. The cropping systems involving diverse crop species or varieties planted in the same field during a crop year — be it sequential cropping, relay cropping, or mixed cropping — is a short-term crop rotation. Crop rotation has been a common practice for disease management since ancient times. Its benefits in minimizing certain harmful and destructive disease problems have been reported elsewhere. The cropping systems

always include paddy rice, and the effect of flooding on diseases is well anticipated.

Rotation is less effective against soil inhabitants than against soil invaders. Soil invaders often are specialized pathogens. They cannot survive long in the absence of their hosts. A major consideration therefore is the host range. Pathogens with a broad host range give less chances of success in minimizing diseases (Zentmyer and Bald 1977). The soil-borne diseases in cropping systems are caused by pathogens with a wide host range.

The relatively few soil-borne diseases of upland crops planted either before or after rice could be due to the flooded condition of the field during the rice growing season. Kelman and Cook (1977) and Williams (1979) arrived at a similar conclusion in their report on a trip to China.

Intercropping has been practiced to determine its effect on the severity of airborne diseases. In CATIE that cultural practice reduced the prevalence of the following diseases: Ascochyta leaf spot and virus diseases of cowpea in maize-cowpea association, and cassava scab in maize-cassava association (Moreno 1975, Larios and Moreno 1976). Reduction in disease severity was attributed to the reduction in the natural dissemination of inoculum by wind with maize acting as a barrier. At IRRI, intercropping mungbean with maize at two-row spacings was tried to determine its effect on powdery mildew of mungbean. Results (Table 3) show that at 44 days after emergence, intercropping favored the disease. The infection was slightly higher at 1.5-m maize row spacing. The yields of mungbean with intercrop were lower than those in monoculture because maize competition depressed yield. The reduction in yield due to powdery mildew was inconsistent among the treatments.

Table 3. Effect of intercropping on severity of powdery mildew and on grain yield of mungbean. IRRI, 1978.[a]

Treatment	Disease rating[b]		Grain yield		Yield reduction (%) due to	
	At 44 DE	At 58 DE	kg/12-m^2 plot	t/ha	Inter-cropping	Powdery mildew
Untreated						
Mungbean	2.60 a	2.67 a	1.73 a	1.44	–	14.79
Mungbean with maize in 1.5-m rows	2.66 a	3.94 a	0.85 b	0.71	50.69	12.34
Mungbean with maize in 3.0-m rows	2.32 a	3.56 a	1.22 c	1.01	29.86	19.84
Treated						
Mungbean	0.66 a	0 a	2.03 a	1.69	–	–
Mungbean with maize in 1.5-m rows	0.62 a	0.45 a	0.97 b	0.81	52.07	–
Mungbean with maize in 3.0-m rows	0.66 a	0.28 a	1.51 c	1.26	25.44	–

[a] In a column, any two means followed by a common letter are not significantly different at the 5% level. [b] Each leaf was rated as follows: 0 = no infection, 1 = 1 to 5% leaf area affected, 3 = 6 to 25%, 5 = 26 to 50%, 7 = 51 to 75%, and 9 = > 75% infection. At 44 DE (days after emergence), based on 4 lower main leaves (leaves arising directly from the main stalk) since upper leaves are still free from infection; sample of 6 plants/plot. At 58 DE based on the leaves at the upper half of the plants using 3 plants/sampling area of 6 in each plot. [c] Benomyl at the rate of 0.30 g/liter of water sprayed at 37 DE.

Chemical control

Chemical control in a disease management program of a cropping system depends on the crop species, their diseases, the environment and, more important, on the interactions of the cropping patterns and the environment. Chemicals are essential to successful crop establishment and production only when cultural procedures, host resistance, alterations of the environment, or alteration of the associated biological factors are inadequate to suppress the pathogen. Losses due to disease might be minimized by increasing the chemical dose or frequency. Inputs for chemical control must be weighed against the potential benefits, such as increased quality and quantity of crop production (Carlson and Main 1976). Chemical control should consider the socioeconomics. Our discussion, however, is concerned only with the pathological implication in the use of chemicals.

Chemical control of airborne diseases aims at reducing the disease inoculum and its spread. But it is not always easy to detect the inoculum in a field. Information from disease survey and monitoring programs is needed. Prediction of disease occurrence or outbreak is not a simple job, and it is even more complicated for diseases of component upland crops in the rice-based cropping systems. The normal approach would be chemical seed treatment before planting of upland crops after rice, against soil-borne diseases; and one or two sprayings of fungicide at bud to flowering against foliage diseases. These preventive measures, disregarding the economic cost, can provide a broad-spectrum disease control.

Foliar diseases of legumes such as leaf spot caused by *Cercospora* spp. and powdery mildew by *Erysiphe* sp. could be prevented or minimized by a spray of benomyl, a systemic fungicide, at a rate as low as 0.15 g/liter water (Table 4). Downy mildew can be checked by seed treatment with another systemic fungicide, Ridomil, at rates ranging from 0.125 to 0.5 g ai/kg seed (Table 5).

The soil-borne diseases are difficult to control. However, combining cultural

Table 4. Effect of treatments on the severity of powdery mildew and yield of mungbean planted after rice. Pangasinan, Philippines, 1978-79.

Barrio	Treatment[a] &/liter H_2O)	Disease rating[b]/leaf			Yield
		10 DS	21 DS	31 DS[c]	(g/m²)
Pao	Benomyl at 0.30	0.16 b	0.23 b	0.66 b	6.69 a
	Benomyl at 0.15	0.21 b	0.41 b	1.79 b	7.92 a
	Control (untreated)	1.94 a	6.62 a	6.10 a	4.60 a
Lipit	Benomyl at 0.30	0.05 a	0.02 b	0.08 b	14.31 a
	Benomyl at 0.15	0.05 a	0.02 b	0.19 b	11.58 a
	Control (untreated)	0.02 a	1.63 a	2.73 a	11.12 a
Caaringa-yan lakay	Benomyl at 0.30	0.10 a	0.05 b	0.59 b	28.12 a
	Benomyl at 0.15	0 a	0.11 b	1.13 b	25.59 a
	Control (untreated)	0.01 a	1.54 a	4.38 a	25.34 a

[a]Applied at 35 days after emergence. [b]Based on 5 lower leaves/plant with 9 plants sampled/plot. Each leaf was rated as follows: 0 = no infection, 1 = 1 to 5% leaf area affected, 3 = 6 to 25%, 5 = 26 to 50%, 7 = 51 to 75%, 9 = 75% infection. Means followed by the same letter are not significantly different at the 5% probability level. DS = days after spraying. [c]Coincided with the first priming.

Table 5. Effect of treatments on the incidence of downy mildew and yield of maize at 2 planting dates Pangasinan, Philippines, 1979.[a]

	Rate of Ridomil 25 WP (g a.i./kg seed)	8 Apr 1979			25 Apr 1979		
		Incidence[b] (%)		Yield[c]	Incidence[b] (%)		Yield[d]
		34 DE	At harvest		34 DE	At harvest	
Macapuno	0.50	0 a	0 a	64.25 a	0 a	0 a	81.25 a
	0.25	0.23 a	0.46 ab	64.25 a	0 a	2.03 ab	77.75 a
	0.125	0.33 a	1.33 b	60.75 a	1.66 a	3.56 b	81.25 a
	0	13.41 b	13.65 c	59.75 a	40.62 b	47.43 c	66.25 a
Sweet maize	0.50	0.50 a	1.25 a	43.25 a	0 a	2.68 a	62.33 a
	0.25	1.32 a	3.14 b	47.50 a	2.87 b	7.09 b	71.00 a
	0.125	4.91 b	9.01 c	46.25 a	11.04 c	21.90 c	63.50 a
	0	71.04 c	87.25 d	11.50 b	71.49 d	96.27 d	7.00 b

[a]Means followed by the same letter are not significantly different at the 5% probability level. DE = days after emergence. [b]Based on the ratio of infected plants to the total population on middle rows/plot; analysis based on values transformed to arcsin. [c] Marketable ears/23.4 m^2. [d]Marketable ears/28.1 m^2.

practices with chemical seed treatment may give good results. The common fungicide for this purpose should be broad spectrum because soil-borne diseases are caused by a variety of pathogens. Dithane M-45 can be used in the Philippines especially against *Rhizoctonia* and *Pythium* damping-off.

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DRY SEEDING OF RICE

Tillage and seeding methods for dry-seeded rice

R. A. Morris

Dry-seeding of rice — the direct seeding of ungerminated rice on unsaturated fields, which subsequently are flooded — has been practiced in rainfed rice-growing areas of northeastern India, Bangladesh, Burma, and Thailand for centuries. Fields in those areas are often characterized by deep flooding during the late vegetative and reproductive stages of rice. The soils in many fields are comparatively light textured, and contain silt deposited on floodplains adjacent to major rivers.

Dry-seeding is also common in rice-growing areas of North and South America, Australia, and Europe, where tillage is by tractors that require soils with high bearing capacity. In those areas, irrigation and drainage facilities are generally well developed.

The introduction of dry seeding into areas that have been traditionally puddled and transplanted is new. In most areas where rice is transplanted, tillage methods have not changed for centuries. There have been some shifts to more modern tillage methods but only the power sources have changed — the power tiller or wheel tractor has replaced buffalo or bullock — but the final product remains a puddled, transplanted rice field.

Two hypotheses have generated interest in substituting dry-seeded rice (DSR) for puddled, transplanted rice.

- First, it is hypothesized that small farmers can now afford intermediate-size power tillers and small tractors, and herbicides are available to make early DSR technically feasible.
- Second, it is hypothesized that grain legumes and other upland crops, for which there is an increasing demand, can be grown following an early planted, shortduration DSR rice crop, and thus increase farm income.

If planted on soils that have not had structure destroyed by puddling, and if planted sufficiently early to avoid severe drought stress in the dry season, an upland crop following rice will yield close to its genetic potential. Maintenance of aggregation is important because aggregation enhances aeration and infiltration and permits

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timely tillage for an upland crop. This paper reviews crop establishment research on DSR for soils that have traditionally been puddled, suggests future research focus, and describes the conditions under which introduction of dry-seeding rice techniques is likely to be successful.

Crop establishment techniques can generally be separated into a tillage component and a seeding component. For DSR, the tillage component appears to be most critical for two reasons: primary and secondary tillage of dry soil are time-consuming or costly, or both, and a high level of weed control must be achieved through tillage to give the rice crop an advantage over weeds. Therefore, I have given priority to tillage methods.

DRY-SEEDED RICE TILLAGE

Bradfield (1971) was a strong advocate of DSR. In his studies on maximum production, he saw it as a way of minimizing problems of both excess and insufficient water. He considered water management during the transition between crops as the major obstacle to developing a satisfactory intensive crop management system; puddling soil for rice aggravated the transition. In an experiment repeated over 3 years, Bradfield compared four methods of establishment — puddled and transplanted, unbedded plowed and drilled, bedded plowed and drilled, and ridged and furrowed — with rice seeded on the furrows. He found no statistical difference among the methods which, over the 3 years, yielded an average of 5 t/ha.

Partohardjono and Harahap (1979) reviewed DSR research in Indonesia. Studies in the 1930s on heavy soils showed tillage to a depth of 10-12 cm was adequate. More recent Indonesian studies have shown that the DSR field can be converted from dryland to wetland at 4-5 weeks after germination without any yield depression (Table 1). Partohardjono and Harahap suggest that adequate drainage be provided during the preflooding period to prevent yield depression.

Scheltema (1974) compared dry primary and secondary tillage, wet primary and secondary tillage (puddling), a combination of dry primary followed by wet secondary tillage, and zero tillage (long period of flooding with chemical weed control). Over a range of seeding and nitrogen fertilizer rates, yields were highest for the dry primary and dry secondary tillage systems. In a comparison of plowing intensity, Scheltema found that by plowing more than once and deeper than 6 cm, yield was not appreciably increased, if at all, regardless of nitrogen level (Table 2, 3).

At IRRI, Sompaew (1979) found that DSR yield was not affected by increasing

Table 1. Effect of time[a] of flooding on the yield (t/ha) of 3 dry-seeded modern rice varieties, Indonesia (Partohardjono and Harahap 1979).

Variety	Grain yield (t/ha) when flooding was			
	3 WS	6 WS	9 WS	12 WS
C4-63	3.8	3.2	3.7	3.5
Gati	3.8	3.5	3.7	3.6
Pelita	4.2	3.8	3.7	4.2
Mean	3.9	3.5	3.7	3.8

[a] WS = weeks after seeding.

Table 2. The influence of plowing intensity on grain yield at 2 levels of nitrogen fertilizer, Surinam (Scheltema 1974).

Nitrogen fertilizer	Grain yield (t/ha) at given plowing intensity			
	None	1 time	2 times	3 times
40 kg/ha	3.2	4.0	4.2	4.2
90 kg/ha	3.9	3.8	4.0	4.2

Table 3. Influence of dry tillage depth on grain yield at 2 nitrogen levels, Surinam (Scheltema 1974).

Nitrogen fertilizer	Yield (t/ha) at given tillage depth			
	0 cm	6 cm	12 cm	20 cm
40 kg/ha	2.9	3.9	3.9	3.8
90 kg/ha	3.6	4.4	4.1	3.8

the harrowings after plowing from 2 to 3 regardless of planting method or variety used.

De Datta et al (1979) reviewed aspects of land preparation for rice. They listed several major advantages of dry tillage: initial crop growth could be obtained from early monsoon rainfall (avoiding waste of water for soil soaking), labor required for seedbed preparation-land preparation-transplanting operations could be reduced, and the soil was left in more favorable conditions for a following nonrice crop. Disadvantages were that draft power requirements were high and often beyond the financial reach of small farmers, the comparatively high percolation losses left the crop susceptible to periodic drought stress, and early weed control requirements were comparatively exacting. If there is a switch to dry seeding, land preparation processes must be evaluated against land and rainfall factors (De Datta et al 1979).

Experiences with DSR cultivation at a cropping systems research site in Manaoag, Pangasinan, Philippines, have illustrated the importance of land and rainfall factors on DSR performance (Morris et al 1979). The sensitivity of DSR to many environmental and management factors is emphasized by a range of yields from 0.5 to 5.4 t/ha (mean of 2.2 t/ha) for 15 farmer-cooperators who harvested DSR during 1975-76 cropping pattern trials (IRRI 1977). Sixteen farmer-cooperators plowed under the DSR crop because of excessive weed growth. That indicates that weed control was a major constraint to successful DSR adoption in the area.

Because DSR has not been extensively studied in the tropics, the literature pool from which to draw general conclusions and to obtain directions for future research is not extensive. For this reason, some of the basic concepts of tillage objectives and effects are examined before discussing the place of DSR in cropping systems and future research directions for DSR tillage.

Tillage objectives and tillage effects

Smith (1955), Kuipers (1963), and Larson (1963) discussed the objectives of tillage for crops in general — to create a seedbed physically, chemically, and biologically

fitted to the growth of crops. Tillage accomplishes this general objective by destroying weeds and incorporating crop residues and manures, by improving aeration, which hastens nitrification and the liberation of other nutrients, by destroying insects and their habitats, by increasing infiltration capacity, and by creating a size distribution of soil aggregates that increases soil-seed contact and thereby hastens imbibition. Tillage has also some negative side effects, such as the creation of a plow pan, a reduction in organic matter, and loss of soil water from moist soil exposed directly to the atmosphere.

The primary objective of tillage for DSR, under most conditions, will be good weed control. It is obvious, however, that tillage alone will seldom cope with weed pressures satisfactorily. Herbicides can aid weed control, but foolproof methods for their use by South and Southeast Asian farmers are not well established (Moody and Mian 1979). Basic studies are being conducted on herbicides and herbicide management for DSR.

For DSR, an increase in soil-seed contact is probably not as important as for other crops because once the wet season starts, rains can be expected to persevere. A moisture limitation to imbibition should not be critical if seeds are positioned 2-5 cm below the surface and soil aggregates are not excessively large. Moreover, aggregate sizes will not likely approach the distribution for optimum soil-seed contact unless an elaborate and energy—demanding tillage system is used (Hadas et a1 1978). Such tillage systems will not be economically viable in most of the rice-growing world and overplanting will remain a common means of assuring adequate plant density.

Soemartono and Hardjono (1972) and Partohardjono and Harahap (1979) caution that DSR should not be inundated until continuous standing water can be assured. That suggests that high infiltration capacity or a capability for surface drainage, or both, are necessary to prevent early intermittent flooding. Excess water during the immediate postplanting period causes depressed germination and loss of small seedlings. Intermittent flooding during the early vegetative growth period also causes yield depressions, apparently by adversely affecting nitrogen availability.

The properties of soils in relation to tillage are described by Baver et al (l972). The major physical factors, which affect both the quality of tillage and the energy requirement, are cohesion, adhesion, shear, and compression. Baver et al listed five categories of work performed during plowing:

1. cutting work by the coulter and plowshare,
2. work necessary to overcome cohesion and shear forces involved in compressing, shearing and turning of soils to break up the soil into crumbs and clods,
3. work to lift and accelerate the furrow slice,
4. work to overcome friction between soil and moldboard, and
5. work to overcome friction between soil and the landside and sole of the plow.

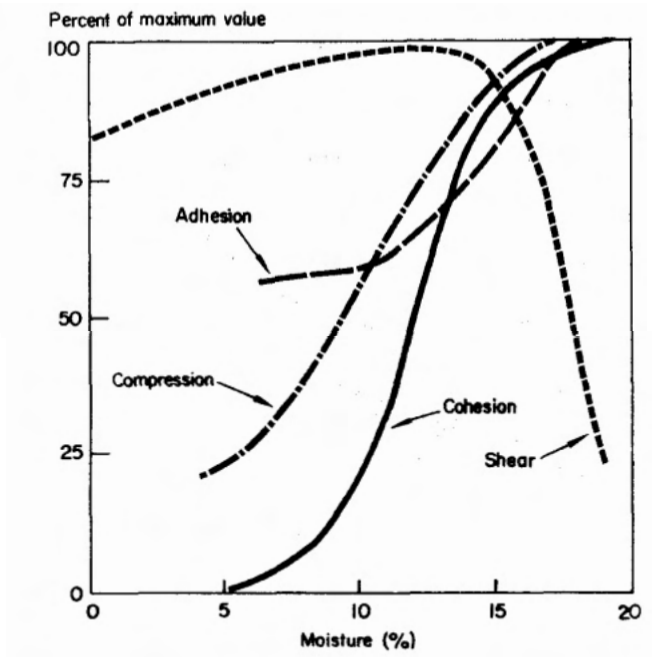
Four resultant effects of the forces applied by tillage implements were listed:

1. shear as soil slips over soil,
2. fragmentation of soil,
3. arch action as a compressive force is vectored through the soil, and
4. compaction as the soil volume is changed by compressive stress.

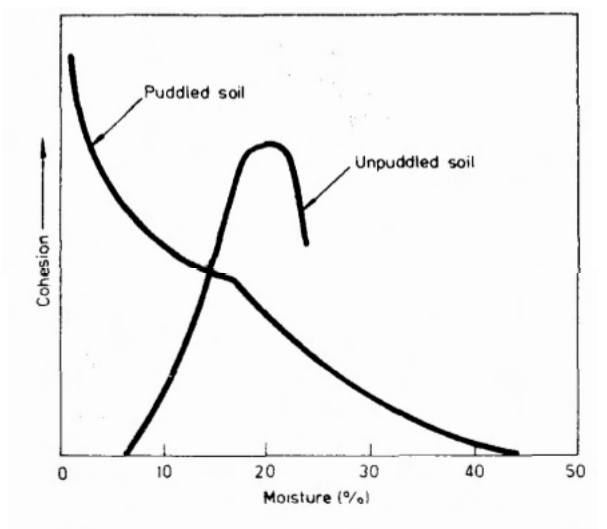
Cohesion, adhesion, shear, and compression are strongly affected by soil water

content (Fig. 1). Draft resistance is lowest somewhere below the plastic limit, but as the soil becomes drier, the shattering (or crumb-forming) action of the tillage operation diminishes. On the other hand, if a soil is puddled prior to plowing, cohesion increases as the soil dries (Fig. 2). High cohesiveness makes dry plowing of previously puddled soil very difficult both from an operational and quality standpoint.

In a study of three previously puddled but fragmented soils, Briones (1977) found



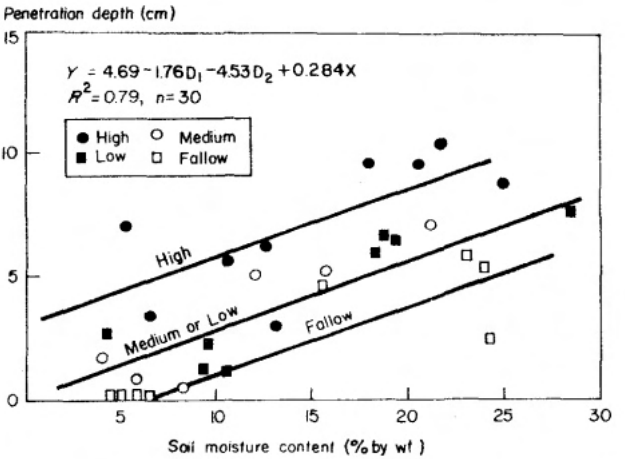
1. Relation of factors involved in tillage (Baver et al 1972).



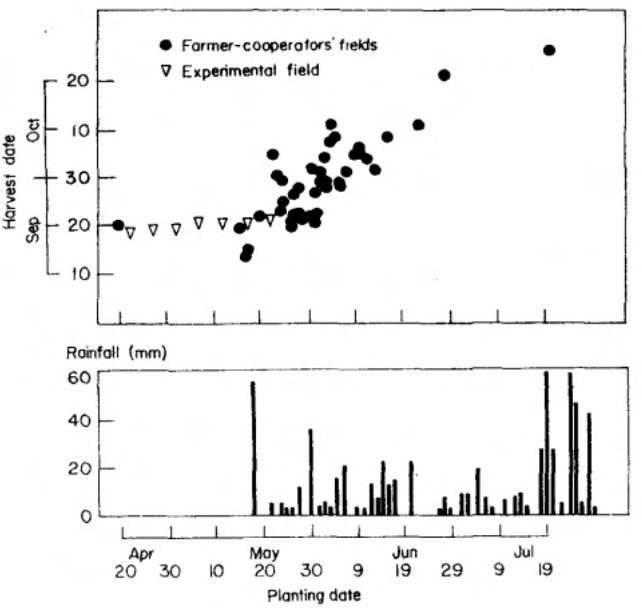
2. Generalized relation of cohesion to moisture of a soil in a puddled and an unpuddled state.

that the field moisture range in which soil clods could be sheared with reduced applied force was below the optimum water holding content for all soils. Above that water content, greater soil deformation occurred before soil rupture, even though shear strength was lower. Shear strength differences among soils were apparently due to differences in clay mineralogy and texture.

The practical importance of soil moisture is illustrated in Figure 3, which shows that static-tip penetrometer measurements increased as moisture content increased in a Pangasinan study. In the same area, farmer-cooperators waited for rains to fall before plowing their DSR fields with animal-drawn plows; researchers used power tillers to plow before the rains (Fig. 4).



3. Effect of soil moisture content and preceding-season soil and crop management on static-tip penetrometer depth (8 kg/cm²). Pangasinan, 1977.



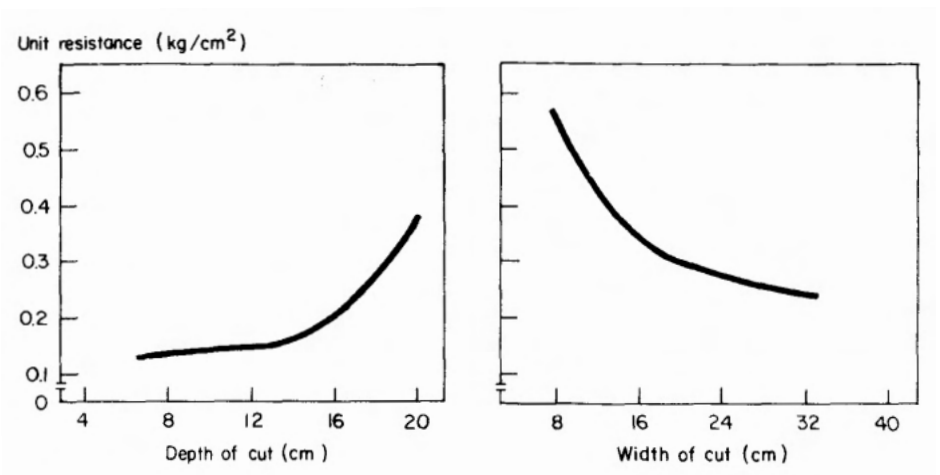
4. Dry-seeded rice planting date vs harvest date in farmer-cooperator and experimental fields (top) and rainfall during the planting period (bottom). Pangasinan, 1977.

Fagi (1977) examined the effect of residue management on DSR tillage and found that soil moisture, and hence soil consistency and the moisture range suitable for plowing, were affected by the method of residue management apparently within a time span of 1 year. This rapid response time suggests that residue management may be effectively used to reduce draft requirements,

Kaburaki and Kisu (1959) found that unit draft resistance increased sharply as plow depth exceeded 12 cm and decreased gradually as width of cut increased (Fig. 5). Total resistance was directly proportional to speed. These relationships suggest that maximum tillage capacity for DSR can be obtained by using plows to work at depths less than 10 cm with widths of 20-25 cm and adjusting speed to take most advantage of the power and speed range of the draft unit. Scheltema (1974) found plowing to 6 cm produced higher DSR yields than deeper plowing (Table 3), which adds to the significance of the unit draft resistance relationships found by Kaburaki and Kisu. One can speculate that plowing to a depth of no more than 10 cm will be adequate if the soil is not massive below that depth. An arrangement of two or three small moldboard plows or a heavy disk harrow, pulled by a moderate-size tractor at 7-8 km/h, should increase DSR tillage capacity considerably. Shallow plowing for DSR, however, may necessitate deeper plowing for an upland crop that follows DSR.

Dry-seeded rice tillage for cropping patterns

Kuipers (1963) and Wingate-Hill (1979) discussed interconnected factors to be compared when alternative tillage systems are evaluated. Both authors note that new equipment makes new tillage systems possible, which makes improved cropping systems possible, which, in turn, can decrease costs or increase returns, or both. Cheap power tillers are likely to be the most attractive piece of new equipment that can be introduced to increase tillage capacity, but where social and economic conditions are favorable, 18-40 hp 4-wheel tractors may be advantageous.



5. Relationship between plowing depth and unit resistance and between plowing width and unit resistance (Kaburaki and Kisu 1959).

For DSR, which initiates several improved cropping patterns, increased total returns are assumed from more crops per year and timelier operations including planting, but total costs are also expected to increase because energy requirements and other tillage inputs are likely to increase. Where DSR is adopted, cost increases are expected to be (or can be) more than offset by the increased value of crops obtained from an intense pattern, even though more fuel is consumed or more animal-hours are used to overcome higher soil strength during primary and secondary tillage operations. Higher yields are obtained because drought during the reproductive stages is avoided by shifting the crops forward in the season. For example, yields of all crops in a DSR - transplanted rice (TR) - upland crop (UC) pattern tested in Pangasinan decreased as DSR planting date was delayed (Table 4), and experiments at IRRI by Singh (1979) verified the benefit to succeeding crops of early DSR seeding. However, the field tests conducted by farmer-cooperators from which the data in Table 4 were taken showed several major weaknesses in the DSR - TPR - UC pattern under farm conditions:

- low tillage capacity of the farmers,
- virtually insurmountable weed problems, and
- dry soil conditions that hamper or prevent early tillage (Morris et al 1979).

As Figure 4 shows, farmers delayed plowing until rainfall reduced soil strength to a level with which they could cope using draft animals and consequently harvest dates were late in comparison to harvest dates of controlled experiments where a power tiller was used. Because farmers must wait until the first rains fall to soften the soil, tillage capacity (i.e. the combined tillage rate of all power units at the disposal of farmers in the community) was reckoned to be a constraint. Using a power tiller with a moldboard plow in a follow-up study on dry fields, satisfactory steering control was impossible to achieve. When a rototiller was used on the dry soil, tines frequently broke, and a seedbed with many nut-size aggregates and large clods was obtained. Fuel consumption and static-tip penetrometer measurements varied according to the tillage level used to establish the previous crop (Table 5).

A study conducted in the same area to compare three tillage systems showed that 4–wheel tractors with disk-plows for primary tillage on dry fields, and draft animals for secondary tillage once rains started reduced preparation time between first rains and planting (Table 6). Tractor operations consumed large quantities of fuel, however, and field conditions following primary tillage were extremely cloddy. No detectable differences in plant density or grain yield resulted from the different

Table 4. Mean yields of DSR,[a] TPR,[b] and mungbean[c] by period of DSR seeding in designed DSR-TPR-upland crop patterns. Pangasinan, Philippines, 1977-78.

Period of DSR seeding	Rough rice yield (t/ha) DSR	TPR	Mungbean (t/ha)
21 May and earlier	5.3	4.0	0.36
22-31 May	4.8	2.4	0.34
1 June and later	4.1	1.5	0

[a]Dry-seeded rice. [b]Transplanted rice. [c]Three of 16 observations on the last crop were converted from either cowpea or sorghum yield to equivalent mungbean yield on the basis of yields relative to the best 4 entries in variety trials; the remaining 13 crops were mungbean.

Table 5. Average power-tiller fuel consumption and penetration depth before and after tillage, as affected by previous tillage and cropping. Pangasinan, Philippines, 1978.

Previous crop and tillage level	Fuel consumption[a] (liters/ha)	Depth (cm) of penetration[b] at 16 kg/ cm^2	
		Before tillage	After tillage
Fallow	44 (4)	<1	4.6
Mungbean, planted after low tillage	38 (6)	3.7	6.8
Mungbean, planted after high tillage	28(6)	7.8	9.4

[a] Numbers in parentheses are number of fields. [b]Each field (about 900 m^2) was divided into 8 sections and 5 penetrometer readings were taken in each section.

systems. A heavy disk harrow, drawn by a tractor at high speed and disturbing soil to 5-8 cm, appeared to work well after a heavy shower weakened the soil, but the method was not included in the study.

There is evidence from these and other studies that once soil puddling is omitted from a pattern, tillage inputs for other crops in the pattern will be reduced. It seems logical that this reduction in input would be most critical as crop intensification forces tillage operations into the drier soil moisture range where the cohesion of puddled soils increases sharply compared to that of unpuddled soil (Fig. 2).

SEEDING METHODS

Dry tillage eliminates transplanting as a practicable alternative planting method for DSR. Three alternatives — broadcasting, drilling, and dibbling — are used. Dibbling is generally considered superior to drilling, and drilling superior to broadcasting as confirmed by Sompaew (1979). Broadcasting is cheap and fast, but drilling and dibbling generally produce more uniform stands, are easier to follow up with hand or mechanical weed control, and facilitate fertilizer placement. Unless mechanized, dibbling is labor demanding, but seed depth control is most precise, and pressure can easily be applied to soil above the seed to increase soil-seed contact. Hand drilling (i.e. opening a furrow with a small plow, dropping seed into the furrow, and covering it with a spike-tooth harrow) is more labor demanding than the *lithao*[1] method of drilling, and depth control and seed concentration are superior with the former method. Drilling can be mechanized with comparative ease if a seedbed of good tilth can be achieved.

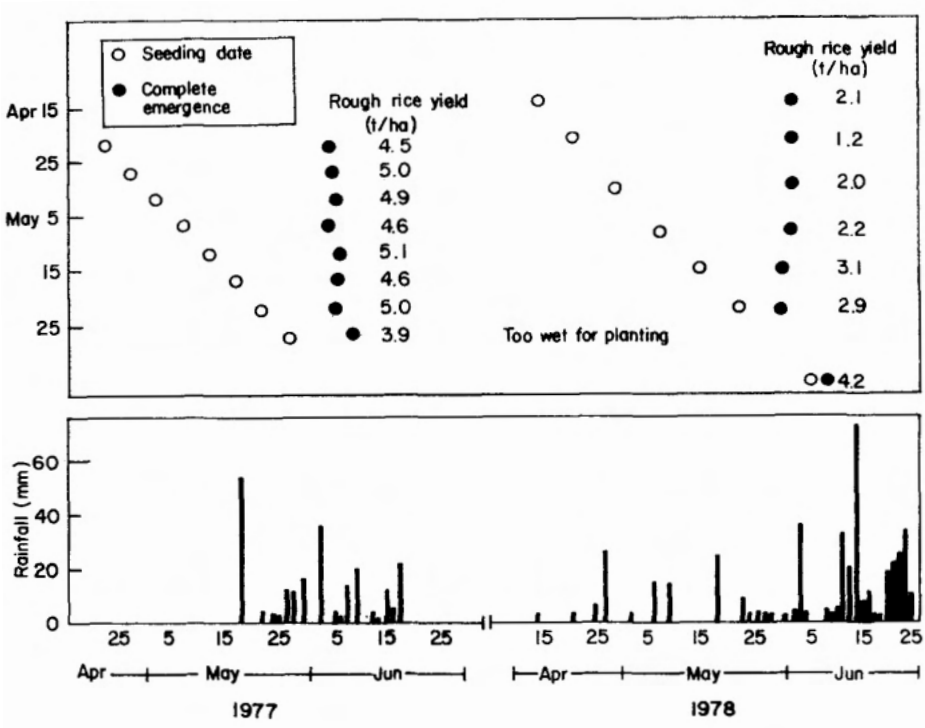
Other factors affect the plant density obtained from a given amount of seed. Depth control appears to be important where field surfaces are cloddy and the soil surface dries between rains, leaving newly germinated shallow seeds without sufficient water to sustain them. Timing of planting in relation to rainfall is critical, as indicated by Figure 6. Light and intermittent rains in 1978 caused loss of stand in the

[1]A *lithao* is an animal drawn wooden implement native to the Philippines. It is used after secondary tillage to open 5 shallow seed furrows on 25-cm centers in one pass. Seed is broadcast on the field and a spike-tooth drag is passed across the field at 45° to the furrows. During this operation, seeds concentrate in the furrows and the furrows are covered.

Table 6. Operation time for disk-plowing and harrowing using three tillage systems as affected by tillage on the previous crop. Pangasinan, Philippines, 1979.

Tillage system[a]	Tractor (h/ha)			Fuel consumption	Carabao (h/ha)			Grand total
	Plowing	Harrowing	Total	(liters/ha)	Plowing	Harrowing	Total	(h/ha)
Fallow after TPR								
Tractor fb tractor	20.0	4.2	24.1	127	–	–	–	24.1
Tractor fb carabao	20.0	–	20.0	98	–	22.6	22.6	44.6
Carabao fb carabao	–	–	–		77.9	31.3	109.2	109.2
Low tillage after mungbean								
Tractor fb tractor	20.9	2.9	23.8	120	–	–	–	23.8
Tractor fb carabao	20.9	–	20.9	80	–	21.2	21.2	42.1
Carabao fb carabao	–	–	–		62.8	30.6	93.4	93.4
Medium tillage after mungbean								
Tractor fb tractor	17.5	2.9	20.4	96	–	–	–	20.4
Tractor fb carabao	17.5	–	17.5	63	–	20.4	20.4	37.9
Carabao fb carabao	–	–	–		63.6	24.3	87.9	87.9
High tillage after mungbean								
Tractor fb tractor	9.7	4.5	14.2	106	–	–	–	14.2
Tractor fb carabao	9.7	–	9.7	66	–	17.1	17.1	26.8
Carabao fb carabao	–	–	–		73.1	25.7	98.8	73.1

[a] Plowing by tractor was started in the dry season after harvest of mung crops. Plowing by carabao was started after a soaking rain. Harrowing by tractor and carabao was done after a soaking rain. TPR = transplanted rice, fb = followed by.



6. Dry-seeded rice seeding dates, dates of 90% emergence, yield, and rainfall distribution. Pangasinan, Philippines, 1977 and 1978.

early planted treatments, which were hand-drilled. In contrast, heavy stand loss was observed in a 1979 experiment comparing 5 methods of DSR establishment, when 145 mm rain fell in 2 days on a soil that was already very wet. No significant differences in emergence rates or final plant density were observed among the establishment methods studied. Data from Scheltema (1974) suggest DSR seeding rates can be used to adjust for expected stand losses when seed is broadcast on a cloddy field, and early nitrogen fertilizer applications can be used to promote tillering if suboptimal stand levels are obtained.

The seeding method ultimately adopted in an area will be dictated by the costs and benefits of alternatives. Costs will be strongly determined by local wage rates and equipment costs. These costs should be considered when selecting methods to compare in applied field trials.

DRY-SEEDED RICE FOR WHAT CONDITIONS?

One may speculate about the place of DSR and its associated tillage and planting requirements in cropping patterns of South and Southeast Asia. The remarks here on land, climate, and market (product and factor) conditions are only in general terms. Several interrelated factors are involved. DSR is likely to be adopted on comparatively young soils (Entisols and Inceptisols with only slight profile expression) of medium surface texture (clay loam, silty clay loam, silt loam, and loam)

located on floodplains or first terraces where high groundwater levels during the peak of the wet season will minimize percolation losses. Because of higher draft requirements in the dry range and susceptibility to occasional early flooding, heavier textured soils may not be as amenable to DSR cultural practices as the lighter textured soil.

Patterns with DSR should find adaptation where the intense rainy period is of about 4 months duration (particularly for DSR-UC) or 7 months duration (particularly for DSR-TPR) or where partial irrigation extends the rice season to 7 months. DSR-UC patterns are likely to find advantage near market outlets for fresh-grown or semiperishable UC. The generally high value of these products may justify the added cost of the dry tillage for rice. Provided tillage and planting operations can be mechanized and weeds can be kept under control, DSR should have an advantage where competition for farm labor has driven transplanting cost to high levels. Future site-related research should identify areas where DSR has a viable position in rice-based cropping patterns, but well-focused and systematic research is needed to overcome problems limiting adaptation and to identify situations in which patterns starting with DSR are viable.

FUTURE RESEARCH NEEDS

Research needs on tillage can be placed into two broad categories; however, some comprehensive studies include experiments that fit both categories.

- In one category, research is designed to expand knowledge of tillage principles through a study of the effects of alternative tillage implements and soil manipulation on changes in soil structural parameters, moisture and temperature regimes, gaseous exchange rates, and chemical components. In this research category, little consideration is given to costs, and crop performance may or may not be compared.
- In a second category, research is conducted to examine the overall performance of equipment configurations and tillage systems that are feasible alternatives under real farm field conditions. In some cases, the comparisons of alternative systems are simple (e.g. comparisons of animal-drawn and tractor-drawn plows without changes in planting dates and other operations). But in many cases, and in probably the more significant ones, the comparisons of alternative systems are complex (e.g. comparisons of conventional tillage and reduced tillage systems in which planting dates are advanced, a new planter is required, and herbicides are used). The effects of equipment configuration, machine capacity, and tillage systems on timeliness and operating costs for a characteristic farm business (area, labor pool, capital, and crops) are major considerations in this type of research. The effects of the tillage system on crop production are often examined in some phase of this type of research, but in cases where yields can be realistically assumed not to change with a change in method, field studies may focus only on time and other cost-related data.

Although the first category of research should lead to benefits for South and Southeast Asian farmers in the distant future, there is need, especially within cropping systems programs, to conduct tillage studies in the second category. The

objectives of this research should be to support the development of viable, intensified cropping patterns for farm adoption in the near future. Fortunately, research in the second category can be conducted without complicated analysis of soil components, which eliminates the need for special instruments and laboratory equipment. It is the second category of research that is needed for cropping patterns that start with DSR. Research emphasis should be on the system's effects on the entire pattern, not on a change in soil condition (although that is important) or on an increase in rice yield (a decrease may even be bearable).

For research in the second category, economic analysis is imperative. Hunt (1973) and FAO (1973) have described methods of determining cost for field operations and equipment use and discussed procedures for selecting alternative tillage systems. Hunt's discussion is of interest because he approaches the evaluation of the timeliness factor (and capacity) on the basis of field-suitable days, or the number of days a unit can work during an interval in which an operation is to be performed. Restrictions are imposed by inclement weather. Although capacity increases generate higher annual fixed costs because equipment is used over a smaller hectarage per year, where timeliness is critical these higher fixed costs can be offset by a higher output value. The probabilities of field-suitable days can be roughly determined for an operation by return period analysis (Moms and Rumbaoa 1980).

Aside from research on the systems aspects of tillage (and trash incorporation and planting) for DSR as a crop in a pattern, there are three management components that appear highly interactive with DSR tillage systems and with each other — water management, weed management, and nitrogen fertilizer management. It is necessary to emphasize that aspects of DSR tillage, weed control, nitrogen fertilization, and water management cannot be adequately examined in isolation. For example, tillage effects reported by Partohardjono and Harahap (1979), Hasselbach and van Amson (1965), and Singh (1979) may be partially explained by tillage-induced differences in soil nitrogen availability during early growth stages as found by Scheltema (l974), but which are related to the water regime of the surface soil. The effects of differences in tillage systems on the water economy of the surface 20 cm (including dry soil mulching to conserve water, increased infiltration capacity, and improved surface drainage to remove water) and their indirect effects on emergence and early growth rates of DSR and competitive weeds, and on mineral nutrition, require extensive study over a range of soils.

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DISCUSSION

De Datta: You commented that tillage practices or operations should be considered in the context of total cropping systems rather than for the dry-seeded rice crop only. My feeling is that farmers would make judgments based on dry-seeded rice alone and may get discouraged if conditions are not attractive for that crop.

Morris: If there is little opportunity to produce marketable upland crops after rice, I agree. But if farmers realize they can get a good cash return for the following crop by shifting the rice crop forward, I feel farmers will recognize and effectively utilize the opportunity.

Fertilizer management for dry-seeded rice

J. R. Hoopper

Dry-seeded rice (DSR) is traditional in areas of Indonesia, India, and Bangladesh. The development of very early-maturing varieties that permit higher cropping intensities has encouraged expanded use of the dry-seeding technique and its introduction into the areas of traditionally transplanted rice.

Fertilizer management is more complicated for DSR than for transplanted rice because at some stage of DSR, soils are converted from an oxidized to a reduced condition. The conversion involves drastic chemical changes that profoundly affect the behavior and availability of native soil nutrients as well as applied fertilizers. Most soils in rainfed wetland areas are low in soil nitrogen, and many are deficient in phosphorus and other nutrients. Proper management of applied fertilizers, especially nitrogen, is essential for their efficient utilization.

This paper:

- describes the chemical changes that a soil undergoes when it is converted from an oxidized to a reduced state, and the implications for management of native soil nitrogen and applied fertilizers;
- discusses the factors affecting the responses of fertilizers; and
- reviews the results of research on fertilizer management of dry-seeded rice.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF AEROBIC AND REDUCED SOILS

Dry-seeded rice is sown in an aerobic soil, which at least once during the crop's growth will be submerged and subsequently reduced. Thus, the rice starts out as an upland crop and finishes its maturity as wetland rice. Aerobic and reduced soils greatly differ in physical and chemical characteristics. Aerobic soils have higher rates of percolation than flooded soils, so that mobile nutrients are easily lost through leaching. Because nutrients are delivered to the roots primarily by mass flow and diffusion, the lower moisture content in aerobic soils reduces the supply of nutrients to the roots (Ponnamperuma 1975).

In aerobic soils the end product of organic matter decomposition is the highly mobile nitrate ion, which may be easily lost by leaching, immobilization, or denitrifi-

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cation in anaerobic pockets. The ammonium ion intermediate may be held by the cation exchange or nitrified to nitrate. When a dry soil is wetted, initial rapid mineralization of soil organic matter occurs, releasing relatively significant amounts of available nitrogen. But this available nitrogen can later be immobilized and rendered unavailable for crop absorption.

The presence of crop and weed residues with a wide C:N at the time of fertilizer application may immobilize part of the fertilizer nitrogen. The International Rice Research Institute (1971) has shown that more applied nitrogen may be immobilized by soil in the aerobic condition than in the submerged condition. Hence, low levels of nitrogen applied to soils containing significant quantities of plant residues may not be available for crop growth.

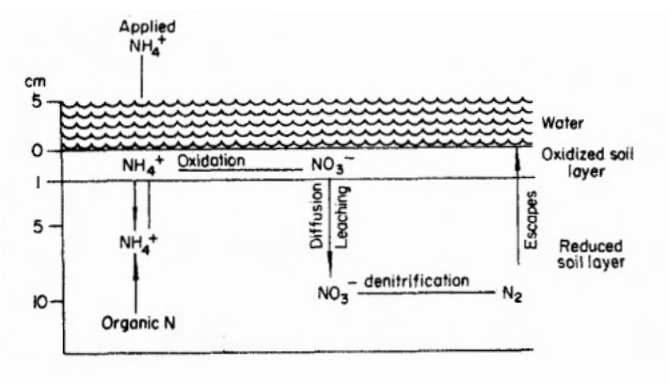
Rice growing in aerobic soils is exposed to many adverse factors not found under flooded conditions. Iron deficiency and low availability of nitrogen, phosphate, and silica occur. Soil acidity and alkalinity may be problems. On strongly acid soils, soluble aluminum and manganese may reach levels toxic to the rice plant. In near neutral or alkaline soils iron deficiency is likely to occur (Ponnamperuma 1975).

When a dry soil is flooded, the structural aggregates become saturated and crumble. Water percolation through the soil decreases, reaching levels of 20 to 33% of the original. Thus, losses due to leaching of nutrients are reduced (Sanchez 1972).

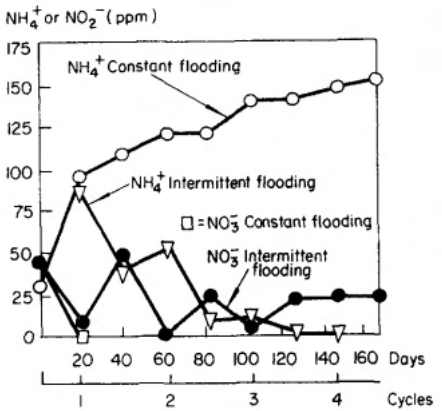
The process of soil reduction induces a series of chemical changes. The nitrates in the soil are reduced to N_2 and N_2O, which are lost into the atmosphere (Fig. 1). About 60% of the nitrates are lost in 7 days and all in less than 10 days (Mikkelsen 1962, Patrick and Wyatt 1964). The amount of soil nitrate denitrified upon flooding can be considerable. Soil collected at harvest from 280 wetland rice fields in the Philippines contained between 10 and 78 kg nitrate nitrogen/ ha (av 26 kg nitrate nitrogen/ha) representing an annual loss of 26,000 t of nitrogen from Philippine rice fields per season (IRRI 1973).

The profile of a reduced soil is not completely reduced. A thin top layer less than 1 cm deep remains oxidized because it is in equilibrium with the oxygen dissolved in the water layer (Fig. 1). Application of nitrates or ammonium to the superficial oxidized layer may cause serious denitrification losses. Thus, ammoniacal sources of nitrogen need to be incorporated into the reduced layer (Sanchez 1972).

The mineralization of organic nitrogen stops at the ammonification stage. The ammonium ion is stable under reduced conditions and tends to accumulate in



1. Applied and native soil nitrogen in a submerged soil.



2. Effects of constant and intermittent flooding on NH_4^+ and NO_3^- production under laboratory conditions. Flooding every 42 days (adapted from Patrick and Wyatt 1964).

flooded soils. Upon soil drying, the ammonium ion is converted to the nitrate ion, which is lost by denitrification when the soil is reflooded. Nitrogen losses are great during the first drying-flooding cycle but tend to decrease afterwards (Fig. 2). The concentration of other elements such as phosphorus, iron, and manganese in the soil solution increases with flooding, reaching maximum values during the first month and then gradually decreasing. Usually these changes are beneficial and make the nutrients more available, but iron and manganese can reach levels toxic to rice (Sanchez 1972). Flooding acid soils increases the pH and thus can induce zinc deficiency (IRRI 1976).

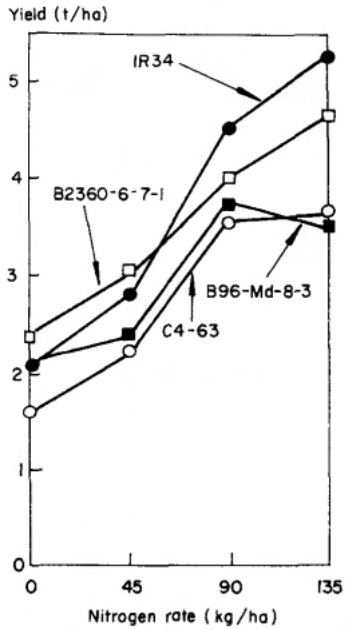
FERTILIZER RESPONSE AND FACTORS AFFECTING IT

Fertilizer response

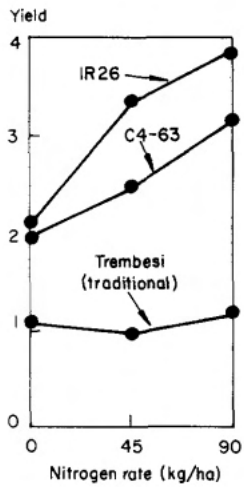
Phosphorus deficiencies are widespread on rice soils, but nitrogen is almost universally limiting. A few experiments on the fertilization of dry-seeded rice have shown that responses to nitrogen fertilizer have almost always occurred. The magnitude of the response depends, among other factors, on variety, water management, cultural practices, soil characteristics, and solar radiation levels.

Variety

Varieties grown by the dry-seeding method differ in the efficiency with which they use nitrogen. In one study in Indonesia, some varieties demonstrated almost linear yield increases with rates of nitrogen application up to 135 kg/ha (Fig. 3). Other varieties produced no yield increases beyond 90 kg N/ha. In another study the traditional variety gave a poor response to applied nitrogen (Fig. 4). The weak-stemmed traditional varieties' response to nitrogen is a height increase that leads to lodging and subsequent yield losses at higher nitrogen rates. The new improved varieties are shorter and have stronger stems; at high rates they resist lodging and produce higher grain yield.



3. Effect of nitrogen levels on 4 cultivars grown by dry-seeding in Ngale, East Java, Indonesia (adapted from Suryatna et al 1978).



4. Effect of nitrogen levels on traditional and improved rice varieties. Average of 3 spacings. Ngale, East Java, Indonesia (adapted from Suryatna et al 1978).

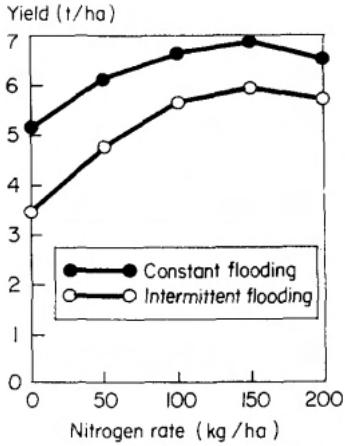
Water management

Water management is one of the most important factors affecting the efficient exploitation and utilization of native soil elements and applied fertilizer, especially nitrogen.

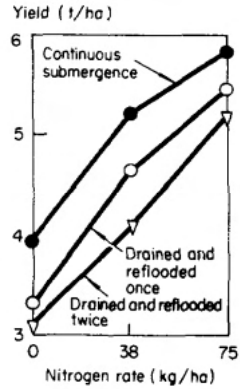
Efficiency of applied nitrogen is lower under intermittent flooding than under constant flooding. Studies with transplanted rice in India (Fig. 5) and dry-seeded rice in the United States (Fig. 6) indicate that the optimal nitrogen levels are the same, but under intermittent flooding the yield potential is lower.

Because of denitrification more nitrogen is lost from soils under intermittent flooding than from soils under either continuously aerobic or submerged conditions (IRRI 1971). Intermittent flooding of nitrogen-deficient soils results in an appreciable decrease in rice growth, yield, and nitrogen uptake (Patrick et al 1967a).

Farmers who have traditionally grown rice by the dry-seeding method recognize the importance of having only one transition from the aerobic to the submerged condition. In Indonesia, farmers construct drainage channels before planting to prevent standing water during the aerobic stage. Surface drainage prevents denitrification and excessive leaching of applied fertilizer as well as of native soil nutrients that can be used for crop growth during the early stages. Fields are not permitted to be submerged until permanent flooding is certain (Soeharsono 1978, Hasmosoewignyo 1962).



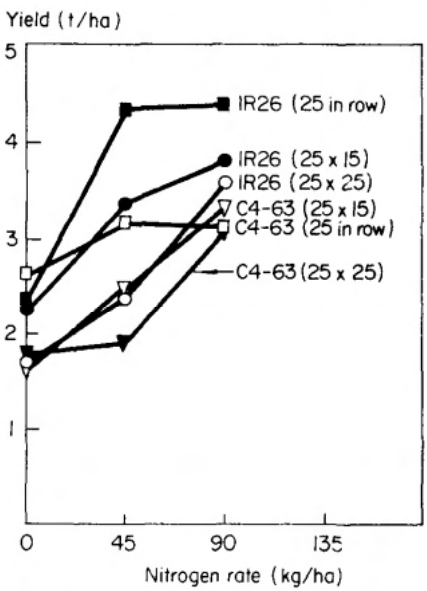
5. Water management effects on nitrogen response of Padina variety, New Delhi (adapted from AICRIP 1969).



6. Effect of number of times rice field was drained and reflooded during the growing season at 3 rates of nitrogen. Av. of 2 years data (adapted from Patrick et al 1967).

Cultural practices

Nitrogen response and tillering capacity are closely related. Seeding rates and plant spacing influence tillering capacity. Thus, optimum nitrogen response often depends on seeding rate and plant spacing. In a nitrogen-spacing study in Indonesia, the optimum nitrogen level was 45 kg N/ ha when IR26 and C4-63 were drilled in 25-cm rows but 90 kg N/ ha when they were dibbled at 25 × 15 or 25 × 25 cm (Fig.7). In the Philippines, seed rates and nitrogen application did not interact but were found to be additive (Table 1).



7. Influence of 3 spacings and nitrogen rates on IR26 and C4-63. Ngale, East Java, Indonesia (adapted from Suryatna et al 1978).

Table 1. Mean grain yield of dry-seeded rice as affected by nitrogen rate and seeding rate. Iloilo, Philippines (IRRI 1979).

Nitrogen rate (kg/ha)	Grain yield (t/ha) at seeding rate of					Mean yield (t/ha)
	60 kg/ha	90 kg/ha	120 kg/ha	150 kg/ha	180 kg/ha	
60	4.7	4.8	4.9	5.3	4.9	4.9
90	4.3	4.9	5.5	5.3	4.7	5.0
120	5.0	5.5	5.6	6.0	5.8	5.6
150	4.5	5.0	5.6	5.8	5.3	5.3
Mean	4.6	5.0	5.4	5.6	5.2	

Fertilizer application should be delayed until weeds are removed (Saefuddin et al 1978, Evatt 1965). If weeds are severe, they may use a considerable portion of the fertilizer; thus, higher amounts of nitrogen will be needed for maximum rice yields.

Soil properties

Dry-seeded rice may be planted on soils with either high or low water retention capacity resulting from their texture, structure, or occurrence of a water-restricting subsoil layer. Cation exchange capacity and available soil nitrogen are the most important soil parameters affecting nitrogen response (Sanchez 1972). The higher the exchange capacity, the larger will be the capacity of the soil to supply and retain ammonium ions (De Datta 1970, Villegas and Feuer 1970). Where the ability of the soil to retain cations is low or where water percolation rates are high, split nitrogen application and higher nitrogen rates may be required for maximum yields.

Solar radiation

Greater solar radiation levels provide more photosynthetic activity and allow larger nitrogen responses and yields. The rainy season with its high incidence of cloudiness provides less solar radiation and consequently lower yields and nitrogen response (Sanchez 1972).

FACTORS THAT AFFECT NITROGEN USE EFFICIENCY

Sources of fertilizer

Early work on fertilizer for dry-seeded rice in the United States established that the nitrate form is not as efficiently utilized as the ammonium form (Wyche and Cheaney 1951) although both can be readily absorbed by the rice plant (Ponnamperuma 1976). Nitrate fertilizer applied before planting was later denitrified when the soil was submerged. When topdressed after the rice was flooded, the nitrate ion moved down to the reduced zone where it was lost through denitrification.

Preplant applications of ammonium sulfate have been found to produce yields equal to or greater than those produced by urea (Wyche and Cheaney 1951, Patrick et al 1967b). When applied to sulfur-deficient soils, ammonium sulfate tended to produce higher yields. Even where sulfur is not deficient, ammonium sulfate is often superior to urea. De Datta and Magnaye (1969) have suggested that this is because before urea is hydrolyzed, it is nonpolar and very mobile; therefore, it cannot be

fixed by the soil particles and is lost. When applied to the soil surface, urea may also be lost through volatilization especially if the soil pH is high.

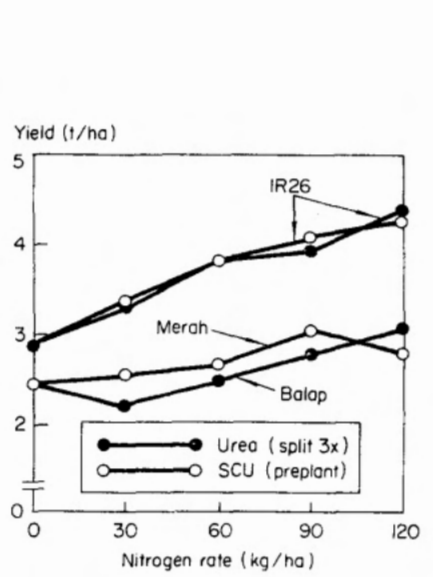
A study in the Philippines suggested that under intermittent flooding ammonium sulfate is more efficiently used than urea (Gines et a1 1978).

Studies comparing sulfur-coated urea (SCU) and conventional forms of fertilizers are few. Under good water control in the United States. preplant applications of SCU have not proved superior to split applications of urea. Higher yields have been obtained, however, from SCU material with more rapid dissolution rates (Westfall 1972). Slow release fertilizers with slow dissolution rates may not be efficiently utilized by early-maturing varieties having a relatively brief period for tillering and high nitrogen demand.

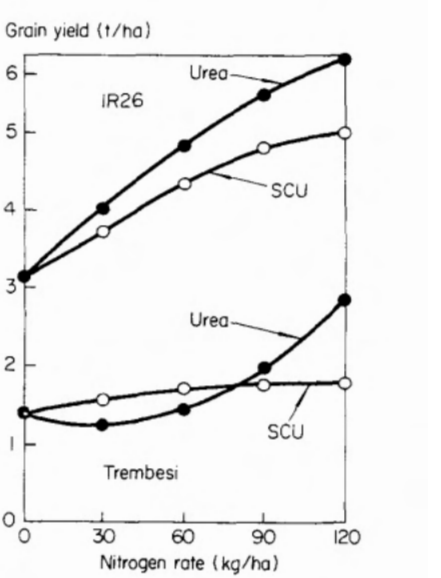
SCU materials would be expected to perform better under intermittent flooding where denitrification, volatilization, and leaching would be problems. Under such conditions, however, SCU has not shown superiority to conventional materials (Gines et al 1978). In a study where rice was transplanted under intermittent flooding, SCU incorporated before planting was superior to conventional sources applied in the same manner and in some instances was superior to split applications of regular urea (Sanchez et a1 1973).

SCU materials as topdressing have not produced yields higher than those with urea or ammonium sulfate applied in a similar manner (Patrick et a1 1967b).

In two studies in Indonesia Partohardjono and Harahap (1979) compared urea in three split applications and SCU. They found SCU gave either no yield advantage or less yield than urea (Fig. 8-9). Suryatna et a1 (1978) suggested that even if yields with urea and SCU are comparable, the use of SCU is desirable — the labor requirement



8. Effects of urea and sulfur-coated urea (SCU) applied at 4 nitrogen levels on yields of IR26 and Balap and Merah. Indramayu, West Java, Indonesia (Partoharjono and Harahap 1979).



9. Effects of urea and sulfur-coated urea (SCU) at 4 nitrogen levels on yields of IR26 and Trembesi, Ngale, East Java, Indonesia (Partohardjono and Harahap 1979).

is reduced as only one application is necessary.

Patnaik and Rao (1978) have indicated that basal applications of slow-release fertilizers are needed in areas of poor water control where it may be difficult to drain off water for topdressing of fertilizers or where the farmer is unwilling to risk draining his fields. Thus, where only basal or early season nitrogen application is possible, SCU materials may be advantageous.

Method of fertilizer placement

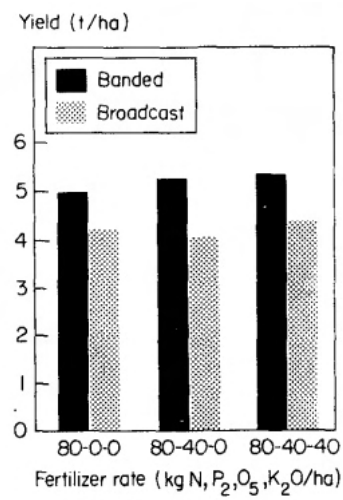
Nitrogen fertilizer may be applied in several ways before planting of dry-seeded rice:

1. placement below or beside the seed, or both;
2. placement in the row with the seed; or
3. broadcast with or without incorporation.

Placing preplant fertilizer nitrogen below or with the seed is generally superior to preplant surface applications (Fig. 10) (also Mikkelsen and Evatt 1971, Evatt and Hodges 1975). Application of low rates of fertilizer (40 kg N, P_2O_5, and K_2O/ha) in the furrow with the seed and placement beside and below the seed produced similar rice stands and yields. Higher fertilizer rates (80 kg N, P_2O_5, and 40 kg K_2O/ha) applied with the seed may reduce emergence and yield (Table 2) or produce delayed and nonuniform emergence (Patrick 1968). Applying high rates of fertilizer either directly below the seed or 5 cm to the side and below the seed has produced equivalent yields (Petersen and Patrick 1968).

In the Philippines three methods of fertilizer application at rates of 30, 60, and 90 kg N/ ha were compared:

- fertilizer broadcast at 10 days after crop emergence (DE), 30 DE, and at panicle initiation (PI);
- one-half nitrogen rate banded in furrows between the rice rows before planting and one-half broadcast 30 DE; and
- one-half nitrogen broadcast and incorporated by plowing before planting and one-half broadcast 30 DE.



10. Effect on rice yield of fertilizer application in band within the soil and broadcast on top of the soil at the time of planting. Louisiana, USA (adapted from Miears and Harrell 1959).

Table 2. Rice stand and yields as affected by fertilizer rates applied with the seed and beside the seed. Crowley, Louisiana (adapted from Miears and Harrell 1959b).

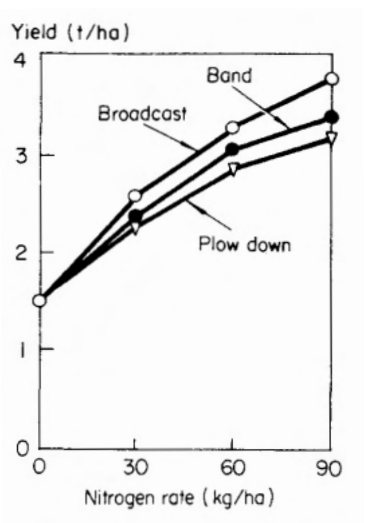
Fertilizer rate (kg N, P_2O_5, K_2O/ha)	Method	Stand (plants/m^2)	Yield (t/ha)
0-0-0		166	1.2
80-0-0	With seed	165	2.8
80-0-0	Side	184	3.3
40-40-40	With seed	194	2.5
40-40-40	Side	177	2.5
60-40-40	With seed	160	2.9
60-40-40	Side	189	3.3
80-40-40	With seed	153	3.3
80-40-40	Side	173	4.0
80-40-0	With seed	123	2.9
80-40-0	Side	193	4.0

Compared to incorporation with a plow and banding, broadcasting in three splits produced significantly higher grain yields (Fig. 11), higher tiller and panicle number per square meter, higher dry matter production, and higher number of filled grains. Banding and plowing down produced equivalent yields. The lower N efficiency of the basal fertilizer treatments suggested that some of the basal nitrogen was lost before it could be absorbed or that it was used ineffectively during early vegetative development.

In Indonesia, Saefuddin et al (1978) found that under both weedy and nonweedy conditions, root-zone placement of 40 kg N/ha was superior to surface banding (Table 3). In nonweedy plots, surface banding of 80 kg N/ha gave yields equivalent to those with root-zone placement of 40 kg N/ha. But in weedy plots, the root-zone treatment was superior.

Timing of fertilizer applications

Nitrogen fertilizer applications must be timed to meet the rice plant's nutrient requirement throughout its growing season. Adequate nitrogen is required at the



11. Effect of 3 methods of fertilizer placement at 4 rates of nitrogen on dry-seeded IR36 (adapted from Polthanee 1980).

Table 3. Effects of methods of nitrogen application and weeding levels on dry-seeded rice[a] (adapted from Saefuddin et al 1978).

Methods of N application	Grain yield (t/ha)	
	Hand weeded 15, 35 DS	Unweeded
Root-zone placement (40 kg N + 50 kg N at PI)	4.8	2.5
Surface banded (40 kg N + 50 kg N at PI)	3.2	1.6
Surface banded (80 kg N + 10 kg N at PI)	4.6	1.5

[a]PI = panicle initiation, DS = days after seeding.

beginning of the active tillering stage for a high number of tillers, and between panicle initiation and flowering for a high number of fertile spikelets per panicle (Sanchez 1972). Polthanee (1980) has suggested that for the most efficient use of limited amounts of nitrogen fertilizer, optimum timing is the same for dry-seeded and transplanted rice.

Under a reliable water supply and low soil water percolation rates, a basal application may be all that is required to meet the rice's nitrogen requirements. But a single application may increase lodging and exacerbate weed infestations (Evatt 1969). Under some circumstances, for example, where deep water prevails after the early vegetative stage, only one fertilizer application may be possible.

In Louisiana experiments to determine the best time for a single nitrogen application, Evatt (1969) found that application of all nitrogen 14 DE (just before flooding) produced yields equal to or significantly higher than application at planting. Application 2 weeks before seeding gave the lowest yields.

Split application is more practical than single application because it can be timed to meet the rice requirements more precisely. Split application may also reduce nitrogen losses particularly on soils with low cation exchange capacities (Evatt 1969) and high percolation rates, or where intermittent flooding occurs.

The best time and rate for split application would depend on many factors. Generally, however, one application at planting time, or soon thereafter during the dry stage, and application of the remainder at least once during the flood stage have produced the highest rice yields (Table 4) (van der Giessen 1942, Evatt 1965, Partohardjono and Harahap 1979).

For early-maturing rice varieties a basal application at the time of seeding or soon after emergence, plus a topdressing before the crop has completed half of its growth generally has given the highest nitrogen efficiencies. Research in the Philippines has suggested that for highest efficiency from a total application of about 70 kg N/ha on IR36, between 40 and 60% should be applied at planting and the remainder at 30 DE (Table 5). Applying the topdressing at either 40 DE or PI, or splitting the topdressing in various proportions between 30 DE, 40 DE, or PI gave lower nitrogen efficiencies than applying all the topdressing at 30 DE (IRRI 1979). Indonesian researchers have also shown that for a total application of 90 kg N/ha on C4-63, yields were higher

Table 4. Yields of rice (variety Cauvery) as affected by time and method of applying nitrogen fertilizers (adapted from Tewari and Singh 1977).

Time and method of N application[a]				Yield
Basal	Max tillering	PI	Heading	(t/ha)
		Soil application		
80				3.8
40	20	20		4.2
20	30	30		4.5
20	20	20	20	4.3
		Foliar application (2% urea)		
40	20	20		3.6
20	30	30		3.6
20	20	20	20	3.5
CD (5%)				0.3

[a]PI = panicle initiation.

Table 5. Effect of number and time of application of 70 kg N/ha on IR36, Pangasinan, Philippines (IRRI 1979, unpubl. data).

Amount applied[a]				Grain yield
Basal[b]	30 DE	40 DE	PI	(t/ha)
0	35	0	35	3.0
35	35	0	0	3.5
28	21	0	21	2.8
35	0	35	0	2.9
35	0	0	35	2.6
42	28	0	0	3.4
28	0	42	0	3.3
42	0	28	0	2.9
20	30	0	20	3.1

[a]DE = days after emergence, PI = panicle initiation. [b]Applied with seed in furrow. CV = 11%.

with application of 25 to 50% 10 DS and the remainder at 49 DS than with applications of the remainder at either PI or heading or splitting the remainder between the two times (Partohardjono and Harahap 1979). These studies suggest that nitrogen applications at PI or thereafter are not as beneficial as applications during the active tillering stage.

On the other hand, Polthanee (1980) suggests that for limited amounts of nitrogen to be applied only twice, most nitrogen should be applied only at the very early vegetative stage (15-30 DE) and at PI. For large quantities, a small amount of basal nitrogen applied to the seed row at planting time may increase yield by increasing early crop growth, provided the nitrogen requirements for later growth stage are satisfied.

The efficacy of basal ammoniacal fertilizer applications will depend, among other factors, on maintenance of the soil nitrogen in the ammonium ion form. Where nitrification rates on aerobic soils are low because of low microbial activity, where the fertilizer is applied into the reduced zone, or where the time between fertilizer application and flooding is short, basal applications may be highly efficient.

For medium-maturing rice in the United States, Evatt (1969) concludes that a portion of the nitrogen should be applied as near to seeding as possible. The remainder should be applied by the time the rice is at the panicle initiation stage; however, there is considerable leeway in applying it before this time.

Timing of nitrogen in relation to flooding is also important for high nitrogen efficiency. Topdressing nitrogen on dry or moist soil between 5 days and 30 minutes before anticipated flooding has produced about 1 t/ha more grain yield than when fertilizer was applied after soil submergence (Table 6). When fertilizer is applied on dry or moist soils, rain or floodwater acts as an effective carrier in moving the fertilizer into the root zone (Mikkelsen and Evatt 1971). Thus, when nitrogen is topdressed at 14 DE, placing it on dry soil has produced about 10% higher yields than placing it on wet soil, and 15-20% higher yields than applying it to flooded soil (Evatt 1969).

Management of phosphorus

Research studies on management of phosphorus fertilizers on dry-seeded rice are scarce. Phosphate does not pose so much of a problem in the dry-seeded rice fields because it can be applied to dry soils without much loss in its availability.

Uptake of phosphorus is less efficient in nonflooded soils than in flooded soils. Therefore, phosphorus deficiencies could be expected to occur more frequently in dry-seeded rice than in rice grown on constantly flooded soils. Because phosphorus is more available in flooded soils, early soil flooding can be used to increase phosphorus efficiency (Sanchez and Briones 1973).

Drilling phosphate at seeding is superior to early season topdressing. Topdressing 2 weeks after seeding has given higher yields than topdressing 4 or 6 weeks after seeding (Patrick et a1 1974). Phosphorus should be applied before the active tillering stage has been completed.

Crop responses to different sources of phosphorus fertilizer have not shown any great variation although rock phosphates have generally given less yields than the more concentrated phosphorus sources such as ordinary superphosphate (Davide 1965).

CONCLUSION

Very little research has been done on fertilizing dry-seeded rainfed rice. In western countries, fertilizer management studies on dry-seeded rice have been conducted

Table 6. Yield of rice as affected by nitrogen application[a] in relation to time of permanent flooding at 18 days after rice emergence (adapted from Mengel and Leonards 1977).

Time in relation to permanent flood	Yield (t/ha)
- 5 days	7.5
- 3 days	7.4
- 1 day	7.5
- 30 minutes	7.2
+ 1 day	6.2

[a] N rate = 90 kg N/ha.

under conditions of good water control, conditions which do not usually exist in rainfed rice fields. Thus, extrapolation of results from irrigated areas must be done with caution.

More research is needed on the utilization and efficiency of different sources, rates, timing and methods of fertilizer application for dry-seeded rice, and on the efficacy of slow-release fertilizers especially where water control is poor. Because water availability in rainfed fields is often variable and has a significant impact on fertilizer efficiency, the soil water conditions under which fertilizer management trials are conducted need to be clearly measured and described.

Data on the effectiveness of basal nitrogen applications are conflicting. The set of conditions under which basal applications produce high nitrogen efficiencies is still not clear.

We need to better understand and quantify routes by which nitrogen is lost from the system and to identify the dominant factors that affect the losses. As our understanding increases we will be able to more intelligently and efficiently manage the fertilization of dry-seeded rice.

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DISCUSSION

Kasmo: We understand dry-seeded rice (DSR) is used mostly in rainfed fields where the supply of potassium depends on the indigenous potassium in the soil. In your paper, there is little mention of potassium fertilization. Do you have information on the best potassium fertilizer source, methods of application, etc., to recommend?

Hoopper: In southern United States, potassium deficiencies in DSR on coarse-textured soils have been reported. Application of 30 kg K_2O/ha as KCl or K_2SO_4 at planting has been recommended.

Potassium deficiencies in rainfed DSR are probably rare because potassium deficiencies generally occur on coarse-textured soils with high percolation rates. Such soils are better puddled to reduce percolation losses.

Carandang: There is a need to describe conditions of the experiments especially for DSR. We need to include relevant information. For instance. in Table 5 presented by Dr. Hoopper, the time of fertilization application is indicated but the time of flooding would have a very significant effect on the effect of time of fertilizer application.

Hoopper: I agree. Many studies on fertilizing DSR have not included a description of soil water availability or other pertinent data, which may significantly influence nitrogen response. Such descriptions are necessary.

Doggett: I am concerned at the state of knowledge on two of the farmers' most expensive inputs as revealed by Hoopper and Morris. In Hoopper's Table 1, the N rate in the range 60–150 kg/ha makes no appreciable difference in yield. Could it have been a variety unresponsive to fertilizer? Under what conditions was this trial done?

In Morris' Table 2, 1 plowing with 40 kg N/ ha gives a yield increase; with 90 kg, 1 plowing decreases the value of the nitrogen applied by more than one half. Admittedly, the whole pattern is likely to be site specific, but it seems that more work needs to be done on the fertilizer-plowing-cultivar interactions, especially on the economics of their use.

Morris: You are correct in suggesting that much more needs to be done on fertilizer-plowing interactions. To this I would add weed control and water management, but delete cultivars, provided that only short-statured modern varieties are considered. Environmental interactions will, of course, be very important in considering adaptation and the place of DSR in cropping patterns. My feeling is that the organizers recognized the dearth of research on DSR as a possible alternative to traditional puddling followed by transplanting, and wanted the speakers to review what has been published and suggest priorities for future DSR studies as applied to alternative cropping patterns. I agree with your suggestion that economic analyses are needed.

Hoopper: I concur with Dr. Morris that too few studies have been conducted on all production aspects of DSR. Moreover, it is difficult to compare what little research has been reported in the literature because research methodologies differed, or were not reported, and the environmental conditions under which the research was conducted were not described. As researchers we need to be more detailed on both points.

Cultivar development for dry-seeded rice

W. R. Coffman and J. S. Nanda

Rice breeding objectives are dictated by water regimes and the relevant physico-chemical and biological stresses of the intended growing areas. The method of stand establishment is generally considered incidental and the same variety may be dry-seeded, wet-seeded or transplanted depending on climatic and edaphic variables. It is often possible to harvest 2 rice crops a year in rainfed wetland areas where 6 to 8 months of high rainfall are expected (Zandstra 1977). To do that, the first crop is dry-seeded at the onset of the rainy season. Our paper reviews the requirements and status of cultivar development for such situations and suggests a procedure by which cropping systems scientists may identify the most appropriate cultivars for a particular production complex.

Jennings et al (1979) present a comprehensive discussion of the various plant characteristics considered in rice improvement. Because of space limitations only those relevant or essential to dry-seeded rice (DSR) culture are discussed here.

AGRONOMIC CHARACTERISTICS

Early vegetative vigor is important for DSR varieties because it helps the crop overcome weed competition, compensates for missing plants, and helps ensure that the crop achieves its critical leaf area at flowering. However, such vigor should not carry through to excessive growth and mutual shading after panicle initiation. Vigor is associated with various combinations of rapid seedling emergence and development, early and heavy tillering, moderately long and initially droopy leaves, and early and rapid increase in seedling height. Early vigor is usually strong in unimproved tropical rice cultivars and, as a result, there is no dearth of improved cultivars that are exceptional in this characteristic.

Early maturity is an obvious requirement for DSR in an intensified double-cropping system. Combining early maturity with high yield potential is premised on exceptional vigor. A 100-day variety has less than 50 days of growth before panicle initiation. Even with the most vigorous early cultivars, precise timing of fertilizer topdressing, control of weeds, and optimum moisture are required for high yields.

Plant breeders, International Rice Research Institute, Los Baños, Philippines.

Table 1. Yield and maturity of some selected early-maturing lines. IRRI, 1979 wet season.

Designation	Cross	Maturity[a] (DS)	Yield[b] (t/ha)
IR36 (check)	IRl561-228//IR24*4/*O. nivara*///CR94-13	109	3.8
IR729-67-3	BG34-8/IR28//IR36	99	4.7
IR13204-3-3-3	IR29/CO39//IR36	98	5.0
IR19743-25-2-2	IR9129-192-2/IR10176-79	98	5.4
IR19746-28-2-2	IR9129-192-2/IR10183-7	98	5.4
IR19819-31-2-3	IR9715-4-2/IR10176-79	98	4.8
LSD (.05)			0.7
C.V. (%)			11.1

[a] DS = days after seeding. [b] Means of four replications.

There are numerous improved cultivars that produce acceptable wet-season yields in less than 100 days (Table 1). These maturity data were recorded in irrigated, transplanted fields. The growth duration should be even shorter for a DSR crop.

Ratooning ability may be highly desirable for DSR where the rainy season is too short for a second crop. IRRI cropping systems scientists evaluated a number of dry-seeded cultivars for ratoonability during the 1978 wet season (Table 2). Results were reasonably promising but the earliest cultivars did not produce a good ratoon. A number of early breeding lines were evaluated for the ability to ratoon during the 1979 wet season. Yields were relatively low and none of the materials appeared outstanding, indicating the necessity of preliminary screening prior to replicated evaluation. During the 1979 wet season, IRRI plant breeders made a preliminary evaluation of about 2,000 cultivars for their ability to ratoon.

Table 2. Grain yield and maturity[a] of the main and ratoon crops of 16 early-maturing rice selections dry-seeded in rainfed wetland plots. IRRI Multiple Cropping Department, 1978 wet season.

Pedigree	Grain yield (t/ha)		Days to maturity	
	Main crop	Ratoon crop	Main crop	Ratoon crop
IR8608-25-3-1	2.9 a	0.6 abc	109 a	64 a
IR8608-125-3-3	2.7 ab	0.5 abc	104 bc	65 a
IR36 (check)	2.7 ab	0.7 abc	109 a	65 a
IR9129-169-3-2-3-3	2.6 ab	0.6 abc	97 d	64 a
IR13168-143-1	2.6 ab	0.6 c	103 c	65 a
IR9703-41-3-3-1	2.5 abc	0.2 d	103 c	64 a
IR8608-231-2-2-3-2	2.3 abc	0.7 ab	103 c	64 a
IR13204-143-2	2.1 bcde	0.5 c	103 c	64 a
IR8608-271-3-2-3-2	2.0 bcdef	0.5 bc	103 c	64 a
IR9698-296-3-1	2.0 cdefg	0.7 abc	103 c	63 a
IR9782-44-3-3-3	1.9 defg	0.5 abc	103 c	65 a
IR9209-89-1-1	1.7 defg	0.6 abc	103 c	64 a
IR8608-167-2	1.6 efg	0.6 abc	106 b	64 a
IR8608-189-2-2-1-3	1.6 efg	0.6 abc	103 c	64 a
IR9129-136-2-2-1-2	1.5 fg	0.5 abc	97 d	65 a
IR9729-321-3-1-2	1.4 g	0.8 a	103 c	65 a
Mean	2.1	0.6	103	64
C.V. (%)	18.0	25.8	1.1	2.1

[a]Any two means followed by a common letter are not significantly different at 5% level.

DROUGHT RESISTANCE

Cultivars clearly differ in their ability to survive and yield in moisture-deficit situations. The phenomenon, however, is highly complex and may involve several mechanisms. IRRI scientists have found that drought resistance mechanisms in relation to climatic, edaphic, and cultural conditions are inherently different and site specific.

A number of techniques of varying sophistication may be used to evaluate drought resistance. Presently, the most practical method is to plant materials in the field during the dry season. The plants may be established by irrigation, but water is withheld to create stress at the appropriate growth stage, which can be determined by examining the climatic data of the target region. At the appropriate time the test entries are scored for stress symptoms and ability to recover after watering.

IR5853-118-5, recently named IR52 in the Philippines, is an example of the progress in combining drought resistance with other essential traits. It is comparable in all respects to IR36 except that it is about 1 week later in maturity and has drought resistance (Table 3) comparable to that of some hardy dryland types such as Salumpikit.

SUBMERGENCE TOLERANCE

Flooding is a common occurrence in vast rainfed wetland tracts of Asia during the monsoon season. Floods can occur more than once in a season and affect the crop at different stages of growth. The rice plant is most susceptible to submergence at the seedling stage. The extent of crop damage varies with the depth and duration of

Table 3. Drought scores[a] of rice cultivars in field screening for 3 successive years at IRRI.

Cultivar	Drought score at soil moisture tension of			Recovery[b]
	2 bars	5 bars	10 bars	
	1977			
IR5853-118-5	3	4	4	3
IR36	4	5	8	6
Salumpikit (resistant check)	3	4	5	4
IR20 (susceptible check)	6	7	8	7
	1978			
IR5853-118-5	1	1	3	3
IR36	2	3	6	4
Salumpikit (resistant check)	1	2	4	3
IR20 (susceptible check)	5	6	9	6
	1979			
IR5853-118-5	1	3	–	1
IR36	1	4	–	1
Salumpikit (resistant check)	1	3	–	1
IR20 (susceptible check)	3	5	–	3

[a] 1980 Standard Evaluation System for Rice (SES): 1 = negligible effect, 9 all plants apparently dead. [b] 1980 SES: 1 = all plants fully recovered, 9 = no plants recovered.

submergence. Submergence tolerance is a desirable character for all wetland rice.

IRRI scientists, working in Thailand and the Philippines, have identified excellent sources of tolerance for submergence (Fig. 1). Attempts have been made to incorporate submergence tolerance from diverse sources into improved varieties. Several tolerant breeding lines have been identified and should soon be available for wide-scale testing.

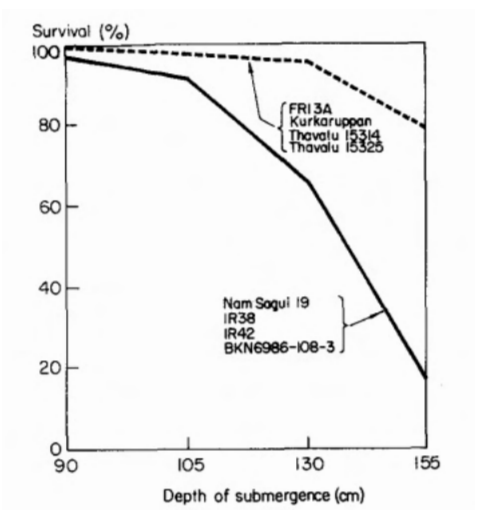
ADVERSE SOILS TOLERANCE

Dry-seeded rice is particularly vulnerable to mineral toxicities and deficiencies because the life cycle of a crop encompasses both aerobic and anaerobic soil conditions. On a soil of relatively high pH, for instance, iron deficiency may be a problem before flooding, and zinc deficiency a serious limitation after flooding. A good degree of tolerance for most adverse soil problems can be readily identified from improved germplasm. IR varieties, for example, have been evaluated under a wide array of conditions by IRRI soil chemists and they appear tolerant of many adverse soil conditions (Table 4). The same is true of improved varieties from national rice improvement programs although they have not, as a rule, been widely tested in the various adverse soils.

PEST RESISTANCE

Tremendous resources have been devoted to the development of pest-resistant varieties over the past several years. Most improved IRRI germplasm carries multiple resistance to the diseases and insects prevalent in the Philippines and Indonesia. The methodology employed in the development of this germplasm has been widely adopted and cultivars with an adequate degree of resistance to major disease and insect pests are generally available throughout Asia.

Rice blast disease may be particularly important with DSR. Because *Pyricularia*



1. Survival of 2 groups of selected varieties after 9 days' submergence. IRRI, 1979.

Table 4. Reactions of IR varieties to adverse soil conditions. IRRI Soil Chemistry Department, 1979.

IR variety	Reaction[a]							
	Wetland soils						Dryland soils	
	Toxicity				Deficiency			
	Salt	Alkali	Peat	Fe	P	Zn	Fe deficiency	Al and Mg toxicities
IR5	3	7	0	5	5	5	4	5
IR8	3	7	5	3	3	4	3	4
IR20	5	7	4	2	1	3	4	4
IR22	5	5	0	3	3	3	5	5
IR24	5	5	0	3	1	4	3	4
IR26	5	8	5	5	1	5	4	3
IR28	7	5	5	4	3	5	5	5
IR29	7	8	5	4	5	3	0	0
IR30	5	8	3	3	3	3	0	0
IR32	5	7	5	3	3	5	4	5
IR34	5	8	3	3	3	4	0	0
IR36	3	3	3	3	1	2	2	4
IR38	5	5	3	3	1	3	5	4
IR40	5	5	5	3	1	2	0	0
IR42	3	5	5	3	3	4	5	5
IR43	3	7	7	4	3	3	3	3
IR44	3	5	3	3	3	4	5	4
IR45	5	7	6	5	3	4	3	4
IR46	3	5	5	4	5	3	4	5
IR48	3	5	5	4	5	5	3	3
IR50	3	5	3	4	3	3	5	4

[a] 1980 Standard Evaluation System for Rice scale: 1 = almost normal plant, 9 = almost dead or dead plant, 0 = no information.

oryzae is a highly variable pathogen, there are no improved varieties with stable resistance to the disease. Cultivars resistant to locally prevailing races should be chosen. Resistance at a number of other sites is also desirable as that may indicate a greater degree of stability.

HERBICIDE TOLERANCE

Cultivars are known to vary widely in their reaction to various herbicides. IRRI scientists have attributed the variation to differences in mesocotyl length. Cultivars with long mesocotyl have their first node near the surface and are susceptible to preemergence herbicides; but those with short mesocotyl are tolerant. This may be an important consideration in selecting DSR cultivars.

GRAIN QUALITY

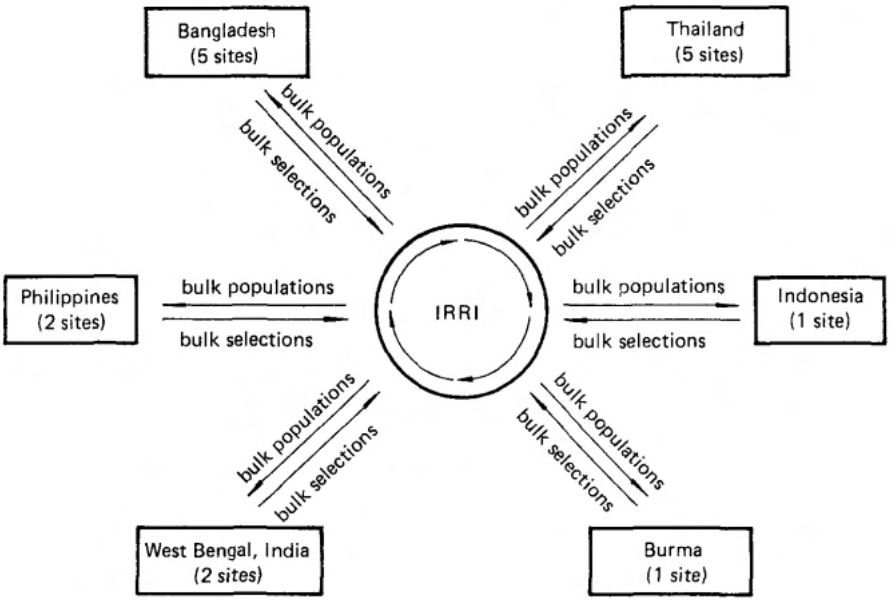
Grain quality does not directly affect the suitability of a DSR cultivar, but it should be considered in the choice of a cultivar for agronomic testing and eventual recommendation to farmers. In many countries, farmers will not accept a cultivar with inferior grain quality unless the economic incentive is substantial. IRRI and many national programs have steadily improved the grain quality of their breeding material. Many available lines now have intermediate amylose, which is preferred in most Asian countries.

COLLABORATIVE RESEARCH

Improved cultivars for most dry-seeded situations and nearly all rainfed wetland production systems will be markedly different from those now widely grown in irrigated areas. Their selling point will not necessarily be yield potential. Rather, it will be yield stability, essentially a guarantee to the farmer that he will have something to harvest, regardless of the weather.

We know some of the components of yield stability such as flood tolerance, drought resistance, and tolerance for mineral stresses. For several years we have been working to incorporate those traits into our improved germplasm. But there are other more subtle factors involved. We have developed a collaborative approach to the improvement of rainfed wetland rice that will, it is hoped, allow us to identify genotypes with both the obvious (drought resistance, for example) and less obvious factors that contribute to yield stability.

Collaborative work on rainfed wetland rice is through a network of scientists situated in six countries throughout the rice areas of South and Southeast Asia. Through this network we shuttle early-generation breeding material through several sites (Fig. 2) in sequential years. Theoretically, this should result in the selection of materials with stable performance. The parents for the crosses that are selected through the system are chosen by the collaborating scientists. The crosses are made at IRRI and distributed to the collaborators in the F_2. Outstanding lines that are eventually selected from this system will be distributed throughout the world in the International Rainfed Lowland Rice Observational-Nursery (IRLRON).



2. Schematic representation of international movement of materials in the rainfed wetland rice collaborative project, IRRI, 1980.

CHOOSING APPROPRIATE CULTIVARS

Choosing appropriate cultivars for cropping systems research may sometimes prove difficult. For that purpose the International Rice Testing Program (IRTP) nurseries and reports can be extremely useful. For DSR cultivars the early-maturing group of the International Rice Yield Nursery-Early (IRYN-E) should be the most valuable sources of cultivars. Seed, field books, and reports from previous nurseries are available through national IRTP coordinators or they can be obtained directly from IRRI.

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DISCUSSION

Khan: What is the number of days required for a ratoon crop harvest? What is the management level planned and followed for ratoon rice?

Coffman: A ratoon crop harvest requires from 50 to 70 days. The management level varies with variety, yield potential, and site.

Khan: Submergence under stagnant water does not represent the actual conditions in many countries. How would you extrapolate results obtained to such situations? A variety may need to have a stronger root system to withstand moderately strong currents. Depth of seeding or transplanting may also have to be considered.

Coffman: We simulate turbid water by lowering the light intensity. We have not investigated the anchorage problem.

McIntosh: In this session we are considering *dry-seeded rice.* What do we understand this term to mean? I address this question to Dr. Carangal.

Carangal: Dry-seeded rice refers to rice seeded in dry or moist soil in wetland bunded rice fields. The land is prepared dry (not puddled) and rice is either broadcast or drilled in dry or moist soil. After establishment, water accumulation is encouraged. This excludes dryland rice.

The need for mechanization in dry seeding rice

Chak Chakkaphak and Raymond C. Fischer

Growing more than one rice crop a year in rainfed fields is possible with direct seeding; suitable variety; weed, insect, rodent, and bird control; and supplemental irrigation such as farm pond or shallow well. But farmers often lack power and mechanization, and so it is virtually impossible to get maximum yields because farming operations cannot be done on time. Working a dry soil is more difficult than working the main-crop wet soil and farmers can probably plant only a small portion of their land to an additional crop without mechanization. Equipment, including suitable machines for dry seeding, is required to reduce the turnaround time between harvesting one crop and putting in the next.

The mechanization of dry seeding of rice has considerable potential in Southeast Asia. In Thailand alone, 90,000 ha of rainfed dryland rice are planted annually.

The 510,000 ha for deepwater rice in Thailand provides an additional area where a simple seeder could be used after the onset of the rainy season but before the field is inundated. Much of the cropped land in the 16 northeast provinces of Thailand grows rainfed wetland rice, which has potential for rice dry seeding before the fields are flooded. The same situations for direct seeding of rice exist in all countries of Southeast Asia.

Moss (1978) cited two relevant studies.

- In India there are frequently not enough men, women, and bullocks in a rice-growing village to do all the work of land preparation, transplanting, harvesting, and threshing on village land for the kharif season crop.
- In Iloilo, Philippines, with a dry-seeded rice - wet-seeded rice cropping pattern, there was a 0.7 t/ ha yield loss for each 10-day delay in planting the second rice crop.

In many areas where animal power is used for primary cultivation it is impractical to commence plowing (traditional cultivation) until rain has softened the soil and until the animals have regained some of the weight and vigor lost during the dry season (Bell 1979). With tractors it may be possible to plow land prior to the rains, but if the ground is hard the operation may be expensive in both fuel and maintenance of implement and tractor. Cultivation prior to the rains will improve infiltra-

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tion. If the land is left in too fine a condition, it may crust with the first rains and be subject to excess runoff and erosion.

Fischer (1978 unpubl.) stated that mechanization of rice production in northeast Thailand has been delayed because rice farmers in general did not have the resources for purchasing equipment. Only 3% presently use irrigation for a second crop. Some workers find off-farm employment after harvest and return to start the next year's crop. Reports of labor shortages for land preparation and harvest point up further the need for mechanization.

STATUS OF MECHANIZATION FOR RICE

Since 1960, applying mechanical power to wetland rice fields has received increased attention. Power tillers and small four-wheel tractors are widely used in Japan, the Republic of Korea, China, Thailand, and other areas of Asia. Adaption of machinery for manufacture and use in local wetland soils is going on in many countries.

Rice farmers in the irrigated area of Thailand adapted quickly to mechanization, but 85% of the rainfed rice land in the country is not mechanized. Mechanization of dryland rice production is even less developed.

There is activity in equipment and machinery development at national and international levels. One example is the IRRI Industrial Extension projects in cooperation with the governments of the Philippines, Thailand, Indonesia, Pakistan, and Burma. IRRI threshing machines are already in widespread production and use. A small power tiller and a dryland seed drill drawn by tiller or animal have been developed at IRRI. Machinery ranging from the lower-cost animal-drawn to the small tractor is under study.

Recent observations in Chieng Mai and Lumphun provinces of northern Thailand indicate that about 20% of the land is used for vegetables or tobacco immediately after harvesting wetland rice in December. Most of the land is prepared by a 75-hp tractor tiller or smaller power tiller. Most such machines are farmer-contractor owned and the charge is US$50/ha.

New developments

Work in the IRRI Cooperative Extension Program with small farm machinery in Thailand indicates that the draft of the animal plow can be reduced. In one comparison, the total draft of a power tiller moldboard, mounted at 30° on the test plow, with more than double the furrow top width and cross-sectional area, was slightly less than for the standard Khon Kaen plow. Additional data are needed. Skids have been fabricated to replace the gage wheels for obtaining data for paddy conditions.

In the first paddy comparison, specific draft was reduced by 30% of that of the standard Khon Kaen plow. If this program is successful, farmers will realize a benefit in timeliness by pulling a wider plow although they use animal power. This will help to mechanize dry seeding of rice.

Some farmers with heavy clay soils do not produce good seedbeds. Surface undulations and clods affect the uniformity of seeding depth. There is need for a simple land leveler, which may replace the last tillage operation and eliminate one

trip across the field. A simple triangular angle-iron leveler was built in the Thailand Cooperative Extension Small Machinery Program and initial trials were encouraging. In addition to surface leveling, it tends to reduce clod size. Farmers could construct the leveler out of wood in whatever width is suitable for the power source. An attached board for the farmer to ride may replace the soil-filled weight box to reduce cost when the leveler is used with a power tiller or buffalo.

CONCLUSION

Multiple cropping in rainfed areas is possible and will expand because it has tremendous potential for increasing the net income of farmers. Mechanization and dry seeding are a necessity for reducing turnaround time between crops.

Seeders and related equipment for rice and other upland crops are being developed. Moisture conservation and erosion control are important in mechanization of dry-seeded rice, particularly that grown in a multiple cropping system.

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DISCUSSION

Santiago: Because of the increasing cost of fuel and the current drive in many countries to conserve energy, and considering also the employment impact of mechanization in small farms, do you think a policy of full mechanization in dry seeding rice is the best approach? Or is partial mechanization better?

Chakkaphak: Growing more than one crop a year plus higher cropping intensity requires additional labor. A policy of partial mechanization is much better because full mechanization is difficult to achieve. A combination of human labor, animal traction, and suitable machines as used in China is highly recommended.

Gunawardena: In many situations mechanization becomes necessary but its adoption is limited by the high cost of fossil fuels. Use of solar energy in farm mechanization would be an attractive possibility. Are any attempts toward utilization of solar energy as a source of power for farm mechanization under way?

Chakkaphak; At the Asian Institute of Technology and in many institutions in the U.S. and Australia, work is under way and a lot of information on solar energy utilization for crop drying, water pumping, and some other uses is available. Much work on using other sources for tractor fuel instead of petroleum-based fuel is in progress.

Khan: While it is true that mechanization is useful for alleviating time and labor constraints, what do you think would be the effect of such mechanization on the farmers of developing nations with regard to employment generation? Don't you think such mechanization will displace a number of people on the farm?

Chakkaphak: Mechanization can be a positive factor in expanding employment opportunities in the rural sector. Draft animals and tractors for improved land preparation contribute to increased cropping intensity in irrigated areas. Higher cropping intensity increases farm output and requires additional labor for weeding and harvesting. This also applies to rainfed farming systems, which allow cultivation of areas usually left fallow each year. In' these examples, although mechanization replaces labor in certain operations, the consequent higher level of production results in a net increase in the total labor requirements during the whole cycle.

Khan: While I agree that during peak periods there is a need for some mechanical aid to reduce turnaround time even in Bangladesh where labor is still cheap, one will, in all likelihood, find himself stuck with a machine for which he may not find use for a considerable period. Further, the investment requirements for such mechanization aids should be considered because of the limited resource capability of most farmers in the developing nations.

Weed control in dry-seeded rice

Keith Moody

In this paper the term dry-seeded rice refers to rice that is seeded dry, generally by broadcasting. The crop begins its life cycle as a dryland crop but as the rainy season progresses, water accumulates in the field and the crop may finish its life cycle as a wetland crop. Rice that is seeded dry on soils with free drainage is not covered in this paper, but has been dealt with adequately elsewhere by De Datta (1979). One of the greatest problems that have to be solved before this method of growing rice can be recommended as a general practice is weed control (Moody 1979b).

Weeds are a more serious problem in dry-seeded rice than in other rice cultures because of differences in land preparation, lack of water, and because the dry-seeded crop emerges at the same time as the weeds. More weeds occur and the composition of the weed flora is different when rice is planted in dry soil than when it is planted in puddled soil (Table 1). Variations occur in the weed flora growing in association with

Table 1. Weight at rice maturity of different weed species in unweeded plots as affected by field conditions. IRRI, 1979.

Weed species	Weed wt[a] (g/0.5 m^2)			
	Puddled irrigated	Puddled rainfed	Unpuddled irrigated	Unpuddled rainfed
Cyperus difformis	2.2	1.0	–	–
Monochoria vaginalis	2.0	–	–	–
Lindernia anagallis	0.4	2.7	–	–
Ludwigia octovaivis	0.4	–	–	–
Cyperus iria	–	8.2	15.3	15.4
Echinochloa colona	–	1.1	8.1	12.3
Cyperus cornpressus	–	0.9	8.9	–
Murdannia nudiflora	–	–	4.6	–
Fimbristylis littoralis	–	–	4.6	–
Digitaria sp.	–	–	–	29.9
Ipomoea triloba	–	–	–	5.7
Others	0.2	3.4	12.1	18.0
Total	5.2 (6)	17.3 (13)	54.2 (14)	81.3 (19)

[a]Number of species is in parentheses.

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dry-seeded rice between and within sites and over years (Table 2). Such variations depend primarily on changes in environmental factors.

In some instances, weed competition is so intense that failure to control weeds in dry-seeded rice may result in no yield. In the past, attempts to introduce dry-seeded rice have failed because of the lack of an appropriate weed control technology (Moody and Mian 1979). Developing such a technology for dry-seeded rice will not be as easy as that for irrigated transplanted rice, nor will it be as cheap.

It is common knowledge that weeds decrease crop yields by competing for light, nutrients, and water. Competition is particularly damaging during the early life of a crop except for a brief period immediately after planting or crop emergence. Most crops will tolerate some weed growth early in their life cycles without suffering yield reductions, provided injury to the crop does not occur when weeds are removed.

DRY-SEEDED, RAINFED, BUNDED RICE

Moody and Mian (1979) reported that maximum yields can be obtained with dry-seeded rice if 3 weedings are done during the first 8 weeks of crop growth. In many instances, the third weeding would be unnecessary; two weedings during the first 5 or 6 weeks of crop growth should be sufficient. However, Shetty and Gill (1975) reported that 2 hand weedings 22 and 55 days after seeding (DS) were insufficient for maximum yields, and Ghobrial (l979) stated that 3 weedings during the first 45 days after rice emergence (DE) were optimum for dry-seeded rice in the Gezira.

Ahmed (1979) reported that the highest yields were obtained when dry-seed rice was weeded 3 times at 2, 5, and 8 weeks after emergence (WE). However, yields from the plots that were weeded once at 3 or 4 WE were not significantly less than those that were weeded 3 times. Generally, though, more than one hand weeding is needed to control weeds in dry-seeded rice.

The exact time after planting or emergence when the dry-seeded crop should be weeded varies with factors such as weed flora, growth characteristics of the rice and weeds, cultural practices, and environmental factors (Moody and Mian 1979). It is therefore, difficult to state how long after seeding a crop should be weeded and how many times during the period of greatest competition.

Yamane (1976) reported that a 6-week weed-free period after rice sowing was all that was needed to ensure optimum yields in dry-seeded rice. Only a small number of weeds emerged after that period and no yield loss was recorded.

Essentially the same result was obtained by Naidu and Bhan (1979) who found that, for optimum yields, the dry-seeded crop must be kept weed free for the first 45 days.

However, Siriwardana (unpubl. data) reported that maintaining 2 rice cultivars weed free from 6 WE did not result in optimum yields. The dwarf cultivar Bg 34-8 was more susceptible to late season weed competition than the tall cultivar 62-355. When the crop was maintained weed free for only 6 weeks, late-season weed competition caused a 50% yield reduction in the dwarf cultivar and a 22.5% yield reduction in the tall cultivar.

Table 2. Major weed species, their importance value (I.V.) based on weed weight, the total number of weed species, and the total weed weight in dry-seeded rice grown in different landscape positions (adapted from Ahmed 1979).

Well-drained dryland				Wetland with a very low ponding potential			
1977		1978		1977		1978	
Weed species	I.V.	Weed species	I.V.	Weed species	LV.	Weed species	LV.
Paspalum distichum	35.4	*Digitaria ciliaris*	50.5	*Echinochloa colona*	65.9	*Echinochloa colona*	28.3
Eleusine indica	23.6	*Amaranthus spinosus*	20.7	*Calopogonium mucunoides*	19.6	*Eleusine indica*	21.9
Dactyloctenium aegyptium	12.6	*Commelina benghalensis*	9.0	*Paspalum fasciculatum*	2.9	*Digitaria ciliaris*	21.7
Leptochloa chinensis	6.5	*Cyperus rotundus*	5.7	*Eleusine indica*	2.6	*Cyperus rotundus*	12.8
Total weed wt (g/0.25 m^2)	96.3		102.0		88.3		95.4
Species (no.)	16		13		17		15

Factors affecting degree of weed control

Land preparation during the dry season. A common practice in rainfed rice-growing ing areas is to leave the field fallow during the dry season after rice harvest. Weeds grow and shed their seed or multiply vegetatively. Animals grale on the weeds and at the same time introduce other weed seeds. As a result. intense weed problems may be encountered if a dry-seeded crop is sown at the start of the rains and the weeds that grow in that crop are the same as those that occur during the dry season.

There may be more advantages in plowing immediately after rice harvest than at the beginning of the next rainy season. Plowing after the rice crop, however, is only possible if the crop's vegetative cycle is shorter than the rainy season so that the soil remains moist. Repeated tillage during the fallow periods to prevent weeds from seeding and to expose vegetative propagules to drying should result in a significant depletion of weed seed reserves in the soil (Moody and Mian 1979).

In the People's Republic of China, intense land preparation by rototilling and maintaining the fields as a clean fallow during the dry season are two methods used to control weeds, which are the major problem in dry-seeded rice (Zandstra et a1 1977). Additional benefits are soil moisture conservation and earlier planting at the start of the rains.

Mahyuddin and Soeharsono (1976) suggested that a dryland crop should be grown after rice instead of merely keeping the soil tilled during the dry season. The land preparation for the dryland crop and interrow cultivation for weed control and any within-row weeding during thecrop's growth should result in the same benefits as continuous tillage throughout the dry season. In addition, the farmer gains the yield of the dryland crop.

Partohardjono and Harahap (1979) reported that tillage in Indonesia is done in the dry season to control weeds and, in areas where drought-resistant dryland crops are grown during the dry season, weed infestations are reduced. They noted, however, that weeds cannot be totally controlled by dry soil preparation.

In Sri Lanka, the growing of a crop during the dry season or maintaining the land weed free by herbicides resulted in no reduction in weed weight in the following rice crop compared to a plot that was maintained as a weedy fallow during the dry season (Siriwardana 1980, unpubl. data).

Moody and Mian (1979) reported that planting a mungbean crop and weeding it once was generally inferior to maintaining a weed-free fallow during the dry season. They also observed that there were significantly less perennial weeds such as *Cyperus rotundus* L. and *Cynodon dactylon* (L.) Pers. and significantly more annual weeds like *Echinochloa colona* (L.) Link in plots that were maintained weed free by tillage than in plots that were kept as a weedy fallow during the dry season.

The effect of previous land use on the weeds growing in association with dry-seeded rice was examined in two farmers' fields in Pangasinan Province, Philippines, in 1978. In one field there were four to six times as many grasses, primarily *E. colona,* in the land that had previously been maintained as weed-free fallow than in the land that had mungbean planted previously or had been left as a weedy fallow. This was reflected in the crop yield. The unweeded check plot from the land that was maintained as a weed-free fallow yielded nothing, but in the other land preparation methods the unweeded plot yielded more than 2 t/ha. Herbicide performance was

also superior in the plots that had less *E. colona* (IRRI 1979).

In a similar trial in 1979 (IRRI 1980), land preparation during the dry season led to a significant reduction in the number of *C. rotundus* but had no effect on the annual grass population.

Land preparation during the dry season appears to have only limited effectiveness in reducing weed problems in the following dry-seeded rice crop.

Use of stale seedbed. It may be possible to reduce weeds in dry-seeded rice by using the stale-seedbed technique. For that, the land is prepared and weeds are allowed to emerge after irrigation or a rain. The weed growth is then destroyed chemically. mechanically. or manually. Chemical methods have the advantage of not bringing more weed seeds to the soil surface where conditions are more favorable for germination. If mechanical or manual methods are used. soil disturbance should be as shallow as possible. Herbicides should be applied or the cultivation should be done when most of the weed seeds in the surface soil have germinated and are in the two- to five-leaf stage.

The crop is sown, with a minimum of soil disturbance, before or after the weeds are controlled. Theoretically, less weeds should grow in association with the rice because most of those in the favorable zone for germination have been killed. Where light rains occur for an extended period before the onset of the monsoons, or if irrigation is available, it may be possible to kill several flushes of weed growth before planting.

The stale seedbed has been used successfully for dry-seeded rice establishment in India and Sri Lanka (Moody and Mian 1979). In Pangasinan Province, Philippines, a 59% reduction in number of weeds (primarily *E. colona*) 2 WE and 78% reduction of fresh weed weight occurred as a result of practicing the stale seedbed technique (IRRI 1980). At 2 WE there was a 30% decrease in the number of grass weeds as a result of a preemergence butachlor application.

When hand weeding followed the butachlor treatment after 3 weeks, the weeding labor was 456 hours/ha in the conventionally prepared plots and 246 hours/ha in the stale-seedbed plots. In the conventionally prepared plots, the yield of the plots treated with butachlor followed by hand weeding was significantly higher than that of the plots treated with butachlor or the unweeded plots, which did not differ significantly from each other. With the stale seedbed technique, yields of the weeded and the unweeded plots did not differ (IRRI 1980).

Delay in planting is, however, a disadvantage of use of stale seedbed technique. The two weeks that can be gained by doing land preparation during the dry season are lost. Moreover, the earlier that planting is done after the start of the rains, the fewer are the weed problems. Delay in planting results in more weeds and more control difficulties (Moody 1977c).

Cultivar grown. The selection of shorter rice cultivars has led to reduced plant ability to compete with weeds and poorer adaptation to weedy situations (Moody 1979a). Visually, weeds appear to have a more damaging effect on the short modern cultivars than on the tall traditional cultivars. If this is the case, the modern cultivars' superior yields exhibited under weed-free conditions could well be nullified in a weedy environment.

Hoque et al (1976) reported that the average number of hand weedings required

for direct-seeded rice was higher for modern cultivars than for traditional cultivars. The weed flora growing in association with different rice cultivars may also change. Hoque et al (1978) reported that the major weeds growing in association with BR3, a short-statured cultivar, were the sedges *Fimbristylis littoralis* Gaud., *Cyperus difformis* L., and *Cyperus iria* L. When Dharial, a tall traditional cultivar, was grown, sedge growth was much reduced and a grass, *Echinochloa crus-galli* (L.) Beauv., became the dominant weed.

Plant characters that increase size and vegetative vigor of the rice plant in the early growth stages enhance competitive ability. Such factors include leaf length and number, a spreading growth habit, plant height, and tiller number.

In the eastern region of Sri Lanka, farmers mix a high-yielding semidwarf cultivar with a tall traditional cultivar of the same growth duration and seed at a high rate to compensate for the poor competitive ability of the high-yielding cultivar (Gunawardena, IRRI, 1980 pers. comm.). The tall cultivar, which comprises about 10% of the plant population, has vigorous early growth and droopy leaves and smothers weed growth appreciably.

Escuro (1978) reported that in Burma the more vigorous early-maturing modern cultivar C22 competed better with weeds than the early-maturing cultivar Doja Sein Nyaung when dry seeded. In Sri Lanka, Siriwardana (1980 unpubl. data) reported that the tall cultivar 62-355 was more competitive against weeds than the dwarf cultivar Bg 34-8.

For rice there is a strong negative correlation between competitive ability and yield. Therefore, only limited success can be expected in exploiting cultivar differences for improved weed control (Moody 1979a). But if two rice cultivars are equal in all other attributes, priority should be given to the cultivar that competes best with weeds.

Seeding rate and row spacing. Increasing seed rates for dry-seeded rice has little influence on weed suppression probably because of the intense weed pressures. In a trial in Pangasinan, Philippines, reducing the spacing between rows from 25 to 20 cm or increasing the seeding rate from 80 to 160 kg/ha had no significant effect on the weeds that grew in association with rice, nor on rice yield (IRRI 1978). At IRRI (IRRI 1980), 3 rice cultivars (IR36, IR42, and IR2823-399-5-6) were dry-seeded at 100 kg/ha in rows spaced 15, 25, and 35 cm and subjected to various weeding regimes. Weed weight was unaffected by cultivar and spacing for all weeding regimes.

In Iloilo, Philippines, when IR36 was broadcast or sown in rows spaced 25 cm at rates ranging from 80 to 160 kg/ha, the method and rate of seeding had no effect on weed weight (IRRI 1980).

In Sri Lanka, farmers use tall rice cultivars and high seeding rates (up to 700 or 800 kg/ha) to overcome the competitive effects of weeds. At a seeding rate of 400 kg/ha, Siriwardana (unpubl. data) reported an 18% decrease in the number of weeds growing in association with a dwarf cultivar and a 25% decrease in the number of weeds growing in association with a tall cultivar compared to the same cultivars seeded at 50 kg/ha. With the dwarf cultivar, increasing the seeding rate did not decrease weed weight at harvest; but with the tall cultivar, increasing the seeding rate from 50 to 400 kg/ha decreased weed weight by 59%.

Considering the cost of seed, it is highly unlikely that many farmers would be willing to use high seeding rates to suppress weeds in dry-seeded rice.

Fertilizer application. Weed growth is stimulated if nitrogen is incorporated in the soil before planting. Smith (1960) observed that rice that was not fertilized but kept weed free yielded as much as rice that was heavily infested with weeds and received more than 100 kg N/ ha. When infestation of *E. crus-galli* was heavy, yield was best when nitrogen was applied when the grass was heading, 8 weeks after seeding (Smith 1980).

In Bangladesh, addition of fertilizer (60-40-40 NPK/ha) to dry-seeded rice without weed control resulted in a nonsignificant yield increase; weed control without fertilizer addition gave a significant yield increase. A further significant increase was obtained from fertilizer plus weed control. The greatest increase in yield was due to weed control and its effect was slightly greater when fertilizer had been applied than when no fertilizer had been added (2.0 t vs 1.7 t/ha) (Islam and Rahman 1977).

Ahmed (1979) reported that weed counts and weights 2 WE of dry-seeded rice increased linearly as the rate of basal nitrogen application increased from 0 to 40 kg/ha. At 5 WE, weed counts increased linearly as the rate of nitrogen topdressed increased from 20 kg/ha (for the plot that had received 40 kg N/ha basally) to 60 kg/ha (for the plot that received no nitrogen basally). Grain yield of rice was not affected by the rate of basal application of nitrogen. The first weeding was easier and faster in the plots that received no basal nitrogen than in those that received 40 kg N/ha as a basal application. The weeds, primarily grasses, were smaller than the rice in the former case, whereas in the latter the weeds were taller than the rice and were difficult to distinguish from it.

In the dry season at IRRI, there was no significant increase in weed weight 25 and 45 DE over the unfertilized check as a result of method (broadcast, band-placed, or plowed-down broadcast), time (basal or 10 DE), or rate (30, 60, or 90 kg/ha) of nitrogen application. In the wet season, at 45 DE, there was no significant difference between application methods but weed weight was significantly higher in the plots treated with 90 kg N/ha than in those that received 0, 30, or 60 kg N/ha. Weed weight was also significantly higher in the plot that received 60 kg N/ha than in the unfertilized check. At 20 DE, weed weight was significantly higher in the plots that received a broadcast application of nitrogen than in those that received a band application or a plow-down broadcast application (Polthanee 1979).

Nitrogen application should be timed so as to prevent weed proliferation and yet obtain maximum benefit from the fertilizer applied (Moody 1977b). Moody and Mian (1979) suggest waiting until after the first weeding to apply nitrogen in dry-seeded rice to reduce weed growth.

Interrow cultivation. Row seeding is rare for dry-seeded rice. In Bangladesh, Mian and Karim (1970) found that the row-seeded crop was easier to weed and weeding was more efficient with it than with the broadcast-seeded crop. The same result was observed for deepwater rice in Mali (WARDA 1979). Yields from row-seeded rice were equal to (WARDA 1979) or significantly higher (Mian and Karim 1970) than those from broadcast-seeded rice. On the other hand, Alim (1956) reported that sowing in rows encouraged weed growth and as a result, more labor was needed for weeding.

Hand weeding can be done in both broadcast and row-seeded rice, but mechanical weeding is feasible only where rice is planted in rows. An exception is a common practice in Bangladesh and West Bengal, India, where spike-toothed harrows are passed through the broadcast-seeded fields 5 to 15 days after emergence of the rice seedlings. This kills some weeds, thins the rice seedlings, and loosens the soil surface. Seedling mortality is overcome by high seeding rates.

Farmers say row seeding is time-consuming and difficult compared to broadcast seeding. But this disadvantage should be more than compensated for by the time saved when weeding. With interrow cultivation, the weeds adjacent to the row are not controlled and can cause appreciable yield reductions. However, a saving in time and labor is achieved using a combination of mechanical and hand methods rather than hand alone (Moody 1977b).

Interrow cultivation works extremely well under ideal climate and soil conditions. But when rainfall is heavy during the first month after planting, mechanical cultivation is difficult to do on time. Even when it is done, the wet soil reduces its effectiveness. Furthermore, with moist soils or if it rains soon after tillage, the weeds may quickly reestablish themselves with little or no apparent injury.

Moody and Mian (1979) noted that equipment now available for seeding and interrow cultivation in dry-seeded rice leaves much to be desired. They stated that suitable equipment must be developed before row seeding could gain widespread acceptance. Lusanandana (1978) recommended that research should be directed toward modifications of the native implements already in use before undertaking design of new implements. The implements that need priority attention are those for tillage, seeding, and interrow cultivation.

Herbicides. Because of the high labor requirements for hand weeding; high wages, particularly during peak periods of farming operations; and unfavorable weather conditions at weeding times, herbicides for controlling weeds in dry-seeded rice are gaining importance in areas where they have not previously been used. Moody (1977a) observed, however, that many herbicides that had been used successfully for weed control in dry-seeded rice grown under well-drained conditions and in wetland rice failed to give adequate weed control or were phytotoxic in dry-seeded wetland rice.

Flexibility in the use of herbicides to match them with suitable conditions to maximize their efficiency is critical in their being accepted for dry-seeded rice culture.

The time of application of herbicides is important with respect to weed control and crop damage. Preemergence herbicides depend on moisture for activation. Their application to a dry seedbed without follow-up rain can result in a complete loss of effectiveness through deactivation and volatilization. Heavy rain soon after herbicide application that results in ponding of water on the field for as little as a day may cause stand reduction due to herbicide damage.

Application on a moist or wet soil and adequate moisture during the first 3 or 4 weeks after application are the conditions that seem to effectively activate preemergence herbicides and give prolonged weed control (Moody and Mian 1979). However, the application of these herbicides after crop emergence when conditions for weed control are more suitable and the chances of crop damage occurring are

lessened should be considered. Some herbicides normally applied preemergence can be applied early postemergence and still give control of germinated weed seedlings without adverse effects on the crop.

The preemergence herbicide chosen has an effect on the method and depth of seeding. The crop should be seeded at maximum depths consistent with optimum emergence and stand establishment; at the same time, it should be seeded deep enough so that it is protected from herbicides that may be leached downward by heavy rain after planting.

Shallow preplant incorporation of an herbicide to reduce losses by volatility and to place the herbicide in the zone where it is needed for activity should also be considered. But because chances of crop damage are greater with such a treatment, deeper planting or the coating of the rice seed with an herbicide antidote may be necessary.

The residual effects of most preemergence herbicides are usually too short to provide weed control until the fields are flooded. A follow-up hand weeding is recommended to prevent yield reductions and to control the weeds that have been inadequately controlled by the herbicide treatment.

Instances of excellent weed control with a single herbicide treatment for dry-seeded rice have been reported. Excellent control of grasses was obtained by Mian and Rahman (1969) when propanil was applied at the two- to three-leaf stage of the grassy weeds. The yield from the propanil-treated plot was 31% higher than that from the plot that was weeded twice (15 and 30 days after sowing) and the cost was cheaper. In deepwater rice, propanil was as effective as hand weeding (WARDA 1979).

In Thailand, yields from plots treated preemergence with oxadiazon or bifenox were significantly higher than those from the unweeded check (Supatanakul et a1 1977). Oxadiazon also gave promising results in the Sudan (Ghobrial 1979). In Bangladesh, however, plots treated with oxadiazon yielded significantly less than the hand-weeded check (BRRI 1977). In this trial, yields from plots treated with butachlor or piperophos - dimethametryn were not significantly different from that of the hand-weeded check.

In a subsequent trial (Hoque et a1 1978) yields from plots treated with these herbicides were significantly lower than those from the hand-weeded check and a plot that received a butachlor treatment followed by a hand weeding. Rathi and Tewari (1979) reported that butachlor followed by hand weeding was superior to butachlor. Not only did this treatment give better weed control and higher yields, but the labor requirement and the total cost were reduced. Gunawardena and Siriwardana (1974) also reported excellent weed control with butachlor. Miyahara (1971) reported that thiobencarb applied preemergence or early postemergence, and propanil applied early postemergence were among the best weed-control treatments for dry-seeded rice.

On the other hand, Shetty and Gill (1975) reported that plots treated with propanil, molinate, nitrofen, propachlor, and butachlor yielded significantly lower than plots that were hand weeded twice. Propanil also performed poorly in the Sudan (Ghobrial 1979). In the Philippines, results have consistently shown that single herbicide treatments are unsatisfactory for dry-seeded rice weed control

(IRRI 1978, 1979, 1980).

Combinations of thiobencarb and propanil applied early postemergence have given good weed control in Japan (Yamane 1976) and the People's Republic of China (Zandstra et al 1977). Other herbicide combinations that have given good results are thiobencarb and prometryn applied preemergence in Indonesia (Pane, IRRI, 1978 pers. comm.); propanil and MCPA applied sequentially as a postemergence treatment in Sri Lanka (Siriwardana, unpubl. data); propanil plus 2,4-D applied postemergence in Thailand (Supatanakul et al 1977); and sequential applications of butachlor, swep or terbutryne and piperophos - dimethametryn in Korea (Lee 1976). Even more complex combinations have been used successfully in Korea (Lee 1976). Propanil combined with 2,4-D was tested in India with poor results (Shetty and Gill 1975). Herbicide combinations applied preemergence (butachlor plus oxadiazon), early postemergence (thiobencarb plus propanil), or sequentially (butachlor or oxadiazon followed by 2,4–D) were very promising in a recent IRRI trial.

The superiority of the herbicide combinations can be explained: they control more species of weeds than single herbicide treatments, and effective control lasts longer than with single herbicide treatments.

Despite a number of problems associated with herbicide applications in dry-seeded rice, it is apparent that they will play an increasingly important role in this type of rice culture.

RICES IN HYDROMORPHIC AREAS

In Africa, hydromorphic rice is grown in areas with hydromorphic soil conditions in the humid forest as well as the savanna zones (Zan 1980). The soils have a fluctuating groundwater table with major differences for wet and dry seasons. During wet seasons, temporary flooding may occur but in the dry season the water table may be at 50 cm or lower.

Weed problems in rice in hydromorphic areas are more serious than those in dryland conditions. Failure to weed usually results in complete yield loss (IITA 1975, 1977; Curfs 1976).

According to Zan (1980) weeds (mostly broadleaf weeds and sedges) are one of the major constraints to growing rice in hydromorphic areas and because of heavy weed growth most of the hydromorphic land is under shifting cultivation. The fallow period suppresses the weeds that are a problem during cultivation and is a cheap and efficient means of weed control (Moody 1975).

Sedges are serious weeds in rice in hydromorphic areas, and, a grass, *Paspalum conjugatum* Berg is particularly troublesome (Akobundu 1979). Akobundu and Fagade (1977) reported that *Fimbristylis* sp., *Echinochloa* sp., *Alternanthera* sp., and wild rice (*Oryza* sp.) are common problems in hydromorphic areas. I have observed that the major weeds growing in association with rice in such areas are grasses. The time of planting rice after clearing the fallow could partially explain these differences. Broadleaf weeds tend to be the major problem in recently cleared fields, while grasses become more important as cultivation continues (Moody 1975).

According to Curfs (1976), different land preparation techniques during the dry

season had little influence on weed growth.

Because of the absence of water immediately after the crop is planted, the cost of weeding rice in hydromorphic areas (as in other types of dry-seeded rice) is far greater than in puddled fields. Three hand weedings are generally needed for optimum yields. With two hand weedings, 7 and 28 DE, 14 and 42 days after planting (DP), and 21 and 42 DP, yield declines of 44% (IITA 1975), 50% (IITA 1977), and 19% (Curfs 1976) have been reported. The number of weedings and the time of weedings depend on the cultivar grown (Table 3). For the tall traditional cultivar OS6, two weedings were adequate and delaying the first weeding until 5 WE did not result in a significant yield decrease, For IR20, a signifcant yield decrease resulted when weeding was delayed until 5 WE; for TOS2578, 4 weedings were superior to 2 weedings, 5 and 8 WE.

Weed growth in rice in a hydromorphic area was greatly reduced as row width decreased below 30 cm (IITA 1977). At row spacings of 18 cm and less, yield reduction due to weeds in the unweeded check were about 20%. Therefore, better weed control would be expected at closer row spacings (IITA 1977).

In a trial in Nigeria (IITA 1975), yields from the best herbicide treatments [piperophos - dimethametryn followed by (fb) propanil, butachlor fb propanil, and bifenox fb propanil] were superior to those from plots that were hand weeded twice, but at least 24% lower than those from the hand-weeded check. In the following year, these treatments proved to be toxic to the rice or failed to give sustained weed control (Table 4). The best weed control with a herbicide treatment was achieved by

Table 3. Effect of time of weeding and cultivar on yield of rice in a hydromorphic area. IRRI. 1979.

Weeding time (wk after crop emergence)	Yield (t ha)[a]		
	IR20	TOS2578	OS6
1 + 4 + 7 + 10	3.9 a	1.5 a	1.9 a
2 + 5 + 8 + 11	3.9 a	1.4 ab	1.8 a
3 + 6 + 9	4.0 a	1.1 abc	1.6 a
1 + 4 + 7	3.7 a	1.4 ab	1.4 a
4 + 7 + 10	4.0 a	0.8 bc	1.7 a
2 + 5 + 8	3.5 a	1.3 abc	1.4 a
5 + 8	2.7 b	0.7 c	1.1 a

[a] In a column, means followed by a common letter are not significantly different at the 5% level.

Table 4. Effect of various weed control practices on the yield of rice in a hydromorphic area. IRRI, 1979.

Treatment[a]	Rate (kg a.i./ha)[b]	Time of treatment[c]	Weed wt (t/ha)	Grain yield (t/ha)
Complete weeding	–	14 DE fb 35 DE fb 56DE	0.4	2.5
Piperophos - dimethametryn fb propanil	3 fb 2	PE fb 21 DE	0.7	2.0
Bifenox fb propanil	2 fb 2	PE fb 21 DE	1.3	1.0
Butralin fb propanil	3 fb 2	PE fb 21 DE	1.4	0.5
Interrow weeding	–	14 DE fb 35 DE fb 56 DE	2.1	0.1

[a] fb = followed by. [b] a.i. = active ingredient. [c] DE = days after rice emergence, PE = preemergence.

piperophos - dimethametryn fb propanil, but a 27% decrease in rice stand resulted and the yield was 22% less than that in the plot that was hand weeded 3 times. Interrow weeding without removing the weeds within the row resulted in a 95% yield reduction, illustrating the importance of controlling weeds within the row and the futility of using interrow cultivation alone as a means of weed control in dry-seeded rice.

Further trials indicated that yields of the best herbicide treatment (fluorodifen plus propanil applied early postemergence) were superior to those of plots weeded twice but 27% lower than those of the weed-free check (IITA 1977).

Optimum yields, therefore, have not been realized for rice grown in hydromorphic areas even with herbicide combinations applied either sequentially or together as an early postemergence treatment. To achieve optimum yields and to reduce the possibility of a buildup of tolerant weeds, a follow-up hand weeding when weeds have reached a level that will cause yield reduction is recommended.

DEEPWATER RICE

Ramiah (1954) commented that in Thailand, Cambodia, and Vietnam it is not uncommon to see deepwater rice fields fouled with weeds. Alim (1956) observed that in general farmers do not pay much attention to deepwater rice culture. Once they sow a crop in the field, the only operation that they attend to is harvest of the crop. Xuan and Kanter (1975) made a similar observation.

Deepwater rice is generally characterized by poor land preparation, broadcast seeding, and lack of weeding. The weeds growing in association with deepwater rice can be divided into four groups:

1. those that grow under dryland conditions and are killed by the flood;
2. those such as *Leersia hexandra* Sw., *Hymenachne pseudo-interrupta* Muell., *Hygroriza aristata* (Retz.) Nees, *Scirpus articulatus* L., and the wild rices (*Oryza* sp.) that grow under dryland conditions and are unaffected by flooding;
3. weeds that grow after the field is flooded; and
4. weeds such as *Eichhornia crassipes* (Mart.) Solms and *Nymphea stellata* Willd. that move into the fields after the flood as a result of wind OF water currents.

A common observation is that weeds that establish under dryland conditions are killed by flood (Alim et al 1962, Datta and Banerji 1978, Eunus 1974, BRRI 1974) and this is a reason why farmers don't weed deepwater rice.

But prior to the advent of the flood, these weeds cause considerable crop damage and reduction in yield through competition. Hasanuzzaman (1974) notes that before flooding, grasses and sedges affect crop growth. Therefore, weeds in deepwater rice should be controlled during early crop growth. However, the magnitude of yield loss due to weeds is not known and studies are needed to determine this.

In Bangladesh, if there is time between seeding and flooding, one cultivation with a spike-toothed harrow is done when the seedlings are 20 to 25 days old (Hasanuzzaman 1974). Hand weeding is occasionally done, but it is not universal (Alim 1956). However, Catling et al (1979) reported that in 1978, 95% of the fields representing many typical deepwater rice areas in Bangladesh were weeded an average of 1.9 times. In West Bengal, harrowing and hand weeding are done 2 to 3 times at 10- to

12-day intervals after the crop is 15 to 20 cm high (Datta and Banerji 1978). In Mali, farmers generally hand weed once before the onset of the flood (Toure 1979). WARDA (1978) reported that weeding was done by most farmers 57 days after seeding on the average while 19% hand weeded twice and 7% weeded by mechanical means.

In Thailand, there have been increasing reports of wild rice causing considerable problems in deepwater areas. This is thought to be primarily due to a change in plowing from the buffalo to the large tractor (Prechachart and Jackson 1975). Weeds, especially wild rice, cause serious crop losses in West Africa (WARDA 1978, Zan 1980).

Chandler (1975) regarded control of weeds, particularly the wild rices, as the biggest problem in deepwater rice. Wild rice is controlled by burning the stubble during the dry season (Hasanuzzaman 1974, Toure 1979), by plowing and exposing the rhizomes to the sun during the dry season (Toure 1979), by rouging (WARDA 1978), and by cutting the weeds almost at ground level in the rising floodwater (Toure 1979). This is only effective when the water level is greater than 60 cm (Toure 1979). Plowing just before the flood plus cutting the weeds once water is 60-70 cm deep or the application of 3-5 kg glyphosate/ha to 20-25 cm-high regrowth was superior to plowing just before the flood or cutting the weeds in water twice for controlling rhizomatous wild rice (WARDA 1978). For annual wild rice control, the only promising practice is repeated harrowing before planting (Toure 1979).

In some areas, rice cultivars with dark purple vegetative parts are sown at high seeding rates when wild rices become a problem. The green seedlings of the wild rice and other weeds can easily be distinguished from the rice and can be readily weeded out (Hasanuzzaman 1974).

Weeding the deepwater rice crop in standing water is generally not done. In West Bengal cultivation is done crosswise with a bullock-drawn light (soil non-inverting) plow when the crop is 30 to 40 cm high and the water is 20 to 25 cm deep (Datta and Banerji 1978). Hasanuzzaman (1974) stated that in some areas weeding is done from boats. In Thailand, some 2,4–D is applied as a spot treatment (Prechachart and Jackson 1975).

Farmers try to prevent floating masses of weeds from entering their deepwater fields by growing *Sesbania aculeata* Poir., *Aeschynomene aspera* L., *Ipomoea* sp., and jute (*Corchorus* sp.); or by constructing bamboo barricades along the river banks and on the borders of their fields (Hasanuzzaman 1974). Attention should be given to trying to control the floating weeds at the source.

Because of the similarities between deepwater rice and dry-seeded rainfed bunded rice, weed control methods now being used or tested for use in dry-seeded rice should be tried with deepwater rice. Results should be similar and the successes and failures encountered the same. Additional research will be needed on the control of aquatic species and the wild rices in deepwater rice; such weeds do not appear as important in dry-seeded rice.

SUMMARY

The status of weed control in dry-seeded rice (*Oryza sativa* L.) grown in fields that are usually flooded for part of the growing season is reviewed.

Possible ways for overcoming the intense weed problems that occur in such a system of growing rice are analyzed and future research directions suggested.

Of the weed control methods reviewed, the application of herbicides in combinations seems to have the greatest potential for controlling weeds in dry-seeded rice.

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DISCUSSION

Wells: In view of the increasing cost and possible scarcity of herbicides, what do you see as their role in developing countries?

Moody: Labor prices are also increasing. The choice of weed control method depends on feasibility and cost. The farmer is more likely to opt for hand weeding where 50 hours may be needed to hand weed I ha, whereas in DSR where 100 hours may be needed to hand weed 1 ha, he is more likely to use herbicides.

Hoopper: You mentioned that cultural practices such as plant spacing, row distance, and seed rate had little or no effect on weed control in DSR. Is there any evidence that cultural practices coupled with other forms of weed control, particularly early season weed control by hand weeding or by use of herbicides, are effective in controlling weeds?

Moody; These practices appear to have no effect when fields are not weeded. We do not have sufficient data for unweeded fields, but it is possible that reduced row distance and increased weeding rate may reduce the number of weedings needed or the time required for these weedings or the herbicide rate.

Saing: In Shan State (eastern part of Burma) where dryland rice is commonly grown, weeds are a major problem. Hand weeding is very expensive because of the scarcity of labor. Chemical weed control may, therefore, be more feasible. I wonder if you have compared the costs of mechanical and chemical weed control methods and also the herbicides used in your experiments?

Moody: Because mechanical methods of weed control have not performed well, we have not made any comparison between mechanical and chemical methods. Estorninos et al made comparisons between chemical control and hand weeding in their paper.

Saing: You said that changes in weed species were observed from year to year. Does this occur on the same plot?

Moody: Yes.

Chatterjee: For dry seeding rice in India we recommend topdressing of nitrogen 15-20 days after sowing, after the first weeding. Potassium and phosphorus are applied as a basal dose, and nitrogen only is topdressing. That minimizes weed and crop competition and increases utilization of nitrogen by the crop.

Moody.: This approach is mentioned in my paper in the section dealing with fertilizer application.

Patel: In developing countries unemployment is alarming and multiple cropping is the most potent tool for solving food and unemployment problems. Management of multiple cropping systems is difficult, especially the weed management in wet season rice where yield losses due to weeds are enormous. Weed control in wetland rice may not be solved by the use of one type of herbicide because weed flora vanes to a great extent. Therefore more emphasis may be given to integrated approach to maximize the yield and for effective weed control.

Upasena: Our experience at Walagambahuwa with postharvest tillage has shown that fields have a high infiltration capacity as a result of this treatment. It allowed the farmers to prepare a better seedbed very early in the monsoon and to establish a DSR crop with better weed control.

Insect pests and insecticide response of dry-seeded bunded rice

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Monsoonal Asia is characterized by distinct seasons based on rainfall. Without irrigation, rice cultivation is restricted to the wet season. In rainfed areas, only one rice crop a year can normally be grown. But with the advent of early-maturing, photoperiod-insensitive rice varieties, 2 rice crops are possible if rainfall exceeds 20 mm/month for 5-6 consecutive months and if the first crop is direct seeded with the onset of the first soaking rains (Moms and Zandstra 1979).

The two rainfed wetland cropping systems sites in the Philippines — Oton, Iloilo Province, and Manaoag, Pangasinan Province — represent regions where, in most years, two rice crops are possible without irrigation if the first crop is direct seeded. Both areas have distinct dry seasons (< 100 mm rainfall/month) from January through April (Iloilo) and December through April (Pangasinan) (Morris and Zandstra 1979).

The plant host range of most of the important rice insect pests in rainfed wetland environments is limited to rice and a rice-free dry season is detrimental to their numbers. Rice insects recolonize rice fields with the onset of the rainy season each year by:

- estivation (dry season dormancy) of which the white stem borer *Scirpophaga (Tryporyza) innotata* and the rice bug *Leptocorisa* spp. are examples, or
- migration from other areas, for example, *Nilaparvata lugens, Nephotettix virescens, N. nigropictus,* and *Sogatella furcifera.*

S. innotata estivates as a last-instar larva in rice stubble (van der Laan 1959) and *Leptocorisa* estivates as an adult in wooded areas (Sands 1977).

The recolonization mechanism for other rainfed rice pests such as yellow stem borer *S. incertulas,* caseworm *Nymphula depunctalis,* whorl maggot *Hydrellia sasakii,* and leaf folder *Cnaphalocrocis medinalis* is not understood. Existing plant host records indicate that use of alternative hosts by these rice insects is not a viable carry-over mechanism. Most of the records describe annual weeds, which do not grow during the dry season. Even perennial weeds grow poorly in the dry season and do not support high rice insect populations.

However, with the onset of the rains, weeds and volunteer rice from seeds left in the soil from the previous crop year flourish. The same rains stimulate the white stem borer to terminate estivation and resume development. In Java, delayed planting of

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the rice crop has been used as cultural control of this insect (van der Goot 1948). Many species of annual grasses proliferate in fallow fields to act as hosts for many rice insects — *N. nigropictus,* zigzag leafhopper *Recilia dorsalis,* whitebacked planthopper, rice bug, and leaf folder.

The traditional practice for rice cultivation in Iloilo and Pangasinan is to transplant a photoperiod-sensitive tall rice variety in July after sufficient rains have fallen to allow soil puddling. Double rice cropping in these rainfed areas is an attractive practice, particularly if the first crop is dry-seeded in bunded paddies. The first crop requires less nitrogen fertilizer than a puddled rice crop, and the early planting date should result in less insect pest buildup.

In our discussion of dry seeding, it must be stressed that except for whorl maggot and caseworm, it is not the method of planting per se that affects insect pest incidence —it is environment and cropping patterns that produce the low insect pest pressure. A dry-seeded field surrounded by irrigated fields would be as attractive to colonizing insect pest populations as an irrigated field. We focus on the effects of a rainfed environment where dry-seeded bunded rice is planted as a first crop with the onsect of monsoonal rains. Trials in Iloilo and Pangasinan for 1977-79 have confirmed that dry-seeded rice does not have major insect pest problems.

INSECT PEST OCCURRENCE

Dry-seeded bunded rice can be attacked by soil pests such as ants, mole crickets, field crickets, rice root aphids, rice mealy bugs, etc., in the early vegetative stages. These pests exist in dryland environments but are normally controlled in wetland fields by flooding.

In our experience, however, the brief period that dry-seeded rice is nonflooded is not sufficient to allow the potential pests to become established. No dryland soil pests were encountered in dry-seeded fields in Pangasinan and Iloilo.

Two major rainfed wetland rice insects — whorl maggot and caseworm — have not been observed as pests on dry-seeded rice. Because dry-seeded rice begins as a dryland crop, the crop is not attractive to whorl maggot or caseworm.

In Pangasinan, only the leaf folder was observed to exceed the economic threshold (10% damaged leaves) in some fields (Table 1), and in only 1 of 3 years. The yellow stem borer is the dominant borer species.

In Iloilo, where the white stem borer is the dominant stem borer species, deadheart and whitehead counts surpassed economic thresholds (10% and 3%, respectively) for the vegetative and reproductive growth stages in 2 of 3 years in some fields. Leaf folder populations were above threshold levels in 1977, and the rice bug exceeded the 4 bugs/m^2 threshold in 1978. In 1979 when rice was seeded early (May) — closer to the rice-free fallow period — no insect exceeded economic thresholds.

For dry-seeded rice the white stem borer is of particular significance because it passes the dry season in rice stubble and becomes active with the same early rains that prompt farmers to start seeding rice.

Other stem borer species, such as yellow stem borer, come from areas outside, and early planting works against early crop colonization and establishment. In Pangasinan, for example, the yellow stem borer is not a pest of dry-seeded rice, but is a

Table 1. Insect pest occurrence on dry-seeded bunded rice (IR36) fields without insecticide in Pangasinan and Iloilo, Philippines, 1977-79.

Year	Month sown	Fields (no.)	Insect pests[a]			
			Stem borer[b] (%)		Leaf folder[c] (% damaged leaves)	Rice bug (no./m²)
			Dead-hearts 35-45 DE	White-heads	55-75 DE	
			Pangasinan			
1977	May	8	0.4 (0.1-0.2)	0.1 (0 -0.2)	15 (6-26)	1 (0 -2)
1978	May-Jun	6	1.4 (0.8-3.1)	0.4 (0 -1.6)	2 (0- 4)	0.2 (0 -0.3)
1979	May	6	3.2 (1.3-7.3)	0.5 (0 -2.9)	2 (1- 3)	0.4 (0.3-0.5)
			Iloilo			
1917	Jun	4	1.7 (0.2-3.2)	3.4 (2 -5.8)	13 (10-15)	1.3 (0 -3)
1978	Apr-Jun	6	4.6 (1.9-12.4)	2.1 (0.94)	2 (1- 2)	5 (1 -9)
1979	May	5	2.2 (1.2-3)	2.4 (0 -4)	1 (0- 5)	1.6 (1 -2)

[a]DE = days after crop emergence. Figures in parentheses indicate range. [b]5-m² plot. [c]100-leaf sample.

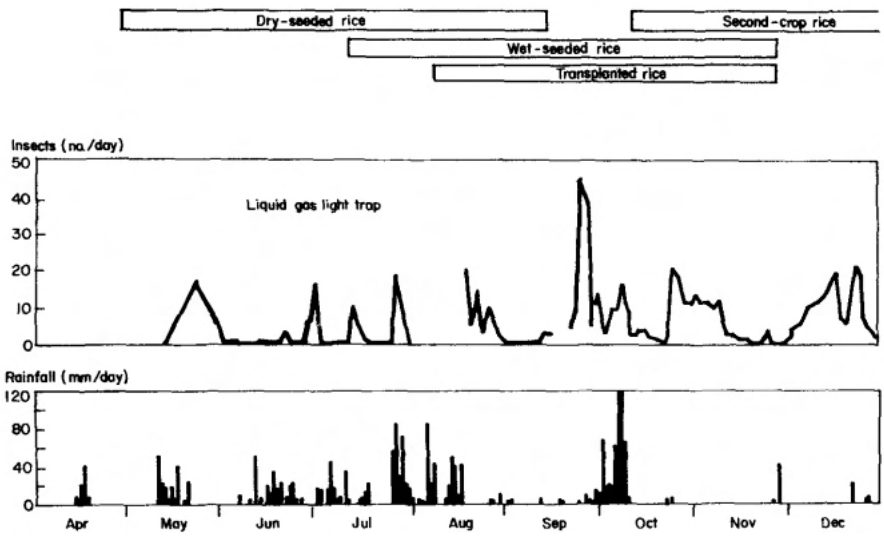
significant pest in later planting. The yellow stem borer overwinters at the base of rice stubble in temperate areas but we have seen no studies detailing its ability to estivate in the tropics.

White stem borer is abundant in Iloilo because of cultural practices. Cowpea is grown in rice fields at the end of the rainy season, normally with zero tillage. Seeds are broadcast into rice stubble, which remains undisturbed throughout the dry season in the cowpea crop. If the rice stubble were plowed under for cowpea establishment, the white stem borer would be adversely affected. But to be effective as a borer control, plowing would have to be done over a large area.

For dry-seeded rice early land preparation at the end of the previous year's crop should reduce white stem borer numbers. However, this is difficult to achieve because soils are usually too hard for tillage with animal power. The effect of land preparation at the beginning of the monsoonal rains on estivating white stem borers is unknown.

In Iloilo white stem borer populations are relatively low after they terminate estivation at the onset of the rainy season. A liquid gas-powered light trap registered an initial flight in late May in response to either mid-April or mid-May rains (Fig. 1).

There were few insects in the initial flight of the white stem borer, meaning that mortality over the dry season was high. The first flight was during the early vegetative stage of dry-seeded rice; subsequent flights during the reproductive stage were also low. The small peaks (Fig. 1) were reflected in low deadheart and whitehead incidence in the 1979 crop (Table 1). A major peak occurred after dry-seeded rice was harvested.



1. Seasonal abundance of the white stem borer *Scirpophaga innotata* recorded by liquid and kerosene gas light traps. Stem borer numbers, plotted as 3-point daily moving averages, are set against cropping pattern and daily rainfall. Oton, Iloilo, Philippines, 1979.

The white stem borer, however, should be regarded as a potential threat to dry-seeded rice because late plantings (June) have had high deadheart and white-head incidence. Most farmers planted a single-crop wet-seeded rice, and a high population peak was seen on this crop (Fig. 1). Drought in 1979 afffected the second-crop rice and it did not have high numbers of stem borers.

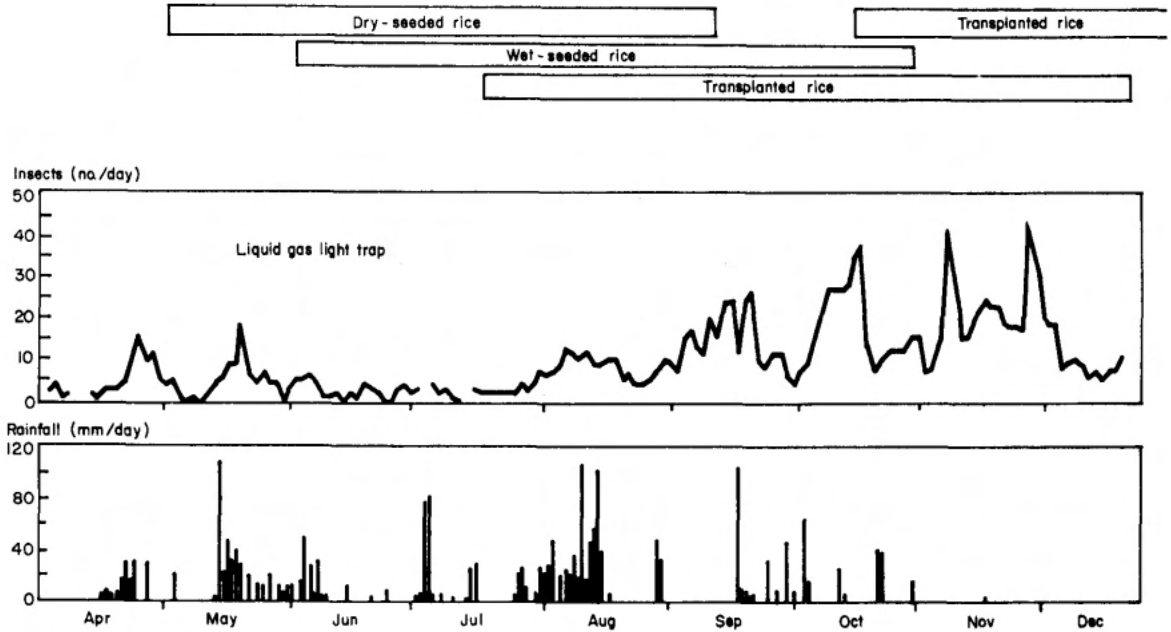
In Pangasinan the yellow stem borer also had flight peaks recorded by a liquid gas light trap during the early monsoonal season, but did not increase on dry-seeded rice (Fig. 2). The major peaks associated with population buildup occurred at the end of the rainy season.

Other rice pests were monitored in the light traps at both sites. Leaf folder and caseworm were low. Rice hoppers had periods of activity during dry-seeded rice although their numbers were low. Green leafhopper was the most abundant hopper species encountered.

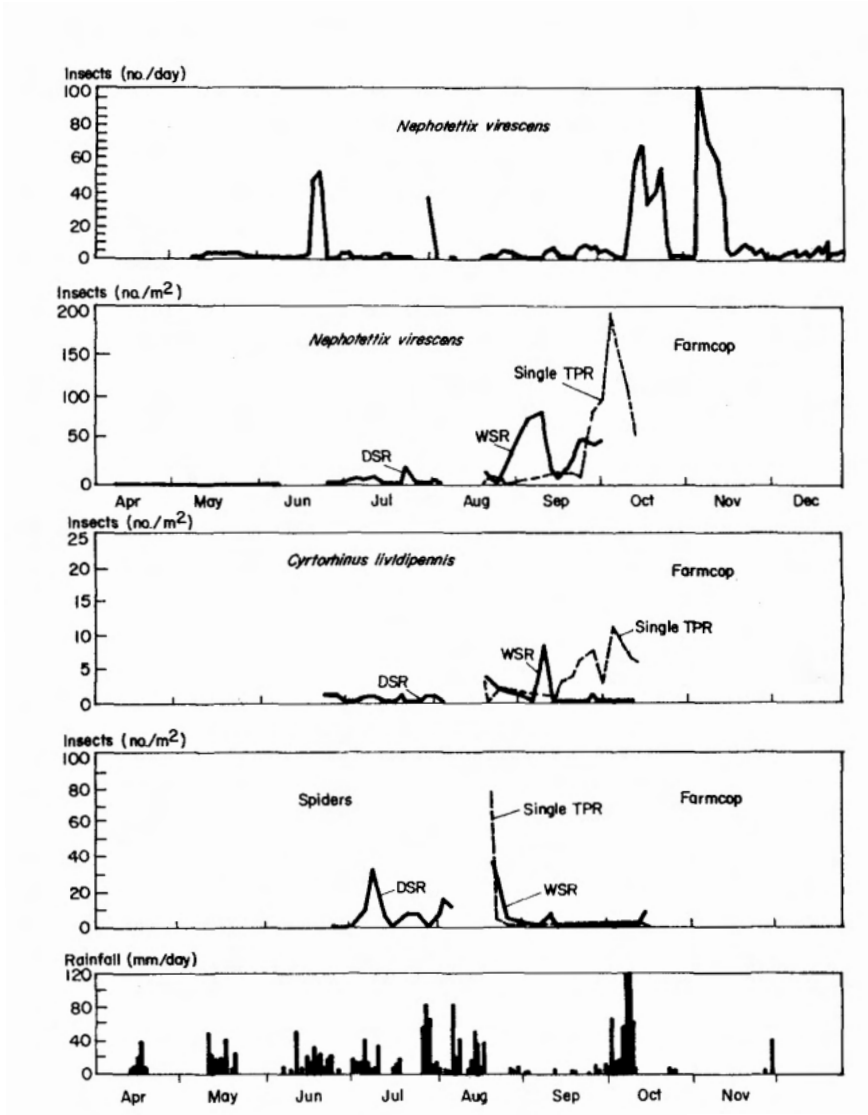
Hopper numbers recorded in light traps were correlated with field populations monitored by the Farmcop suction sampler (Cariño et al 1979). Twenty samples per field from two to three fields per sampling date were taken from plots (IR36) receiving no insecticide.

Green leafhopper field populations were low in dry-seeded rice in Iloilo. Two peak flights occurred (Fig. 3), but the actual numbers were relatively small—less than 700 per night. In times of green leafhopper infestations, thousands can be caught in a single night.

Pangasinan had high influxes of green leafhoppers during the dry-seeded rice crop. The number exceeded 1,000 insects/ night, but the field populations were low (Fig. 4). Higher field populations were found in wet-seeded rice after the recorded flight periods; they were, however, not sustained, even though rainfall was favorable.



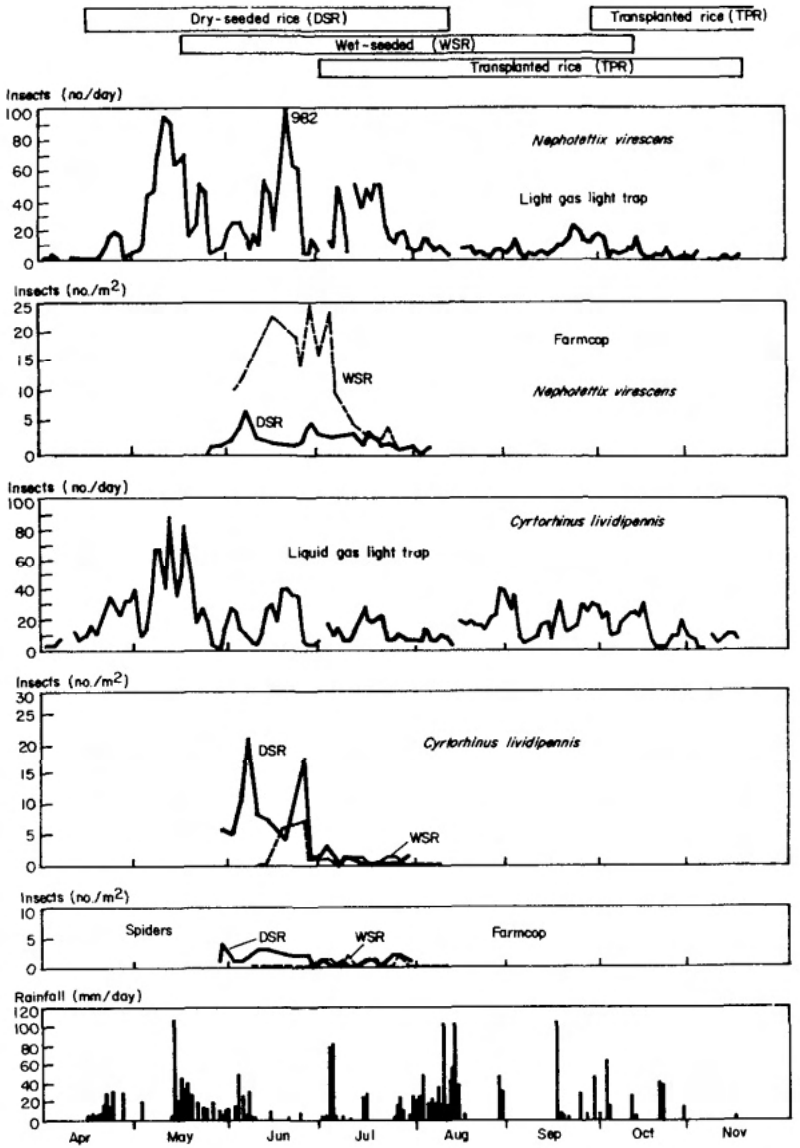
2. Seasonal abundance of the yellow stem borer *Scirpophaga Incertulas* recorded by a light trap. Stem borer numbers, plotted as a 3-point dally moving average, are set against cropping pattern and rainfall pattern. Pao, Manaoag, Pangasinan, Philippines, 1979.



3. Seasonal abundance of green leafhopper *Nephotettix virescens* recorded by a light trap (plotted as a 3-point moving average), and Farmcop field sampling set against natural enemies (*Cyrtorhinus* bug and spider predators), cropping pattern, and daily rainfall. Iloilo, Philippines, 1979. DSR = dry-seeded rice, TPR = transplanted rice, WSR = wet-seeded rice.

NATURAL ENEMIES OF RICE PESTS

The natural enemies of rice insect pests are subjected to the same stresses as the pests in rainfed wetland rice fields and must recolonize the fields each year. There is little available information on how natural enemies accomplish this.



4. Seasonal abundance of green leafhopper *Nephotettix virescens* recorded by light trap (plotted as a 3-point moving average), and Farmcop field sampling set against natural enemies (*Cyrtohinus* bug and spider predators), cropping pattern and daily rainfall. Pangasinan, Philippines, 1979.

We collected data on some natural enemies from dry-seeded rice from the 1979-80 crop year in Pangasinan and Iloilo. Spider and mirid bug predator *Cyrtorhinus lividipennis* were monitored in insecticide-free plots with the Farmcop suction sampler.

The most common spiders, in order of abundance were: *Callitrichia formosana* (Micryphantidae), *Oxyopes javanus* (Oxyopidae), *Tetragnatha japonica,* and *T. javana* (Tetragnathidae), and *Lycosa pseudoannulata* (Lycosidae).

In Iloilo, the spiders were more abundant than the green leafhopper on dry-seeded rice (Fig. 3). Spider population peaks matched those of the brown and whitebacked planthoppers, and must have played a role in suppressing the pests' numbers. Spiders readily colonized dry-seeded rice fields. In fact, spiders in Iloilo were more abundant in dry-seeded rice than the hoppers in wet-seeded and single transplanted crops.

In Pangasinan, however, spider populations were very low in dry-seeded rice and in the succeeding rice crops, despite the presence of hoppers in greater numbers than in Iloilo (Fig. 4).

Cyrtorhinus, on the other hand, was much more prevalent in Pangasinan. Flights of *Cyrtorhinus* occurred at the same time as invading hoppers (Fig. 4). Field populations and numbers of *Cyrtorhinus* coincide with the peak periods of rice hoppers. *Cyrtorhinus* was more abundant on dry-seeded rice than on wet-seeded rice.

Egg parasites of the brown and whitebacked planthoppers and green leafhoppers were monitored on dry-seeded rice in Pangasinan in 1979 using Otake's egg exposure method (Otake et a1 1976). The major egg parasites were mymarids — *Gonatocerus* sp. for green leafhopper and *Anagrus flaveolus* for brown and whitebacked planthoppers. The egg parasites were as prevalent in dry-seeded rice as in the succeeding transplanted rice crops (Fig. 5). They were initially low in dry-seeded rice, but they multiplied rapidly. Overall parasitization was quite constant irrespective of parasite species, host, or crop, and averaged 11-13% on dry-seeded rice compared to 13-14% for all crops.

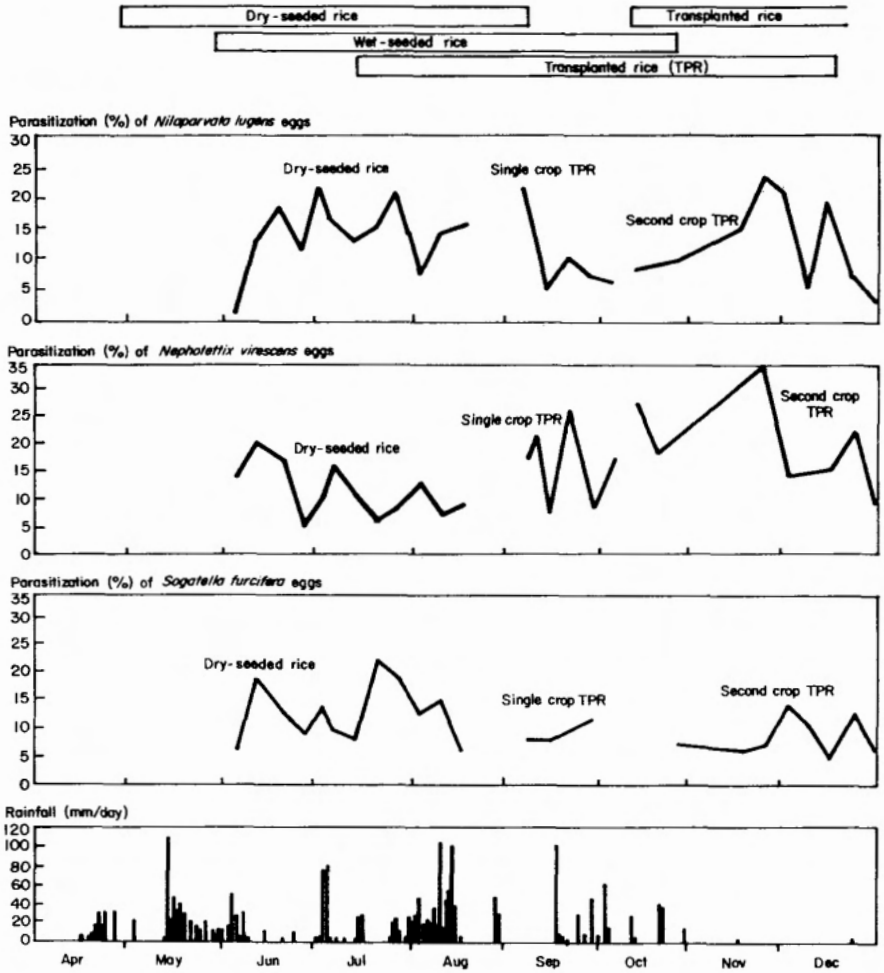
Parasite and predator activity in dry-seeded rice, and indeed in the rainfed wetland environments studied, was much lower than what has been recorded for irrigated rice (IRRI 1979, Kenmore 1979). *Microvelia,* a major predator, was not detected by sampling, perhaps because of fluctuating paddy water level typical of rainfed wetland fields. But it was observed in rice fields in Iloilo and Pangasinan.

The low natural enemy numbers are believed to be more a reflection of low insect pest numbers in rainfed wetland fields than of the natural enemies' ability to colonize harsh environments.

YIELD RESPONSE TO INSECTICIDE

Chemical control trials in 1977-79 on dry-seeded rice in Iloilo and Pangasinan determined yield losses from insect pests and evaluated the need for chemical insect control.

Each year chemical control trials were replicated across 4-8 farmers' fields. Each trial included a complete protection plot with broad-spectrum insecticides applied at



5. Seasonal parasitization of brown and whitebacked planthopper and green leafhopper eggs shown by Otake's egg exposure technique, set against cropping Pattern and daily rainfall. Pangasinan, Philippines, 1979.

high dosages and frequencies at the vegetative, reproductive, and ripening stages.

Carbofuran granules mixed with fertilizer were applied in the seed furrows at planting, monocrotophos sprays protected the reproductive stages, and either monocrotophos, endosulfan, or carbaryl sprays were applied during the ripening stage. The purpose of the treatments was to eliminate insect pests as much as possible. Loss from insect pest was then measured as the yield difference between the completely protected and unprotected plots.

A high dosage of carbofuran (1.5 kg a.i./ ha) was used in 1977 but was reduced each succeeding year to make insecticide usage more economical to farmers.

In 1977 yield differences of 0.89 and 1.47 t/ ha in Pangasinan and Iloilo were

Table 2. Yield responses to insecticides on dry-seeded rice (IR36) in Pangasinan and Iloilo, Philippines, 1977-79.

Year	Month sown	Fields (no.)	Yield[a] (t/ha)		
			Complete control[b]	Carbofuran only[c]	Untreated
			Pangasinan		
1977	May	8	6.36 a	6.22 a	5.47 b
1978	May-Jun	6	3.40 a	3.57 a	3.58 a
1979	May	6	4.36 a	4.40 a	4.09 a
			Iloilo		
1977	Jun	4	5.35 a	5.51 a	3.88 b
1978	Apr-Jun	6	4.96 a	5.02 a	3.99 b
1979	May	5	3.60 a	3.99 a	4.03 a

[a]In a row, means followed by a common letter are not significantly different ($P \leq 0.05$). [b]Carbofuran G was applied basally in seed furrow (0.5-1.5 kg a.i./ha) and broad-spectrum foliar sprays at the reproductive and ripening stages. [c]Applied in the seed furrow at the rate of 1.5 (1977), 1 (1978), and 0.5 (1979) kg a.i./ha. No foliar sprays.

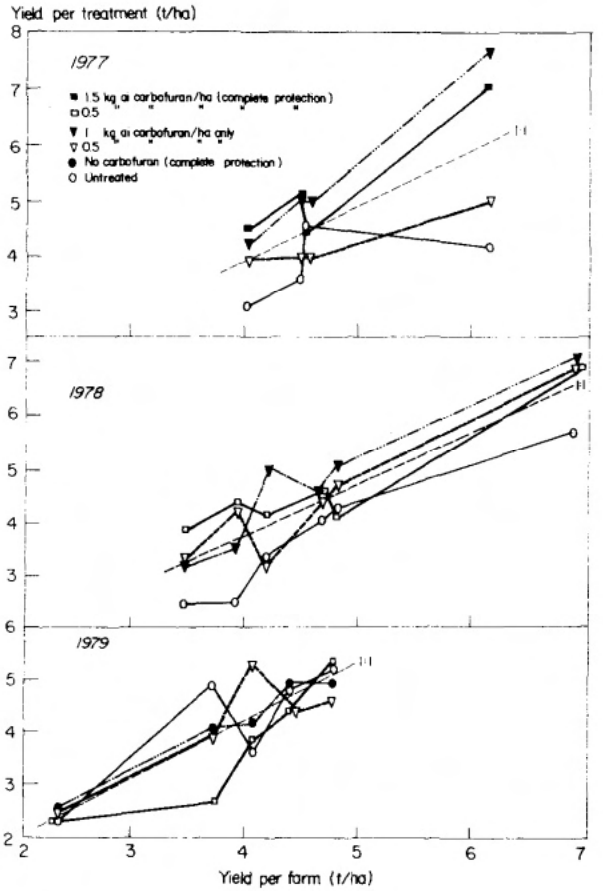
recorded (Table 2), in the apparent absence of high insect pest populations. The yield difference occurred only during the vegetative stage. Sprays during the reproductive and ripening stages (complete protection) did not significantly increase yields (Fig. 6, 7). Soil insects might have caused the yield differences because not all fields responded equally.

In 1978 we repeated the experiment and searched the fields intensively for possible soil pests. None were found in Iloilo, but a 0.92 t/ha yield difference was observed in the carbofuran plot. Plots protected with diazinon or γ-BHC granules (1 kg a.i./ha), both well-known soil insecticides, did not show yield increases. In Pangasinan, however, the average yield difference in the treatment using 1 kg a.i. carbofuran/ha was negligible. Some fields, however, indicated a positive response over untreated plots (Fig. 7).

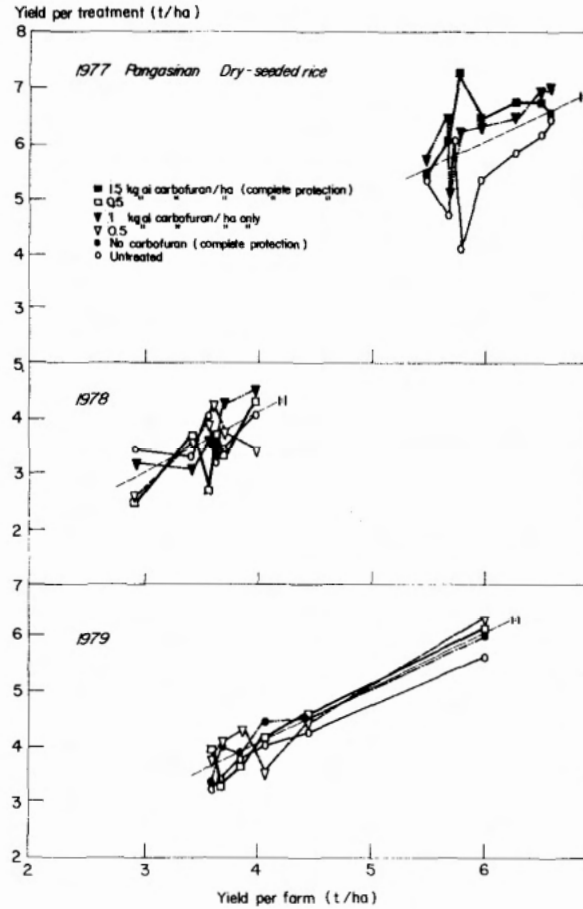
Our 1979 trials at both sites had no yield difference with 0.5 kg a.i. carbofuran/ha. Aldicarb or diazinon granules (1 kg a.i./ha) gave yields identical to those of the untreated control.

Because carbofuran might be directly stimulating the growth of rice, a greenhouse trial using heat-sterilized soil (120° C for 20 minutes) to eliminate living organisms was planted. Carbofuran 2 F was applied as a seed treatment (10 g a.i./kg seed) to IR36 rice seeds. The results confirmed that carbofuran directly affects the growth of rice (Table 3). Carbofuran significantly increased plant height, root weight, tiller number, percentage of productive tillers, grain weight, and 100-seed weight as well as induced maturity 7 days earlier than in the untreated check.

Studies where carbofuran has been used to measure yield reduction from rice insects need to be re-evaluated in the light of this finding. Yield promotion evidently is more pronounced if rice is under stress, particularly from drought. This effect is particularly pronounced on dry-seeded rice and high yield responses have occurred on dryland rice elsewhere in the Philippines (Litsinger, this volume). Additional research is needed to better define the dosage-response function and the environ-



6. Farm-to-farm comparison of the effect of carbofuran on the yield of dry-seeded rice (IR36) over a 3-year period. Iloilo, Philippines, 1971-79.



7. Farm-to-farm comparison of the effect of carbofuran on the yield of dry-seeded rice (IR36) over a 3-year period. Pangasinan, Philippines, 1977-79.

Table 3. Effect of carbofuran on the growth characteristics of rice.[a] IRRl greenhouse, 1979.

Insecticide	Germination (%)	Seedling ht (cm) 80 DE	Seedling root wt (mg) 21 DE	Tillers (no.)	Productive tillers (no.)	Days to flowering	Grain wt (g)	100-seed wt (g)
Carbofuran 2 F[b]	90 a	101 a	9.9 a	17.3 a	57.9 a	76 a	8.3 a	1.7 a
Untreated check	100 a	87 b	4.5 b	11.2 b	35.9 b	83 b	4.2 b	1.2 b

[a]Av of 4 replications. DE = days after emergence of IR36 seeds. In a column, means followed by a common letter are not significantly different ($P < 0.05$). [b]10 g a.i./kg seed. F = flowable.

mental or cultural factors that gave the observed high field-to-field and year-to-year variability.

We conclude that insect pest problems in rainfed dry-seeded bunded rice planted after a rice-free dry fallow are minimal if an early-maturing variety such as IR36 is grown. The crop matures before pest populations build up to damaging levels. A high spatial and temporal variability in the growth response from carbofuran granules applied in seed furrows occurred. Therefore, it would be uneconomical to recommend prophylactic insecticide applications on this crop.

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DISCUSSION

Alam: We have heard that the white stem borer *Tryporyza innotata* is a major rice pest in Australia. May 1 know your comment on its distribution in these regions and its status as a rice pest in the Philippines.

Litsinger: The white stem borer isdistributed widely in tropical Asia, including Australia, in areas with distinct dry season. In the Philippines and Asia it is the dominant stem borer species in rainfed wetland environments where the rice stubble is left undisturbed during the dry season crop. When irrigation systems are developed to allow a dry season crop, the white stem borer is replaced by the yellow stem borer. Evidently the yellow stem borer is more competitive than the white stem borer, perhaps because of its greater dispersal abilities once allowed to multiply year-round. It is also possible that the two species are not reproductively isolated, but in fact are subspecies and the white form is expressed if the only way to survive the dry season is through aestivation. However, if aestivation is not necessary for the population to survive, the yellow form becomes dominant.

Manwan: In certain conditions the white stem borer may not necessarily aestivate. In South Sulawesi it is found on both wet and dry season crops. It is also true that in areas where there is only one rice crop a year, the insect aestivates during the dry season. Work in South Sulawesi showed that about 90% of the larvae would have been killed if we changed the method of harvest from panicle harvesting to cutting off the rice stubble about 10 cm above the ground. In certain areas where this new method has been practiced, the stem borer population was reduced significantly.

Khan: Referring to your studies on carbofuran at different dosages in different years, I do not find the logic behind this when one could use 3 treatments in a single year repeated, if necessary, over 3 years.

Litsinger: In retrospect you are right. Now that we realize carbofuran directly affects rice yields, perhaps there are two ranges of dosages involved when using an insecticide such as carbofuran:

- minimum effective dosage that provides adequate insect control, and
- minimum effective dosage that stimulates a yield response.

Because our objective was to develop the minimum effective dosage to control insects, we reduced the original level of 1.5 kg a.i./ ha to 1 kg a. i. ha based on experiences with broadcast and soil incorporation of carbofuran in transplanted rice. We further reduced the dosage of 0.5 kg a.i./ha because it was banded in the seed furrow, thus concentrating the insecticide in the root zone. Apparently the minimum effective dosage to produce direct growth stimulation is higher than that to provide insect control. However, we also believe that the growth stimulation effect is conditioned by environmental factors and we are looking at the moisture status of the field during the vegetative growth stage of rice as a possible explanation.

Khan: It appears that the harmful insect population was effectively checked by the higher natural enemy population. Have you considered the danger or loss to DSR should the enemy population decline or does not build up for some reason? The predators definitely play an important role. How would one “ensure” a good predator population?

Litsinger: Insect pest numbers are checked by three factors in DSR: 1) host-plant resistance, 2) cultural control (early planting to escape insect pest buildup), and 3) natural enemies. Fortunately the natural enemies are able to establish their numbers quickly in DSR but you are right when you said their effect could be severely suppressed if insecticide was frequently used. Fortunately, we do not expect a need for repeated insecticide applications, because of host-plant resistance and cultural control. These are the benefits derived from applying integrated pest management techniques.

Economics of dry-seeded rice in Sri Lanka

N. F. C. Ranaweera

Present estimates indicate that in Sri Lanka nearly 80,000 ha is planted to dry-seeded rice in the Manawari areas of the dry zone and the intermediate zones of Kurunegala, Badulla, and Moneragala. Table 1 gives an estimate of the areas under cultivation.

Although dry-seeded rice (DSR) is most common in the dry zone and intermediate zones, it is planted on about 18,000 ha in the wet-zone areas, particularly in Kurunegala district. In the wet-zone areas only long-duration, photoperiod-sensitive (6 months) varieties are used.

One major problem in the assessment of the economics of DSR is lack of adequate data. Even though the economic problem in the Manawari areas has existed for a number of years, less attention had been given to it than to rice grown under other conditions. This is probably due to the relative importance of irrigated crop research during the last decade or more. This presentation, therefore, suggests the direction that future research can take.

Jayasuriya and Price (1979) indicate that the problems associated with DSR result in a diminishing of its economic attractiveness to farmers. They identify the following problems as being the most important:

- severe weed problems,
- uneven germination,
- initial stunting and slow growth, and
- failure of crops due to long dry periods.

Table 1. Extent of rainfed dry-seeded rice in Sri Lanka.

District	Area (ha) under dry-seeded rice			
	1975	1976	1977	1978
Vavuniya	10,373	23,312	12,701	12,306
Batticaloa	28,421	31,428	31,883	30,975
Amparai	13,524	13,522	14,358	13,913
Kurunegala	30,264	30,091	30,679	30,072
Total	82,582	98,353	89,621	87,266

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In Sri Lanka, those problems have also been identified. In theory it is possible to overcome most of them by providing certain technological changes. However, it has still not been established whether the problems can be overcome in an economically justifiable manner.

The problems that pertain to Sri Lanka are briefly discussed in the following sections.

WEED CONTROL

At present the most serious problem of DSR in Sri Lanka is weeds. One way of eliminating the problem is by row seeding; however, Sri Lanka has no effective row seeders (hand operated) that can efficiently do the job. The other alternative of manual row seeding is also impracticable because of the holding sizes (about 2 ha in the Manawari area). The obvious alternative left is chemical weed control, but its economic attractiveness is low.

UNEVEN GERMINATION

Uneven germination has been identified as another major problem in DSR. In Sri Lanka at present, seeding of DSR uses about 200 kg seed/ha. Even at this high seeding rate, uneven germination still occurs.

STUNTING AND SLOW GROWTH

Because of lack of adequate research on DSR, fertilizer recommendations are not as specific as those for wet-seeded rice or transplanted rice. Fertilizer use in the DSR areas is low and contributes to stunting and slow growth of the crop. Agronomists also indicate that farmers do not use much fertilizer because they believe that it promotes weed growth. Stunting, retarded growth. and crop failure due to long periods of drought are also common. The varieties used by farmers in DSR areas in Sri Lanka are relatively low yielding. The most common variety is 62-355, which covers nearly 60% of the total area. There is, however, a large area planted to improved varieties such as BG34–8, BG94–1, and BG34-6 which are presently popular in Sri Lanka (Table 2). Nevertheless, the yield levels in all the DSR areas are about the same. This is due to two reasons:

Table 2. Areas under improved varieties in Sri Lanka.[a]

District	Area (ha)					
	1975		1976		1977	
	Maha	Yala	Maha	Yala	Maha	Yala
Vavuniya	17,315	195	32,482	572	18,915	1,314
Batticaloa	35,346	6,428	32,161	7,263	40,183	6,189
Amparai	33,951	46,068	94,291	60,832	99,670	32,529
Kurunegala	9,016	31,900	42,210	26,802	59,591	41,420
Total	95,628	84,591	205,144	95,469	218,459	81,452

[a]Source: Department of Census and Statistics.

- The variety 62-355 has *non optimal* qualities — such as lodging and too much vegetative growth, etc. — which puts its potential in farmers' fields at around 2 t/ha.
- The more improved varieties yield about the same as 62-335 because of the relatively low input use for them under DSR conditions.

In a discussion of the economics of planting, DSR cannot be compared with either wet-seeded rice or transplanted rice. DSR is environment specific and, hence, the main problem is the question of risk. Agriculture of any form is risky business, therefore, it is necessary to figure out the relative riskiness of DSR. The data used here are from district averages that are available in the Department of Agriculture.

In Anuradhapura district (Table 3), the average cost of cultivating a hectare of irrigated paddy is around $207 (including family labor costs). The average yield is 3.75 t / ha. At present prices of $0.12/ kg, total income is $465/ ha, giving a net profit of $258/ ha per season. In terms of profitability per unit of paddy, the cost of production is $0.06/ kg, giving a profit of $0.07/ kg.

Under DSR conditions the figures from Vavuniya district provide a different picture (Table 4). The total cost of production amounts to $182/ha for a yield of only 2.08 t/ ha. The cost per kilogram is $0.09, thus giving a profit of only $0.03/ kg. Land preparation was with buffaloes. If tractors were used, the profits would have been 1ower. This roughly indicates the relative profitability of the two systems.

The question then can be asked: Does DSR serve any purpose and, if so, where can it be applied? In my opinion, assuming that the answer is yes, this can be approached from two angles.

First, DSR does have an important role in the dry zone of Sri Lanka if it is used with the minor tank system. Under these conditions, DSR can be planted with the onset of the first rains; near the end of the season, the tanks can provide supplementary irrigation. As has already been illustrated in earlier cropping systems meetings, the research at Walagambahuwa indicated that DSR can be adopted. Adoption in Kurunegala district is in fact significant. However, it is under the very specific

Table 3. Cost of cultivating 1 ha of irrigated paddy in Anuradhapura district, Sri Lanka.

Operation	Labor		Tractors		Material input cost ($)	Total cost ($)
	Days (no.)	Cost ($)	Hours (no.)	Cost ($)		
Plowing[a]			6.45	28.69		28.69
Pulverizing and leveling with mamoty	24.11	33.29				33.29
Broadcasting[b]	8.65	9.22			18.13	21.35
Application of fertilizer						
Basal[c]					18.25	18.25
Topdressed	8.65	6.12			18.99	25.71
Chemical weeding	1.41	5.14			5.56	11.30
Harvesting and processing	45.47	43.65	1.16	18.25		61.90
Total	94.89	98.62	14.21	46.94	60.93	206.49
Family labor	29.40	30.22				30.22
Total excluding family labor	65.49	68.40		46.94	60.93	116.21

[a] With 4-wheel tractors. [b] Includes final manual leveling. [c] Labor for application is included in labor for land preparation.

Table 4. Cost of cultivating 1 ha of rainfed paddy in Vavuniya district, Sri Lanka.

Operation	Draft power and machinery							Material input cost ($)	Total cost ($)
	Labor		Buffaloes		Tractor		Sprayer cost ($)		
	Days (no.)	Cost ($)	Hours (no.)	Cost ($)	Hours (no.)	Cost ($)			
Plowing with buffaloes	4.45	2.81	80.33	13.80					15.13
Pulverizing and leveling with mamoty	29.16	18.68							18.68
Broadcasting [a]	8.15	7.70						15.38	23.08
Application of fertilizer									
Basal [b]								14.10	14.10
Topdressed	3.21	2.93						23.08	26.01
Manual weeding	16.56	11.23							11.23
Chemical weeding	2.47	1.71						10.68	12.39
Application of insecticides	2.72	2.01					4.21	7.51	13.79
Harvesting and processing	60.79	37.24			21.7	12.58			49.82
Total	127.51	84.37	80.33	13.80	21.7	12.58	4.27	70.75	184.23
Family labor	34.35	22.59							
Total excluding family labor	93.16	61.78		12.26		12.58	4.27	70.75	161.64

[a] Includes final manual leveling. [b] Labor for application is included in labor for land preparation.

condition of supplementary irrigation availability.

Second, the system can be further developed if a technology that can be given to the farmers exists. The technology can be varieties, better cultural practices, or machines with which to row-weed.

Unfortunately, neither is being done to any great depth in Sri Lanka at present, which I feel is primarily due to the emphasis on irrigated rice research.

CONCLUSION

It is not possible to give any definite conclusion on the profitability of DSR as such. What can be said, though, is that with the present technology, DSR cannot be considered an economic practice. The risks involved are higher than those associated with other cultivation practices, because of the uncertainty that the environment has built into the cultivation of the crop. It would be difficult to convince farmers to use high input levels, with the present varieties they have.

There will be some hope if better varieties and cultural practices can be developed. The only way out at present is to include it in the cropping program of farmers who have facilities for supplementary irrigation.

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DISCUSSION

Morris: At what time during the DSR crop period is supplementary water applied in the Kurunegala district'?

Ranaweera: Supplementary irrigation is provided during the later stage of crop maturity. Dry seeding of rice is done just before the rains and later, when rainfall fails, supplementary irrigation is provided. This is possible *only* in situations where there is adequate water.

Zandstra: Although weed occurrence is considered a major problem in DSR, farmers do not appear to be spending much on weed control. Why is this so?

Ranaweera: This is primarily due to the high cost of weed control in Sri Lanka.

CROPPING PATTERN TESTING

Cropping systems research in Indonesia

Suryatna Effendi, Inu G. Ismail, and J. L. McIntosh

The Indonesian government's goal is a 4.6% annual crop production in the second 5-year plan (Repelita II). Of the 6.7 million hectares of wetland rice now harvested. 4.1 million hectares received some irrigation. About 94.4% of rice production comes from this wetland rice area, but only 12% of the 55 million hectares is considered suitable for cultivation.

Because the areas suitable for expansion of irrigated and rainfed wetland rice are limited, the best way to increase food production in them is by increasing cropping intensity. Based on 4 years of cropping systems research in several irrigation categories. good potential exists for increasing food production by using early-maturing rice varieties with high yield potential and making a fast turnaround time to enable the planting of a second early-maturing crop. This can also be true for a third crop planted immediately after the second crop is harvested.

Another major way to increase food production is by extensification in the upland areas, particularly in the outer islands. which are not yet subject to the high population pressures. To date little effect has been expended in solving the many problems attending upland cultivation — low fertility, drought, problem soils, plant pests, etc. — and a sustained research effort to address these problems is necessary. Through research, a new technology should be developed for opening this new land and changing the slash-and-burn agriculture into permanent agriculture. Central Research Institute for Agriculture (CRIA) research in Lampung had indicated good management practices can convert impoverished red-yellow Podzolic soils under *Imperata cylindrica* to land for productive agriculture.

CROPPING SYSTEMS RESEARCH AND IMPLEMENTATION

Indonesia selected two target areas for intensive research in 1973. One site was in Indramayu, West Java; the other in Bandarjaya, Central Lampung. The objective was to identify and remove on-farm constraints to more intensive cropping patterns in the two areas. Poor water control and heavy clay soils characterized the Indramayu location. Low soil fertility and pH and infestation of the land with *I. cylindrica*

Croppings systems agronomists. Central Research Institute for Agriculture (CRIA), and cropping systems agronomist, Cooperative CRIA-IRRI project, Bogor, Indonesia

characterized the Lampung location.

This research was completed in 1977. The cropping systems research sites were expanded to 6 in 1978 and to 13 sites by 1980, covering irrigated, upland, and tidal swamp areas.

Selection of target areas

Cropping systems research results are valueless until implemented. The research must fit within the framework of government plans and meet policy and developmental needs. Consequently, areas for research must be carefully selected. Criteria for selecting areas for cropping systems research are:

- characterization as critical areas in terms of food shortages and governmental designation;
- large area with similar soil and climate;
- an indication of the feasibility of intensifying cropping patterns based on prior evidence; and
- availability of markets and infrastructures.

The order of priority will depend upon the extent of government participation in food production activities.

The overall objectives of Indonesia's cropping systems research program are summarized as follows:

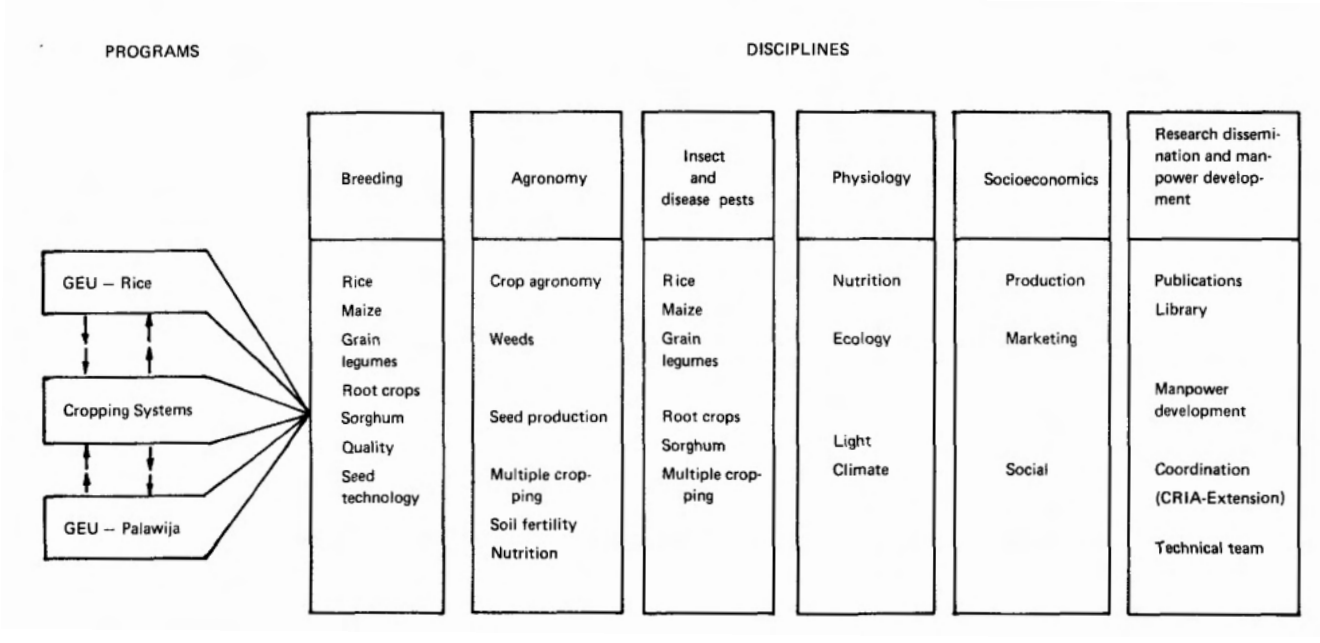
1. Increased food production by increasing total area in crops and production per hectare through
   - development of viable cropping systems for new lands;
   - more intensive use of present cropland including interplanting food crops with estate crops such as rubber, coconut, sugar, coffee, etc; and
   - amending and maintaining soil fertility.
2. Increased employment opportunity by increasing the opportunity for labor through
   - spreading out time for planting and harvest;
   - expanding of total area in production; and
   - concomitant increase in agribusiness activity.
3. Improved small farmers' bargaining position by increasing the frequency of harvests and minimizing the need to borrow (which may include items other than money).
4. Facilitation of institutional interaction and implementation of research findings.

These objectives may appear idealistic and unattainable, but, the Indonesian cropping systems program has gradually evolved a systematic plan of work for this kind of research in selected areas. The systematic program outlined in Table 1 is based on experience within the Indonesian context. Figure 1 shows how the cropping systems program fits into the CRIA system in Bogor. The program consists of a coordinated working group of scientists from the various disciplines involved in the program. The core staff emanates from the Multiple Cropping Section of the Agronomy Division. Figure 2 shows the research sites presently under study, those recently completed, and those soon to be started.

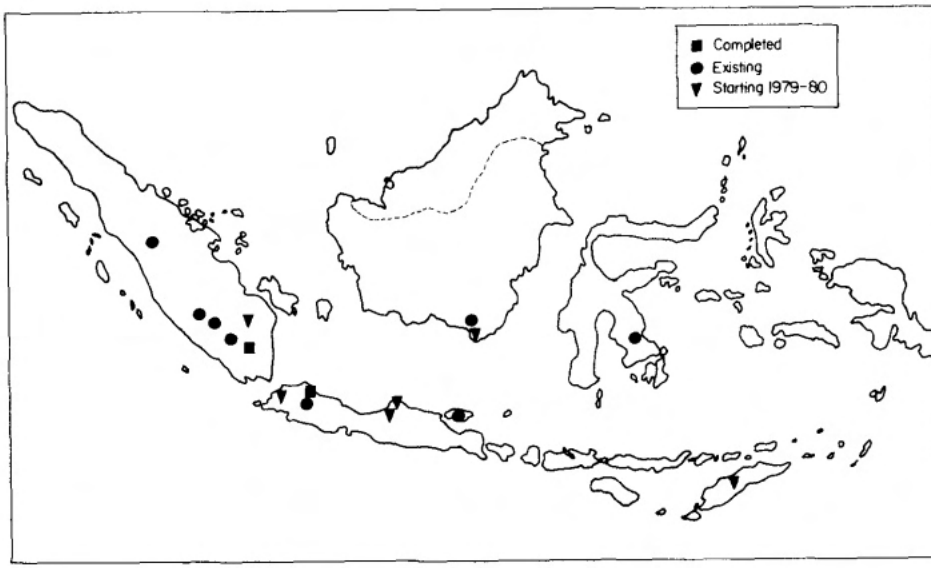
Table 1. Cropping systems research and development for selected areas. Central Research Institute for Agriculture, Bogor, Indonesia.

Component	Phase I	Phase II	Phase III[a]	Phase IV	Phase V
Activity	Site selection and description	Biological feasibility and evaluation	Design and testing of cropping patterns	Reproduction testing	Implementation
	I. Physical A. Soil taxonomy B. Rainfall distribution C. Irrigation D. Other climatic data	I. Sequential testing on small plots A. Varieties B. Fertilizer response C. Crop combinations D. Other component technology	I. Partition of target area A. Water availability B. Soil capability C. Market accessibility	I. Research-managed plots on 34 ha A. Increase visibility and demonstrate potential	I. BIMAS type program cropping patterns not commodities.
	II. Economic A. Agroeconomic profile	II. Economic - farm recording A. Income B. Labor C. Market price	II. Pattern design A. Farmers' - monitor only B. Farmers' - optimum mgt. C. ICP - low input D. ICP - optimum mgt.	II. Desa level A. Identify biological and institutional constraints to large scale Production	
		III. Problem focused surveys	III. Testing - 1000-m^2 plots[b]		
Methodology	Data collection and survey	Secondary data and small plots	Agroeconomic evaluation in farmers' fields	Field level evaluation	Production program
Responsibility	Research and extension	Research	Research	All relevant agencies	All agencies
Time frame	Initial	Year 1-2	Year 1-3	Year 3-5	

[a]In phase III and succeeding phases, all planning must be coordinated by the BAPPEDA. [b]Standardized data collection, data handling, data processing, and reporting.



1. Central Research Institute for Agriculture functional framework.



2. Cropping systems outreach sites, Indonesia, 1979.

Site selection and description

Site selection and description are done as soon as possible after the target area has been selected. Most of the data can be collected from secondary sources. The survey and data collection teams should be interdisciplinary groups of scientists and extension workers.

CROPPING SYSTEMS RESEARCH HIGHLIGHTS IN TARGET AREAS

Irrigated areas

There will be no problem producing good rice crops in areas with more than 9 months of irrigation with the use of late-maturing varieties with some degree of resistance to brown planthopper. But the goal is for at least two good crops of rice with an added yield a grain legume crop by using early-maturing rice varieties with a high yield potential.

Research results for 1977-78 showed that IR36 followed by IR36 produced average yield of 6.8/ha and 5.7/ha within 240 days for the first and second rice crops. Furthermore, there was sufficient time and water for a soybean crop after either one or two rice crops. From the areas of 10, 7, or 5 months irrigation per year together with the existing rainfall, a double crop of rice and one crop of grain legume can be grown for each irrigation category, as shown in Table 2. If this technology can be implemented, food production on irrigated areas can be easily increased by intensifying the existing cropping intensity.

Upland rainfed areas

Vast areas — about 70 to 80% of the total arable land in lndonesia — are upland rainfed. The current farming practices continue largely unchanged from the old

Table 2. Yield of an improved cropping pattern of rice, soybean, and cowpea, in areas with 10, 7, and 5 months irrigation. Indramayu, Indonesia, 1976-78.

Cropping pattern	Yield (t/ha) in areas with irrigation for		
	10 months	7 months	5 months
1. Transplanted rice -	5.5 (IR34)	5.9 (IR28)	4.7 (IR28)
wetland rice -	5.4 (IR26)	4.3 (IR30)	5.0 (IR30)
grain legume	0.5 (cowpea)	0.9 (soybean)	0.6 (cowpea)
2. Transplanted rice -	6.3 (IR28)		
wetland rice -	4.3 (IR30)		
wetland rice	4.8 (IR28)		
3. Transplanted rice -		6.0 (IR28)	
wetland rice -		4.7 (IR34)	
grain legume		0.7 (cowpea)	
4. Direct-seeded rice -			5.1 (IR26)
transplanted rice -			5.1 (IR30)
grain legume			0.6 (cowpea)

traditional ways because the modern crop varieties and farming technology do not meet the needs of the nonirrigated areas.

Research results indicate that soils in the project sites are highly productive if managed properly. Even with complete rainfall dependence, it is still possible to have continuous cropping and good crop production throughout the year. There was no trouble with growing five crops per year in a relay-intercrop sequence using dryland rice, maize and grain legumes intercropped with cassava. Rice bean and cowpea grew well during the driest periods of the year, even though it was rather difficult to establish a perfect stand due to dry weather.

The major constraint to crop growth and good yield in the upland rainfed areas is low soil fertility. Fertilizers, expecially nitrogen and phosphorus, are key factors to solve this problem. There was some indication that newly opened fields needed less nitrogen fertilizer than expected. In some cases, increasing rates of nitrogen for dryland rice caused increased blast disease infection. Phosphorus was the key element for crop growth and yield at all sites. Fertilizer rates comparable to those used for irrigated wetland rice in good rice land in Java doubled the total production in terms of calories per hectare compared with production in unfertilized plots. Furthermore, the total production of calories from crops in a year-round sequence on the fertilizer plots was equivalent to more than 18 t of unhulled rice/ha (Table 3).

Table 3. Calories produced per hectare from year-round cropping patterns with no and full fertilizer treatments, Bandarjaya, Indonesia. 1973-74.

	No fertilizer		Full fertilizer	
	Yield (kg/ha)	kcal/ha	Yield (kg/ha)	kcal/ha
Maize	455	1,615.2	1,350	4,792.5
Rice (unhulled)	769	1,840.0	2,724	6,521.3
Peanut	222	1,003.4	567	2,562.8
Rice bean	93	307.8	627	2,075.4
Cassava (whole)	14,600	17,520.0	23,200	27,840.0
Total		22,286.4		43,792.0
Unhulled rice equivalent	9.309		18,292	

In terms of protein production the yields were equivalent to more than 11 t unhulled rice/ha. Yields from two other sites have also been consistent (Table 4).

Several alternative cropping patterns are shown in Table 5. The introduced cropping pattern gave two times as many calories as farmers' cropping pattern.

Some diseases and insects that limit crop production have been identified. Rice varieties resistant to blast disease and maize varieties resistant to downy mildew are badly needed. Pod borers are the most damaging insects on grain legumes, especially for soybean and peanut. Seedling maggot on rice, shoot fly on maize and *Agromyza*

Table 4. Yield of crops, calories, and protein in year-round cropping studies, Way Abung, Indonesia (av in 1976-77 and 1977-78).

Cropping pattern	Yield (kg/ha)	
	1976-77	1977-78
Maize +	1,169	2,553
dryland rice +	1,858	3,688
cassava +	22,200	19,888
peanut +	680	580
rice bean	228	280
Total calories (kcal/ha)	39,341	45,645
Total protein (kg/ha)	620	843
Unhulled rice equivalent (kg/ha per year)		
Calorie	16,433	19,066
Protein	9,110	12,349

Table 5. Yield of crops, calories, and protein from alternative cropping patterns in year-round cropping systems studies. Way Abung, Indonesia, 1977-78.

Cropping pattern	Yield (kg/ha)	Calorie (Kcal/ha)	Protein (kg/ha)
1. Introduced pattern			
Maize +	2,553	9,063	235
dryland rice +	3,688	8,829	250
cassava +	19,888	23,866	139
peanut -	580	2,266	148
rice bean	280	1,266	70
		45,646	843
2. Introduced pattern			
Maize +	1,815	6,443	167
mungbean I +	320	1,104	71
dryland rice +	3,456	1,104	235
cassava +	28,725	34,470	201
mungbean II +	280	966	62
cassava II	2,373	2,848	17
		54,105	753
3. Farmers' pattern			
Maize +	634	2,251	58
dryland rice +	2,432	5,822	165
cassava	10,906	13,087	76
		21,160	299

on grain legumes almost always attack the young seedlings. They are effectively controlled with a systemic insecticide.

Farming systems research

Farming systems research came into the picture because research deals with farm activity as a whole and not a particular farm activity or farm commodity. This shows the change to the more integrated efforts of many disciplines toward developing a package of farming system technologies for farmers to produce more stable agriculture. This task is projected to increase not only food production, but also farmers' income and productivity of their land.

Toward this direction, the Agency for Agricultural Research and Development (AARD) formed a research working group in 1979. The group members come from several research institutes within the AARD. The team has begun to implement current research activities to support the transmigration program, and will be assigned to handle farming systems research in the transmigration areas.

DISCUSSION

Denning: In your paper, you described a 5-phase approach to cropping systems research and development. From Table 1, it appears that component technology research does not extend beyond Phase II. Is this the case? If so, how do you expect to cope with problems that arise during the production program phase? One such problem could be the emergence of an unforeseen nutritional problem induced by continued cropping of the recommended pattern.

Effendi: I agree with you. We have to extend research beyond Phase 11 to get a refinement of the component technology before the preproduction program.

Santiago: In Table 2, why is the second-rice-crop yield in the 5-month irrigation category higher than that from the first crop? In the second crop of the 10-month or 7-month irrigation category why is the yield lower than in the first?

Effendi: There are varietal and basic soil fertility differences because these trials were not located side by side. We also had some insect losses in the second rice crop in the 10-month irrigation. The second crop comes in later and is more exposed to insect pressures.

In the 5-month irrigation, the second rice crop yielded higher than the first probably because of increased solar radiation intensity.

Malla: In your country what factors limit increased yield of the late-season rice? If water is limiting, what about the situation of light intensity and light duration during the late-season rice?

Effendi: Water availability is the most limiting factor. Light intensity is not very much different throughout the year, but there are slight differences between the rainy and dry season.

Zandstra: Have you tried the variety C171-136 in your upland system in Sumatra? It has been shown to be a very attractive variety in Batangas, Luzon, and Bukidnon, Mindanao.

Effendi: No. We would like to. Would you please send us seed of that variety through Dr. R. Cowan.

Zandstra: How does the total variable cost of the recommended patterns compare with that of the farmers? Do you consider cost of production a limitation to farmer adoption?

Effendi: Cost of production is not the only limitation. Seed availability and marketing, especially for secondary crops like peanut, soybean, and maize, limit adoption. But we will try to give credit for inputs and help market the produce.

Testing of rice-based cropping patterns at four selected sites in Bangladesh

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The cropping systems of Bangladesh are essentially rice-based: about 74% of the country's total cultivable area is devoted to rice and about 92% of the farmers grow rice. About 18 rice-based cropping patterns are in use on the farms of the country. Although most of them exhibit considerable biological stability, their agronomic productivity and economic profitability are generally low. Most of the farmers' patterns need modification, particularly in terms of improved varieties, optimum planting schedule, input use, and management of individual crops included in the patterns.

Improved cropping patterns were designed and tested in farmers' fields at the cropping systems research sites of the Bangladesh Rice Research Institute (BRRI). This paper presents the results at four sites within the BRRI project. The sites represent about 6 million hectares of cultivated land.

METHODOLOGY FOR CROPPING PATTERNS TESTING

A representative block of 60-80 contiguous plots at each site was selected for monitoring and descriptive work. The sites at Bhogra, Salna, and Jarunbari represented one land type; at Laskarchala two land types (level highland and shallow valleys) were used. Whole-farm record keeping was also done on 6 farms.

Cropping pattern testing was done by modifying the existing patterns in the block or whole farm. Modifications included change of variety, improvement of management or inputs, and introduction of a new crop, depending on the site. Attempts were made to introduce modifications that fitted the existing intensive land use, and all normal operations were done by the farmer. Where there were differences from the existing pattern, inputs were given free to the farmer or operations were done by the researcher.

The number of cropping patterns tested at each site ranged from 2 to 10 per year. In most cases, the patterns were replicated in three to four farmers' fields. The testing was also done in the entire individual plot, usually measuring more than 1,000 m^2. In a few cases the designed patterns were tested in the form of superimposed treat-

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ments. Data were collected on the planting schedule, field operations, man and animal hours for different operations, and input use. The climatic and pest and disease situations were monitored. Production was measured by crop-cuts. Collected data were subjected to statistical and economic analysis, depending on the need and situation.

CROPPING PATTERNS TESTING

Bhogra: rainded, double-rice-crop site

Site description. All the soils in the BRRI project area belong to the Madhupur tract. Madhupur clay is a weathered, unconsolidated, alluvial sediment probably of marine deposit. The clay minerals are mainly illite and kaolinite. At Bhogra, the soil is a grey terrace soil (Aeric Haplaquept) with a grey, compact, clay substratum and a silty clay surface. It has shallow flooding in the monsoon season, is slowly permeable, and has poor moisture retention in the dry season. Cation exchange capacity is low and pH is acidic. The site is close to the BRRI station at Joydebpur, and data for that station will show climatic conditions at the site (Table 1).

The land is usually planted to two crops of raided rice per year and is kept fallow in the dry season. This common cropping pattern in Bangladesh covers about 3 to 3.5 million hectares. The first crop is direct seeded or transplanted, depending on rainfall distribution and variety, in April or May. In the last 2 years, however, the first crop was entirely transplanted. The second crop is transplanted after the harvest of the first crop in July, August, or September. In the dry season, some seedbeds are used for vegetables or pulses; otherwise, the land remains fallow.

Forty-two percent of the farmers cultivate less than 1 ha, but 1 farmer had more than 3 ha. The number of livestock possessed by cultivators varied greatly: less than one pair for 26% and one pair for 50%. Larger holdings had more manpower and draft power. Family size averaged more than 8/farmer. Most household heads were illiterate, but 80% of the sample had one literate person in the household. Only 3% of the 38 cultivators received credit in the last 5 years. The major constraints to higher crop yields were lack of irrigation facilities, drought in the premonsoon and post-monsoon periods, and availability of adequate production inputs and credit.

Results of cropping pattern testing. Modified patterns have been tested at Bhogra since 1976 when preliminary testing was done on four modified rice cropping patterns and five farmers' patterns. The patterns and the grain production per hectare are presented in Table 2. The highest production per hectare (10.2 t) was obtained from the newly designed BR3 - BR4 pattern, followed by that in the BR3 - Nizersail (7.4 t) pattern. Among the farmers' patterns, Chandina - Pajam gave the highest production (6.8 t/ha), followed by IR8 - Nizersail and Chandina - Nizersail. The lowest production per hectare (4.1 t) came from the farmers' Pukhi - Pajam pattern. The result of the preliminary testing indicated that with favorable rainfall, two crops of modern rice varieties (MV) a year could be grown with maximum production per hectare; if rainfall were suboptimum, a MV aus - local transplanted aman (t. aman) pattern would be the best alternative for maximum grain production.

Table 1. Average monthly climatic data for Joydebpur, Dacca, Bangladesh.

Factor [a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average rainfall (mm)	18	28	60	150	235	368	353	387	267	149	40	14	2069
Rainfall (mm)			445					1524			101		2069
Min rain (mm)	0	0	0	2	34	123	11	70	40	5	0	0	1097
Med. rain (mm)	8	17	48	142	216	349	347	352	257	112	28	8	1883
Max rain (mm)	205	117	364	475	547	843	880	1755	580	457	184	71	2703
P 25 mm (%)	20	41	67	90	100	100	100	100	100	98	76	50	
P 100 mm (%)	2	4	15	67	91	100	98	98	96	56	7	0	
P 200 mm (%)	0	0	0	0	54	91	88	88	68	24	0	0	
Mean evap. (mm)	64	83	137	144	154	103	99	87	91	81	68	55	1167
PE (mm)	101	132	170	160	118	74	55	67	74	89	107	96	
Aridity index	0.11	0.6	0.27	0.74	2.03	4.73	5.92	5.16	3.21	1.64	0.22	0.02	
Av temp, max (°C)	25.3	28.3	32.8	34.4	33.5	31.5	30.1	30.9	31.3	30.7	28.7	25.9	
Av temp, min (°C)	11.9	14.1	19.3	23.3	25.1	25.8	26.1	26.2	25.8	23.6	17.7	12.8	

[a] Med. = median, evap. = evaporation, PE = pan evaporation.

Table 2. Average productivity of 9 rainfed rice cropping patterns under farmers' management. Bhogra, Bangladesh, 1976 aus and transplanted aman seasons.

Cropping pattern		Grain yield (t/ha)			Samples
Aus rice	T. aman rice	Aus	T. aman	Total	(no.)
Pukhi	Nizersail	1.8	2.6	4.4	10
Pukhi	Pajam	1.9	2.3	4.1	9
Chandina	Nizersail	2.8	2.1	5.0	11
Chandina	Pajam	4.1	2.7	6.8	4
IR8	Nizersail	3.5	3.2	5.9	11
Pukhi [a]	BR4	1.9	4.3	6.2	4
BR3[a]	Nizersail	4.6	2.8	7.4	4
BR3[a]	Pajam	3.7	3.2	6.8	1
BR3[a]	BR4	5.7	4.4	10.2	1

[a] Newly designed cropping patterns.

Table 3. Influence of 2 levels of management on the productivity of 5 rice cropping patterns. Bhogra, Bangladesh, 1976 and 1977 aus and t. aman seasons.

Cropping pattern		Total grain production (t/ha)		Increase (%) over farmers' management	Samples (no.)
Aus rice	T. aman rice	Farmers' management	Recommended management		
Pukhi	Nizersail	4.5	4.8	8	1
Pukhi	Pajam	4.5	5.5	22	5
Chandina	Nizersail	4.1	5.4	32	1
IR8	Nizersail	5.4	6.2	15	5
BR3	Nizersail	6.9	8.7	25	3
1976 av or total		5.1	6.1	20	15
Pukhi	BR4	5.6	7.0	24	3
Chandina	BR4	7.1	8.8	24	3
BR3 & IR8	Local	5.5	7.6	39	3
BR3 or IR8	Nizersail	8.2	10.1	24	3
1977 av or total		6.6	8.5	27	12

In the same year, five selected cropping patterns (Table 3) were compared at farmers' and recommended levels of management with regard to fertilizer application, weed control, and insect control. The recommended level of management increased the productivity of each cropping pattern. The increase ranged from 8 to 32%, depending on the pattern. A similar result — average 27% increase in yield with recommended management — was found in 1977 (Table 3). The recommended level of management was 80-60-40 kg N, P_2O_5, and K_2O/ ha, with the nitrogen split in 3 equal applications at basal, tillering, and panicle initiation stages; weed-free plots; and 2 applications of insecticide. The farmers' level averaged 50-30-0 kg N, P_2O_5, and K_2O/ha, weeding was good, but no insecticide was given. The average extra management cost of US$32.25/ha per crop gave a cost-benefit ratio of 3.52.

In both years, and at both levels of management, the new pattern, BR3 - Nizersail gave the highest production per hectare. BR3 was the major reason for the high yield, but its long field duration restricts the use of modern rices in the following crop. Modern rices are not adapted to late transplanting (later than August) in t. aman season in Bangladesh.

Studies were also undertaken to determine the influence of management levels in the aus crop on the performance of the following t. aman crop in 1976 and 1977. Yields of the aus crops increased by 17 to 34% with the recommended level of management. The high management given to the aus crop had a residual effect (5 to 24%) on the following t. aman crop in all the patterns tested, in addition to an increase due to the recommended management package.

Economic analysis of the Bhogra patterns was made in 1978 after detailed collection of labor figures for all the operations done in the field. The average productivity and net returns from the basic cropping patterns grown by the farmers in 1978 are given in Table 4. The highest average yield (5.9 t/ha) and the highest average net return (US$541.26/ ha) at the prevailing costs and prices came from the MV aus - MV t. aman pattern. Although the local aus - MV t. aman pattern gave

Table 4. Net returns[a] and yields of the 4 basic cropping patterns grown at Bhogra, Bangladesh, 1978.

Cropping pattern[b]		Area (%)	Aus		T. aman		Total	
Aus rice	T. aman rice		Net return (US$/ha)	Yield (t/ha)	Net return (US$/ha)	Yield (t/ha)	Net return (US$/ha)	Yield (t/ha)
Local	Local	0.4	161.96	2.3	105.02	1.5	266.98	3.7
Local	MV	0.9	46.94	1.4	381.62	3.9	428.56	5.3
MV	Local	71.7	293.42	3.1	171.37	1.9	464.79	5.1
MV	MV	24.3	323.66	3.5	217.60	2.4	541.26	5.9
	Local	2.7			93.62	1.6	93.62	1.6

[a]Taka (Tk) was converted at the rate of US$1 = Tk 15.51. [b]MV = modern variety, T. aman = transplanted aman.

higher production than the MV aus -local t. aman pattern, the total net return in the latter was higher mainly because of higher market prices for the liner quality grains of the local t. aman varieties. This finding provided support to the MV aus - local t. aman patterns for this rainfed site, particularly for years with early withdrawal of monsoon rains or late premonsoon rains.

In 1978, four patterns were tested. The highest total per-hectare production and net return came from the BR3 -BR4 pattern (Table 5), but this pattern is not feasible unless farmers can transplant BK3 early enough (early May) to enable BR4 to be transplanted by mid-August. The three other patterns required less rigid planting times and the Chandina - Pajam pattern gave the best net returns.

In 1978, watermelon and tomato were grown in pits and irrigated by hand after t. aman harvest in one of the Chandina - Pajam pattern plots. Although markets would limit the usefulness of this modification, results showed that net returns from watermelon and tomato were US$662.86 and $62.15 per hectare. with a cost-benefit ratio of almost 4 for watermelon. Tomatoes were not successful because of low market prices at harvest.

Additional crops could also be grown on the t. aman seedbeds left fallow after the seedlings were uprooted. More than 1 t/ha of soybean was obtained on such plots without irrigation in 1977. Vegetables, mungbean, and mustard are other possible crops for those plots.

In 1979 only whole-farm studies were conducted at Bhogra. Table 6 shows the cropping patterns used in the aus and t. aman seasons on six farms on the land surrounding the block. Cropping patterns were greatly changed in 1979 because the monsoon rains started late (10 June compared to early May). In 1979 farmers only

Table 5. Total yields and net returns from 4 cropping patterns tested under farmers' management at Bhogra, Bangladesh, in 1978.

Cropping pattern		Samples (no.)	Total yield (t/ha) per pattern	Total net return (US$/ha)[b]
Aus rice	T. aman rice[a]			
Chandina	BR4	6	5.0	501.16
Chandina	Pajam	9	6.2	633.40
BR3	BR4	4	7.1	745.58
BR3	Nizersail	7	5.0	471.37

[a]Transplanted aman. [b]Converted from taka (Tk) at the rate of US$1 = 15.51 Tk.

Table 6. Cropping patterns on 6 farms at Bhogra, Bangladesh, in 1978 and 1979.

Cropping pattern		Sample area (%)	
Aus rice	T. aman rice[a]	1978	1979[b]
Local	Local	5	24
Local	MV	4	–
MV	Local	37	21
Mv	MV	26	–
Single MV rice crop		–	16
Single local rice crop		–	3
Other patterns [b]		28	30

[a] Transplanted aman. MV = modern variety. [b] other patterns include boro rice grown on low land some distance away from the land type chosen for the block.

grew double-cropping patterns with either local or modern aus followed by local aman. Nineteen percent of the land was planted to only one crop in 1979. The 1979 data for the six farms were used in comparing MV aus - local t. aman patterns with a single MV crop in terms of yield and net returns (Table 7, 8). Double-cropping gave higher grain yields and net returns even when local varieties were grown. That was due mainly to the high prevailing market price for the fine quality local varieties in 1979. When Nizersail instead of the fine quality rice Chinigura and Binnisail was grown with local aus, a single crop of BR4 gave better net returns (Table 8). Despite lower yields, however, a single crop of Chinigura gave better net returns than a single crop of Pajam or BR4. This explains why farmers are reluctant to adopt modern varieties and prefer instead the finer quality local varieties, and how fluctuating market prices can upset predictions about possible net returns.

Input levels were below recommendations, especially for potash and insecticide use. Component technology studies indicate low response to those inputs. Total labor requirements did not differ significantly between patterns at Bhogra; they averaged just over 1,250 labor hours/ ha for both crops.

Salna: irrigated rice site

Site description. Salna is an irrigated rice area. Aus, t. aman, and boro rice crops are grown in different patterns. The cropping systems research site is a tube well irrigated block that includes medium highland and depressed valleys.

The soils of the area are similar to those at Bhogra site and belong to the Chhiata soil series (Aeric Haplaquept). The climatic data in Table 1 can also represent those of this site.

Before the development of irrigation facilities, the site had a rainfed aus - t. aman cropping pattern. Afterwards, the cropping pattern changed to boro - t. aman, aus - t. aman, and boro - aus - t. aman. Irrigation facilities have led to cultivation of more MV boro followed by aus or t. aman. Because of irrigation and photoperiod-insensitive MV, the traditional concept of aus, t. aman, and boro is vanishing at the site. Now farmers are growing either single-, double-, or triple-rice patterns with irrigation. The Salna site represents about 1.2 to 1.6 million hectares in the country.

In general, the area is developed and is connected with the national capital and other areas with good communication systems. Farmers have good access to markets. It has been a project area for other development projects including the

Table 7. Productivity of rice cropping patterns on 6 farms at Bhogra, Bangladesh, in 1979 aus and t. aman seasons.

Cropping pattern [a]		Total production (t/ha) from the pattern in farms						Av production (t/ha)
Aus rice	T. aman rice	1	2	3	4	5	6	
Local	Local	–	–	4.7	5.4	5.2	4.6	5.0
MV	Loca1	6.5	6.4	5.7	–	5.9	5.9	6.0
Single local crop		–	–	2.6	–	3.7	2.8	3.0
Single Pajam crop		–	–	–	3.1	3.9	3.9	3.6
Single MV crop		4.1	–	5.3	4.8	4.4	–	4.7

[a] T. aman = transplanted aman. MV = modern variety.

Table 8. Net return per hectare from rice cropping patterns at Bhogra, Bangladesh, in 1979 aus and t. aman seasons.

Cropping pattern [a]		Net return [b] (US$/ha)						
Aus rice	T. aman rice	Farm 1	2	3	4	5	6	Av
Local	Nizersail	–	–	745.20	906.96	872.60	767.18	822.99
Local	Local [c]	–	–	–	1336.81	1315.02	1196.39	1282.74
MV	Nizersail	1015.73	1063.70	941.78	–	907.67	981.24	982.02
MV	Local	–	–	–	–	1299.42	–	1299.42
Single local		–	–	719.88	–	1207.93	883.17	956.99
Single Pajam		–	–	–	513.47	655.38	693.17	620.67
Single MV		790.00	–	953.71	885.75	769.89	–	849.84

[a] T. aman = transplanted aman, MV = modern variety. [b] Price of rice: local aus = US$0.24/kg, MV aus = $0.23/kg, local t. aman Chinigura = $0.39/kg, Binnisail = $0.34/kg, Pajam Nizersail = $0.21/kg. Prices were converted from taka (Tk) at the rate of US$l = Tk15.51. [c] Local t. aman includes Chinigura and Binnisail, which had a higher market price.

self-reliance and the family planning programs of the national government.

The average farm size at the site is about 1.47 ha. The family size is about 8 to 9 persons, 3 to 4 of whom do farm labor. Farmers use bullock power for farming. Some farmers (15%) enjoy government credit facilities. Soil problems appear to be increasing, and crop yields at the site are thus reduced.

Results of cropping pattern testing. Monitoring of the farmers' cropping patterns at Salna started in 1977 in a block of 78 contiguous fields. Table 9 shows the cropping patterns, cropping intensity, and percentage of plots grown to rice in aus, aman, and boro for 1977 to 1979. The major double-cropping pattern in 1978 was boro followed by t. aman (42%), but aus followed by t. aman was grown on 21% of the area. Yields are generally highest in boro, followed by the t. aman and aus seasons. The highest farmer production was 9.3 t/ ha from a MV boro - local aus -Pajam t. aman pattern.

Seven rice cropping patterns were tested in 1978-79 under farmers' management level (Table 10). The highest total production (10.3 t/ ha) and the highest net return ($1,280.66/ha) came from the MV aus - Pajam t. aman - MV boro pattern. Among the double-cropping patterns tested, Pajam t. aman - MV boro gave the highest net return of $958.091 ha. In 1978-79, the possibility of growing wheat after aus and t. aman crops was tested as superimposed treatments. The yield of wheat ranged from 1.4 to 2.3 t/ha. This particular cropping pattern is being further tested in 1979-80.

Table 9. Cropping patterns and cropping intensity at the Salna site, Bangladesh, from 1977 to 1979.

Cropping pattern, intensity, season	Percentage of plots		
	1977	1978	1979
Cropping			
Fallow	1.3	3.8	2.8
Single	15.4	23.1	29.5
Double	69.2	64.1	59.0
Triple	14.1	9.0	9.0
Cropping intensity	196	178	175
Season			
Boro	69	62	81
Aus	40	35	15
Aman	87	80	78

Table 10. Seven selected cropping patterns studied in farmers' fields in Salna, Bangladesh, 1978-79 aus, aman, and boro seasons.

Cropping pattern[a]	Total labor (h/ha)	Total pair of animal (h/ha)	Yield (t/ha)			Production cost[b] (US$/ha)			Total net return[b] / pattern (US$/ha)
			Aus	Aman	Boro	Aus	Aman	Boro	
MV aus - Pajam t. aman	1431	542	2.9	2.5	–	145.07	114.06	–	545.58
MV aus - Pajam boro	1626	321	2.2	–	3.5	141.59	–	209.54	721.92
Pajam t. aman - MV boro	2019	606	–	3.0	4.3	–	170.21	245.97	958.09
Pajam t. aman - Pajam boro	1609	525	–	2.4	3.9	–	139.72	225.40	878.40
MV t. aman - Pajam boro	2883	851	–	4.1	3.5	–	271.57	285.49	901.55
MV aus - Pajam t. aman - Pajam boro	2614	668	2.3	3.5	4.1	162.99	139.97	221.40	1250.74
MV aus - Pajam t. aman - MV boro	2347	575	3.4	3.4	3.5	147.52	100.19	216.38	1280.66

[a] MV = modern variety, t. aman = transplanted aman. [b] Converted from taka (Tk) at the rate of US$1 = Tk 15.51.

Wheat instead of boro rice allows the soil to be dried in winter and may alleviate some of the soil problems that exist with continuous rice production and submerged soils.

Jarunbari: low-lying, single-boro-rice cropping site

Site description. The Jarunbari site is a single-cropped low-lying area. It is flooded every year with 91 to 183 cm water during the period July to early September. On two sides of the site are highlands; one side is continuous with the lowland while the other side is blocked by a highway. Farmers transplant boro rice using water available in the field, and irrigate the crop at later growth stages with water from a deep tube well.

The soil in this deeply flooded valley site belongs to the Khilgaon series (Fluvaquentic Haplaquept). It is a poorly drained, dark grey basin clay. The climate is more or less similar to that of the other sites (Table 1).

Before the development and introduction of the high yielding modern rice varieties, farmers used to grow a deepwater rice in the area. This photoperiod-sensitive rice crop was direct-seeded in March-April, grew with floodwater, and was harvested in November-December. After the harvest of the deepwater rice, farmers kept the land fallow.

Results of cropping pattern testing. The farmers' cropping patterns were monitored in the 1976-77 boro season (Table 11). It was found that a MV (IR8) boro crop was much more profitable than either Pajam or local boro. On the average, the MV crop gave more than six times the net return obtained with a local boro crop. In the same season, an experiment was made to see the effect of higher management practices on the yield of the MV boro as compared to the farmers' level of management. Data presented in Table 12 indicate that the productivity of the farmers' MV boro crop could be increased by 14-32% by applying a higher level of management.

To increase the cropping intensity at Jarunbari, a deepwater rice crop was grown after the boro crop. Results indicated a great potential for an additional deepwater rice crop on the higher ridges at the site, if seedlings of deepwater rice are transplanted immediately after boro harvest. Relay cropping was possible, especially if the spacing in boro was wide, but yields were less than when deepwater rice was

Table 11. Yield and economics of growing different rice varieties at Jarunbari, Bangladesh, 1976-77 boro.

Item[a]	IR8	Pajam	Muktahar (local)
Plots (%)	75	13	12
Farmers (%) that used NPK	100-91-71	100-100-75	100-86-57
Rate of N-P_2O_5-K_2O (kg/ha)	78-28-29	63-35-32	69-41-11
Av no. of weeding	2.58	2.63	2.43
Yield (t/ha)	4.1	3.0	1.7
Gross return (US$/ha)	566.60	414.51	230.24
Total variable cost (US$/ha)	177.24	165.25	169.95
Net return (US$/ha)	389.36	249.19	60.28
Return over hired labor, power, and cash cost (US$/ha)	436.30	296.32	117.86

[a]Costs and returns were converted from taka (Tk) at the rate of US$1 = Tk 15.51.

Table 12. Effect of management level on the yield of IR8 at Jarunbari, Bangladesh, 1976-77 boro.

Management level [a]			Grain yield (t/ha) of IR8			
Fertilizer	Weeding	Insect control	Farmer 1	Farmer 2	Av	%
F	F	F	3.6	3.3	3.5	100
F	R	R	3.1	4.2	4.0	114
R	F	R	4.4	4.8	4.6	132
R	R	F	3.9	4.0	4.0	115
R	R	R	4.3	4.8	4.5	131

[a] F = farmers' level, R = recommended level.

transplanted just after boro harvest. Nitrogen fertilizer at 40 kg N/ha significantly increased deepwater aman yields in this pattern.

Laskarchala: irrigated site

Site description. The soils at Laskarchala are moderately well-drained, yellowish to brown clay loams (Typic Paleudults) on the level highland and poorly drained, grey silty clay loams (Aeric Haplaquept) in the narrow valleys dissecting the upland area. Irrigation by deep tube well is available for dry-season cropping. The data in Table 1 give an idea of the climatic conditions at the site.

The traditional cropping pattern was a crop of direct-seeded rice or mesta fiber (*Hibiscus* sp.) followed by pulse or oilseed on the highland and double rice crop on the narrow valley land. The introduction of tube well irrigation in 1975 changed the cropping patterns. Two crops of transplanted rice are grown on the valley soils with an increased proportion of MV. The cropping patterns for the highland area include aus rice - wheat /vegetables/ mustard, aus rice - t. aman rice/ pulse - wheat, aus rice - t. aman rice and single crop of rice and vegetables. Irrigation has increased the area planted to wheat and vegetables in the dry rabi season.

The average cultivated farm area is 0.91 ha (range of 0.34 to 2.43 ha). Most farmers own their land and 37% rent extra land. Seventy-four percent of the farmers own two draft animals, and larger farms have more animals. Lack of credit, animal power, and seed were major constraints to increased production at this site. Another constraint is the many absentee landlords who have large holdings in the area but underutilize their land.

Results of cropping pattern testing. Cropping patterns on two land types (flat highland and depressed shallow valley) were monitored starting 1977. The percentages of fields under fallow, single-, double-, and triple-cropping patterns during the last three years are given in Table 13. In the highlands, the area under fallow and single-cropping decreased in 1978 and 1979. In 1979, a severe drought decreased the cropping intensity. In the shallow valley lands, no fields were kept fallow. The single-cropped area decreased and triple-cropping with partial irrigation started.

The productivity and costs and return analysis of six tested cropping patterns on the highlands and valley land in 1978-79 are presented in Table 14. On the highlands, the highest net return came from a pattern of local rice (Pukhi) - black gram (legume) - wheat; the next highest came from the MV aus rice (BR3) - MV wheat pattern. On

Table 13. Cropping patterns and cropping intensity at Laskarchala, Bangladesh, 1977-79.

Cropping pattern, intensity	Fields [a] (%) 1977	1978	1979
		Highland	
Fallow	5.5	1.8	3.7
Single	23.6	7.3	16.7
Double	67.3	69.1	61.1
Triple	3.6	21.8	18.5
Cropping intensity	169	211	194
		Shallow valley land	
Fallow	na	0	0
Single	na	29.0	14.3
Double	na	71.0	66.7
Triple	na	0	19.0
Cropping intensity	–	171	205

[a] na = not available.

Table 14. Productivity and cost and return analysis of 6 tested cropping patterns in the highland and valley land at Laskarchala, Bangladesh, 1978-79.

Cropping pattern: Aus	Arnan/pulse	Rabi	Samples (no.)	Av yield (t/ha): Aus	Aman/pulse	Rabi	Total costs (US$/ha)	Total net return (US$/ha)
				Highland				
Pukhi	Fallow	Wheat	10	1.2	–	2.3	257.58	265.05
Pukhi	Pulse	Wheat	2	2.0	0.3	2.1	243.13	482.79
Chandina	Fallow	Wheat	2	2.6	–	1.9	316.83	394.78
BR3/IR8	Fallow	Wheat	8	2.8	–	1.8	295.16	431.53
IR8	Fallow	Mustard	1	2.3	–	0.3	248.74	226.82
				Valley land				
Pukhi	Nizersail	Fallow	1	1.0	2.4	–	186.20	348.94
Chandina	Nizersail	Fallow	3	2.8	2.2	–	205.80	588.07
Chandina	Pajam	Fallow	3	3.0	3.0	–	193.36	763.12
Fallow	Pajam	Wheat	4	–	2.8	1.3	293.62	324.56

the shallow valley lands, the highest net return ($763. 12/ha) came from a MV aus rice (Chandina) - Pajam t. aman pattern; the next highest was from the Chandina aus - Nizersail t. aman pattern.

Various nonrice crops were tested as substitutes for wheat and aus rice and as suitable crops for the t. aman season. Chili, cabbage, and potato provide high cash incentives to the farmers, but low credit availability limits the area for them. Peanut, maize, soybean, millets, sweet potato, and sorghum have been tested with good results. However, farmers are not ready to accept these crops without markets or uses for the output. Good varieties of mung, black gram, and sesame that have insect and disease resistance and uniform maturity would easily fit the cropping patterns between the aus and wheat crops.

In summary, the highlands can grow any crop. The best patterns would involve a single monsoon season rice (direct seeded if a suitable variety is available, or transplanted) followed by two nonrice crops. Credit and markets must be developed, however, to support the cultivation of this pattern. In the narrow valley areas two modern transplanted rice crops with or without a dry season rabi crop would be a good pattern, but farmers must be encouraged to use the tube well and recommended inputs as efficiently as possible.

PROBLEMS IN INCREASING CROPPING INTENSITY

The physical, technological, and socioeconomic constraints that limit cropping intensity at the four sites are listed in the following sections:

Bhogra: raided, double-rice-crop site

- *Lack of irrigation facilities.* Although the aus and t. aman rice crops are grown with available rainwater during the period April to November, irrigation is needed to supplement the residual soil moisture so that nonrice winter crops can be grown during the period from December to March. Additional irrigation can also be beneficial for earlier land preparation and planting of the aus crop.
- *Soil texture and moisture-holding capacity.* The soil at the Bhogra site is a silty clay and possesses poor moisture-holding capacity during the rabi season (October to March). This restricts the production of various upland crops after the aus and t. aman crops.
- *Plow pan.* Most of the fields at this site have a strong plow pan, about 10 to 15 cm below the surface soil, which cannot be broken by the farmers' traditional plow. Although considerable moisture exists in the subsurface soil, it is difficult to use for growing the nonrice rabi crops.
- *Drought.* Drought periods are frequent during the early part of the aus season and the later part of the t. aman season. Drought in the pre-aus period delays the start of the aus - t. aman pattern and ultimately reduces the possibility of growing a third nonrice crop or even growing two rice crops. Late drought in the t. aman season reduces yield, especially of the more drought-sensitive modern aman varieties.
- *Long turnaround time.* Sometimes a turnaround time of 2 to 3 weeks is observed in some farmers' fields between the aus and t. aman crops. That long

period delays the transplanting and maturity of the t. aman crop, and reduces the possibility of growing a third upland crop with residual soil moisture.

- *Lack of suitable varieties.* The most important cropping pattern at Bhogra involves a MV aus followed by local photoperiod-sensitive t. aman varieties, which take a longer time to mature. The fields could be cleared earlier for the rabi season crops if short-duration photoperiod-insensitive MV rices could be identified, developed, and transplanted immediately after the aus harvest.
- *Lack adequate research findings.* The potential of different nonrice crops after aus - t. aman crops at Bhogra need to be worked out. Although some information has been generated on the potential for watermelon, tomato, and wheat as third crops at this site, more research work is needed to determine that for the drought-resistant crops such as sorghum and safflower.

Salna: irrigated rice site

- *Soil texture.* The clay soil of the Salna site may not be suitable for most upland crops.
- *Emerging soil problems.* Continuous rice cropping at Salna causes the soil to remain wet year-round. Soil problems, particularly deficiencies of nutrients such as sulfur and zinc, occur.
- *Absentee landowners.* Several absentee landlords possess lands in this area. That contributes to the less intensive land use and even to poor crop management and lower yields in the area.
- *Lack of ,farmers' motivation to use available irrigation facilities.* Although irrigation facilities are available at the site, farmers are often reluctant to use those facilities particularly for the aus and t. aman crops, which are grown mainly rainfed.

Jarunbari: low-lying single-boro-rice-crop site

The potential intensive cropping pattern for the Jarunbari site could be MV boro deepwater rice. The following, however, are constraints to the introduction and adoption of the pattern at the site.

- *Hydrological situation.* A greater part of the area (about 60-75%) has very low elevation and gets flashflooded during the early part of the annual flooding period (July-October). That prevents the growing of a deepwater rice after the boro crop (December-May: June).
- *Early floods.* In some years, floods may come early in June-July and thus restrict the planting of deepwater rice even on the higher ridges. Even if the deepwater rice is planted, it may be totally damaged by the early flood.
- *Lack of early-maturing high-yielding boro varieties.* Farmers usually sprefer long-duration boro varieties like IR8 and BR3 for maximum yields per hectare. They are rightly reluctant to use the presently available short-duration but relatively low-yielding varieties like Chandina and BR6 (IR28). Shorter-duration varieties would increase the possibility of a second deepwater rice crop.
- *Water hyacinth and strong water currents.* Sometimes, deepwater rice is severely damaged by the water hyacinth carried by strong water currents when the crop is grown in patches.

- *Rat problems.* Very often deepwater rice is badly affected by rats. Thus, farmers are not encouraged to grow it, particularly at the expense (partial) of the MV boro crop.

Laskarchala: irrigated site

Rice, other cereals, and vegetables are grown at the Laskarchala site. The major constraints to intensive cropping are as follows:

- *Lack of suitable MV aus rice for direct seeding.* The yield of direct-seeded aus rice is reduced by heavy weed infestation in the short-statured MV.
- *Problem in land preparation.* There is the problem of preparing land for nonrice crops after the soils have been puddled for transplanted aus or aman crops.
- *Lack of farmer motivation.* Because of various socioeconomic reasons, farmers are not always motivated to make best use of the available irrigation facilities.
- *Lack of marketing facilities.* At Laskarchala, farmers very often do not get good market price and marketing facilities for their crops, particularly the perishable items such as vegetables.

DISCUSSION

Van der Veen: Farmers' motivation as a constraint is vague. Usually we find that farmers are rational in their decision making. Why do farmers decide not to increase cropping intensity?

Hoque: By "motivation" I mainly meant farmers' reluctance to utilize available resources and facilities to the fullest extent. For example, some farmers could start the aus rice earlier with supplemental irrigation, where irrigation facilities exist. They could harvest the first crop earlier and transplant the second crop in optimum time, which ultimately can facilitate the production of a third crop. If farmers depend only on rainfall despite the availability of irrigation facilities, this may be considered as lack of motivation.

Verma: You pointed out that lack of suitable aus varieties of rice creates problems in some sites in Bangladesh. In similar situations, certain high yielding varieties (HYV) of 90-100 days' duration, such as Pusa 2-21 and Cauvery, have given very good yields in Bihar and West Bengal. Did you test those varieties in Bangladesh?

Hoque: Our breeders at BRRI are screening a number of entries under upland rice-growing situations. They are also collaborating with IRRI and other countries, including India. I cannot say at this moment whether Pusa 2-21 or Cauvery are included in the Bangladesh trials. However, the fact is that we still do not have any good number of suitable high-yielding rice varieties that could be grown as aus crops in upland situations.

Kasmo: Do you anticipate that by introducing early maturing HYV in your recommended pattern you also stimulate the buildup of pest populations and also pest infestation? Have you taken any precaution?

Hoque: Field duration of a crop definitely influences the population dynamics of the insect pests in a particular area. The local aus rice varieties used by the Bangladesh farmers mature in 85 to 100 days. Our intention is to get some HYV with similar maturity to replace the local aus varieties. If the new varieties are resistant to insect pests, then the crop duration itself may not cause that much problem.

Cropping pattern testing in Sri Lanka

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D. Senadheera, S. Senthimthan, M. Silva, and S. Thieviyanathan

Sri Lanka's Cropping Systems Program was initiated in 1976 by the Department of Agriculture with financial assistance from the International Development Research Centre, Canada. In mid-1977, the program was expanded with financial support from the United States Agency for International Development. The national program now covers almost the whole country with five sites in operation:

1. *Walagambuhuwa* is essentially a semi-irrigated project where cropping patterns are worked out to match the prevailing bimodal rainfall pattern, which is supplemented by irrigation from the minor tanks.
2. *Katupotha* is completely rainfed and pluvial rice lands are to be exploited to grow either two rice crops or a rice crop followed by a dryland crop during drier years.
3. *Paranthan* concentrates on the possibility of developing the rainfed northeastern coastal belt in the northern Dry Zone, which is traditionally referred to as Manawari lands, either by increasing the intensity of crop production or by increasing the yield of rice during the *maha* (wet) season.
4. *Bandarawela* is in the Intermediate Zone at a higher elevation and with fairly intensive traditional agricultural production. The project goal is to increase productivity either by crop intensification, by increasing the yields of individual crops, or both.
5. *Mahaweli* is in the Dry Zone and on fully irrigated land. The area has high potential for increased food production.

Two other projects are in the southern Dry Zone at Angunakolapelessa and in northwest Sri Lanka at Mannar.

Because each project represents a significantly different physical environment with different socioeconomic conditions, each site had to develop its own objectives and methodology. That allowed concentration on site-specific problems within the overall program objectives of intensifying crop production. The general program in each site is reviewed in this paper.

THE WALAGAMBAHUWA PROJECT

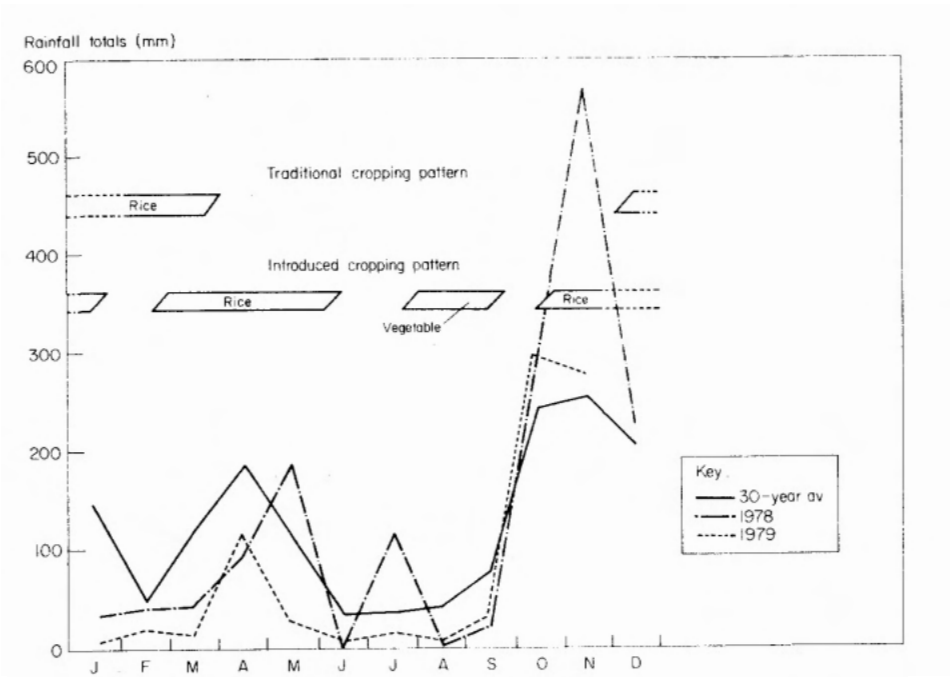
Walagambahuwa represents a typical cross section of the Dry Zone minor-tank-based village settlement. The tank or reservoir stores runoff during the heavy-rain

period for growing a rice crop during the dry season. There are 8,000 to 10,000 minor tanks in the Dry Zone with a command area of 104,200 ha of rice lands. The Dry Zone has a bimodal rainfall distribution pattern with the major rainy season from late September to mid-January with an average rainfall of 930 mm and a minor (*yala*) season from March through May with an average rainfall of 380 mm.

The predominant soil type in the area is Reddish Brown Earths (Rhodustalf) with low humic gleys in the valley bottoms. The properties change with the associated drainage characteristics in the catenary sequence of the undulating landscape. Most of the paddy area tract is covered by ill-drained or imperfectly drained soils; the welldrained paddy area is about 10-15% of the total paddy tract.

A base-line survey in March 1976 clearly showed that the farmer community at Walagambahuwa is poor and cash resources are limited. The average farmer's family has 6.2 members. About 90% of the farm labor is family labor. There is a big gap between labor availability and labor use even at the peak season when only 50% of the available labor is used for farm operations.

In the traditional pattern of agriculture in the village settlement, land preparation for shifting cultivation (*chena*) starts with the felling of trees as early as July. Chena crops are sown in early September before the onset of rains in October, and rice cultivation starts in mid- or late December (Fig. 1). Normally, the farmers take the level of water in the tank as the criterion for decision whether or not to grow rice under the tank. The rice lands are often allowed to remain fallow when the rainfall is unsatisfactory. A rice crop is grown only once in 5 or 6 years in traditional agriculture.



1. Annual rainfall pattern distribution and cropping patterns at Walagambahuwa, Sri Lanka.

The new concept of development for the Walagambahuwa Project includes two components:

1. the advancement of planting date, so that the first rice crop is planted as early as October with the onset of rains, to make maximum use of natural rainfall; and
2. the use of a suitable 3-3.5-month maturing variety of rice so that the *maha* crop will mature with the minimum of supplementary irrigation from the tank.

Depending on the amount of stored water in the tank a second crop of rice or subsidiary dryland crops can be grown. The work during the last 3 years demonstrates that the new technology has brought about a significant improvement over the traditional agriculture. The rice - rice cropping pattern has increased rice production by 350%.

The cropping patterns tested at Walagambahuwa are in Table 1.

The new technology developed at Walagambahuwa has contributed to the crop production and changes shown in Tables 2 and 3.

THE KATUPOTHA PROJECT

The cropping systems research activities in Katupotha are concentrated in two rainfed wetland tracts in adjoining villages at Alankara and Moragana in the Intermediate Agroecological Region. The annual rainfall pattern is bimodal, with

Table 1. Cropping patterns tested at Walagambahuwa Sri Lanka. 1976-80.

Crop year	Cropping pattern	Annual rainfall (mm)
Before 1976	Traditional pattern rice - fallow	
1976-77	Rice - pulse	817
1977-78	Rice - rice - vegetable	1036
1978-79	Rice - rice	925
1979-80	Rice - rice	742

Table 2. Cropping patterns tested and rice production trends at Walagambahuwa Sri Lanka. 1976-80.

Year	Cropping pattern	Resource status	Annual rice production (tiha)
Before 1976	Traditional pattern	Resources available in the village	1.0-1.3
1976-77	Rice - pulse	New technology + project resources + farmers' resources	1.5-1.8
1977-78	Rice - rice - vegetable	New technology + credit facilities + farmers' resources	3.6-4.1
1978-79	Rice - rice - vegetable	New technology + farmers' resources	3.6-4.1
1979-80	Rice - rice	New technology + farmers' resources	3.6-4.1

Table 3. Differences brought about by the introduction of new technology at Walagambahuwa, Sri Lanka, 1976-80.

Traditional agriculture	After adoption of new technolow
1. Rice crop once in 5 or 6 years	1. A rice crop every year
2. No second crop	2. A second rice crop every average year or a second pulse crop every poor year
3. Annual rice production 1.0-1.3 t/ha	3. Annual rice production 3.6-4.4 t/ha
4. Risks involved high and minimum investment in terms of cash inputs	4. Risks involved minimum, with potential for investment in the rice crop

965-1,066 mm in the wet season and 762-838 mm in the dry season. Rice is traditionally grown during the wet season and the land is fallowed or planted with early maturity rice varieties in the dry season.

The rice crop is usually a failure, especially on lands on higher parts of the slope. The rice yields are generally low due to soil problems in the paddies as well as management practices of the farmers. Hash floods are also experienced in many years.

The Red-Yellow Podzolic soils of the Kurunegala series are the major soil group in the region. The soils are light textured with low chemical fertility characteristics (available K < 27 kg/ ha; available P < 0.9-27 kg/ ha; and pH between 5.1 and 6.0).

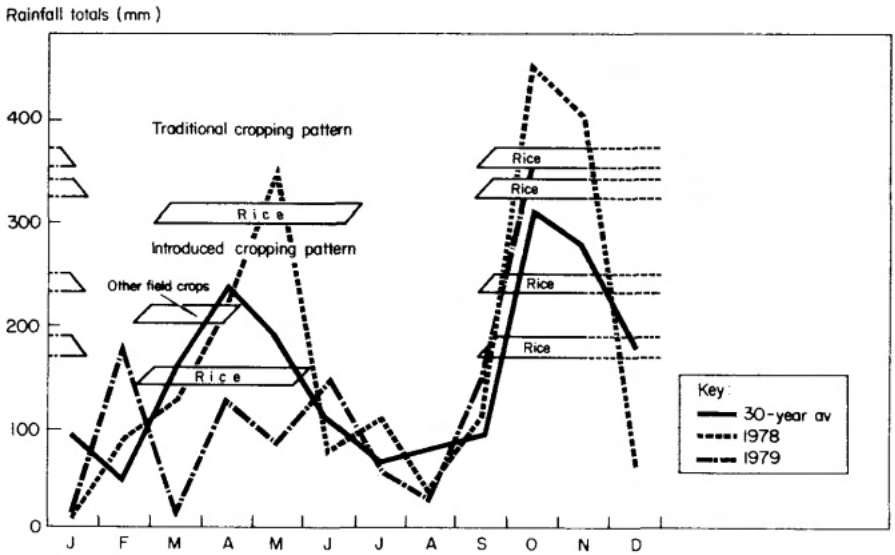
The farms in both villages are composed of paddy lands and coconut lands. The average farm size is 2.6 ha at Alankara and 1.9 ha at Moragane. The average paddy holding is 0.89 ha for Alankara and 0.63 ha for Moragane. Average family size is 5.7-6.0. A gross underemployment of labor is evident, as it is at Walagambahuwa.

Two years of research work has demonstrated that the crest, the slope, and the valley bottoms need different attention with respect to cropping pattern testing. The soil moisture retention relationships are very different in the three different soil types down the catena. The following cropping patterns seem appropriate (Fig. 2):

Land class	*Cropping pattern*
Crest	Rice + other field crops
Slope	Rice + rice
Valley bottom	Rice + rice

The cropping pattern testing program with the improved technology has shown vast potentials for increasing productivity. In farmer-managed trials BG 94-1, BG 90-2, and BG 11-11 yielded 2.47, 2.25, and 0.5 t/ha, but with improved technology BG 94-1 yielded as high as 6.34 t / ha. Dryland crops such as cowpea on the crest land have demonstrated the possibility of producing 1.14 t/ha.

Preliminary investigations have revealed that the rainfed wetland rice yields are unexpectedly low during the dry season because of phosphorus deficiency (Table 4). Although the farmers are aware of this deficiency, the risk involved in dry season cultivation prevents them from applying a basal fertilizer that provides all the phosphorus requirements of the crop.



2. Annual rainfall pattern distribution and cropping patterns at Katupotha, Sri Lanka.

THE PARANTHAN PROJECT

Paranthan represents the northeastern coastal belt. This agroecological zone covers an area between 20,000 and 25,000 ha of rainfed paddy lands. The agroclimate is much like that of the Dry Zone except that dry season rainfall is much lower. The annual average rainfall is 1,200-1,600 mm; the distribution pattern is bimodal. Alluvial soils of varying texture and drainage cover a major portion of the project area. A sandy topsoil texture allows easy dryland preparation before the onset of monsoonal rains for dry seeding. The texture of the soil below the varying depths of sandy topsoil varies from clay sand to sandy clay. The topography is flat.

Half of rainfed rice in the Dry Zone comes under *manawari* cultivation, which refers to rainfed wetland rice in bunded fields. A base-line survey found that the average farm size is large — 4-5 ha/family. Availability of labor is low and farming operations are mainly by use of tractors. Most of the farmers are nonresident.

The traditional pattern of land use is a wet season crop of rice followed by fallow. Resident farmers cultivate small plots of chili and vegetables on the drainageway of the major tanks during the dry season. The rice yields are generally low, averaging 0.5-2 t/ha.

Table 4. Responses to phosphorus in the Katupotha project, Sri Lanka.

Variety	Rice yields (t/ha)	
	0 kg P_2O_5/ha	67 kg P_2O_5/ha
BG 400-1	2.08	2.86
BG 90-2	0.91	1.35
H4	0.90	3.14
Mean	1.32	2.45

The cropping system activities in Paranthan generally seek to increase the productivity of *manawari* rice lands through crop intensification or through increasing the rice yields of the wet season crop, or both. Low rice yields are due to:

- lack of suitable varieties,
- lack of appropriate weed control, and
- improper use of fertilizer.

The initial field effort concentrated heavily on component technology with variety evaluation, weed control, and fertilizer use based on dry-seeded rice.

Varietal screening

Ten varieties of different maturity were grown in three soil types — sandy soil with standing water, clay loam with standing water, and clay without standing water. The performance of the 10 varieties is summarized in Table 5.

The water was not a constraint because good rainfall prevailed. All improved varieties did significantly better than the traditional varieties. It appears that the medium tall varieties were generally better on all the three groups of soils. Tall varieties did not perform well. Yields on the researcher-managed trials were similar to those of the farmer-managed trials.

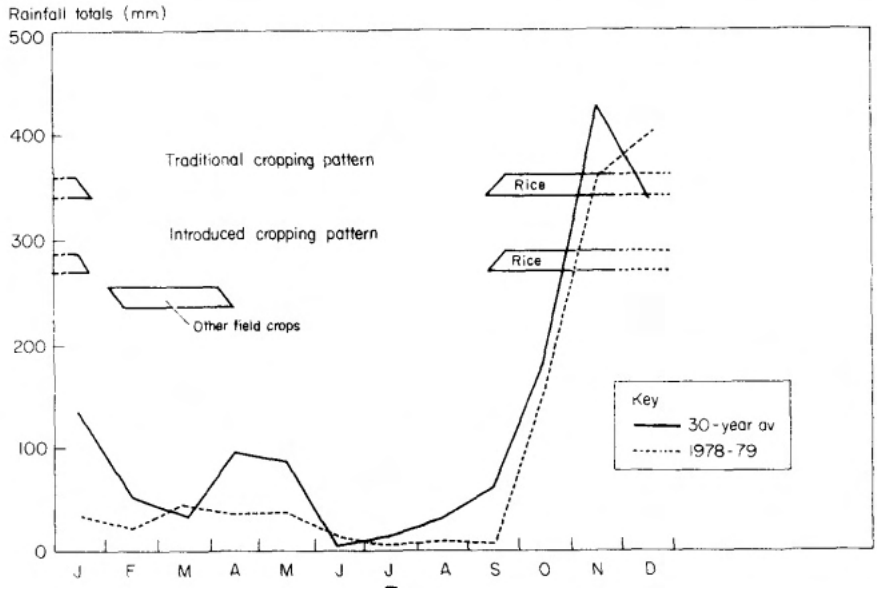
The effect of the split application of nitrogen on the yield of dry-seeded rice was also studied. Split application of nitrogen was generally better than the control. Fertilizer at 2, 4, and 6 weeks after sowing gave yields similar to those from split applications 2 and 6 weeks after sowing.

The following cropping patterns were tested with a view to increase the cropping intensity (Fig. 3):

- Rice (DSR) - mungbean with yields of 2.1 t/ ha wet season and 0.25 t/ ha dry season,
- Rice (DSR) - cowpea with yields of 1.8 t/ ha wet season and 0.30 t/ha dry season, and
- Rice (DSR) -sesame with yields of 2.2 t / ha wet season and 0.35 t/ ha dry season.

Table 5. Performance of 10 varieties tested at Paranthan, Sri Lanka, 1978-79.

Variety	Yield (t/ha) on soil type		
	Sandy with water	Clay loam with water	Clay (no standing water)
Tall			
62-355	2.9	2.5	1.8
75-148-1	1.3	2.6	1.3
H4	1.1	2.6	2.1
Karuppan	1.9	3.0	2.5
Medium tall			
76-7283	4.0	3.9	2.8
BG 401-1	3.8	5.3	3.0
Short			
BG 33-2	3.3	2.8	2.4
BG 94-1	28	4.9	2.2
BG 304-2	3.0	4.4	2.5
BG 280-1	3.1	5.0	2.8



3. Annual rainfall pattern distribution and cropping patterns at Paranthan, Sri Lanka.

The performance of the dryland crops was discouraging. The unstable dry-season rainfall and the lack of short-duration dryland crop varieties are problems in promoting a dry-season crop.

THE BANDARAWELA PROJECT

Bandarawela is in southeastern Sri Lanka at an elevation of 1,300 m above mean sea level. Of the 5,000 ha of rice lands under the project. 500 ha are rainfed and the balance irrigated. The soils are predominantly Red-Yellow Podzolic in a rolling landscape.

The average annual rainfall is about 1,150 mm. The rainfall distribution is similar to that in Walagambahuwa with a peak from October to January and a minor peak from March to May. Maximum temperature is 25° C from October to March, but the temperature ranges from 25°-27°C from March to September. The minimum temperature is experienced from January to March (12°-14° C) and increases to 15°-17° C April through December. This temperature regime restricts rice cultivation. Any planting before January results in sterility. With the onset of the southwest monsoon, severe wind is experienced during May-July, which causes severe crop losses in certain areas; thus rice is planted during early January and harvested during the latter part of May.

A socioeconomic survey has shown that the Bandarawela land-use pattern is similar to that of Walagambahuwa. Farm size is generally small and family and exchange labor are used for most of the farming operations. The traditional cropping pattern is rice - vegetable or rice - potato. Normally the farmers derive high

gross incomes but not high net incomes because of nondevelopment of the marketing facilities to parallel development of agricultural production.

The Bandarawela cropping systems research is based at Idama in Uva-Paranagama electorate. This site provides three types of land categories:

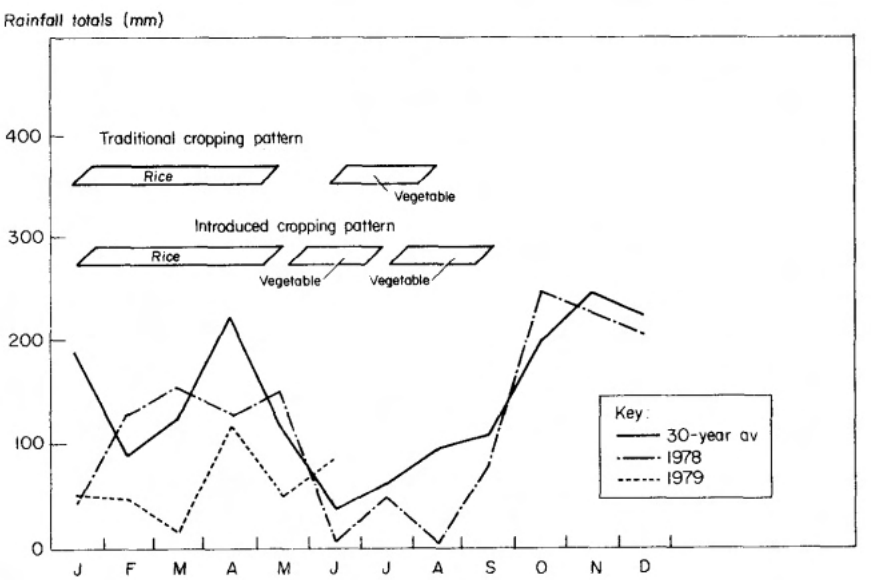
1. fully-irrigated rice lands,
2. rotational irrigation areas, and
3. rainfed areas.

In the fully irrigated areas a rice - vegetable - vegetable cropping pattern was tested (Fig. 4). In this pattern, the additional vegetable crop is possible only by reducing the duration of the rice crop in the field. The technology introduced was:

- introduction of early-maturing rice varieties,
- transplanting of seedlings,
- early planting, and
- an upland nursery technique.

Under the rotational irrigated and rainfed areas, where irrigation facilities are limited, one rainfed rice and one or two vegetable crops with limited water supply were proposed. In 1978-79 experiments, potato and bush bean were grown at Idama near Uva-Paranagama. Several varieties of potato and bean were tested in two drainage types because soil drainage was important (Tables 6-7).

The mean sprouting percentage of tubers was significantly superior in the imperfectly drained soils, but there was no significant difference in yield. A large number of rotten tubers had to be discarded in the imperfectly drained soils, which indicated that a high tuber yield could have been obtained if proper drainage had been provided.



4. Annual rainfall pattern distribution and cropping patterns at Bandarawela, Sri Lanka.

Table 6. Varietal performance of potato as influenced by drainage at a Bandarawela site, Sri Lanka, 1978-79.

Variety	Mean sprouting percentage [a]		Mean tuber yield (t/ha)	
	Well-drained	Imperfectly drained	Well-drained	Imperfectly drained
Coliban	85.7	93.7	4.5	4.7
Sequia	87.2	95.4	4.5	4.6
Desiree	85.0	91.8	4.3	4.2
Deliware	84.1	96.4	4.5	3.9

[a] LSD (soil type): 5% = 3.90, 1% = 5.23, C.V. = 7.37%.

Table 7. Performance of bush bean as influenced by drainage, Bandarawela site, Sri Lanka, 1978-79.

Variety	Yield (t/ha)	
	Well-drained	Imperfectly drained
Top - crop	21.4	8.5
Wade	18.0	8.6
Canadian Wonder	42.4	11.5
Contender	24.0	12.2

All bean varieties suffered severe disease attack in the imperfectly drained soils. This phenomenon was well marked in the soils where the gley layer was found above 60 cm.

Estimation of rice yield

A crop-cut survey of rice grown by farmers with their management was made to estimate yields. Yields of varieties extrapolated on a net area basis were BG 90-2, 6.8 t/ ha; MI 273, 6.5 t/ha; and H4, 6.1 t/ha. The high yields were obtained with minimum inputs. The only fertilizer used was a little urea as topdressing.

Rice varietal trial at the Bandarawela Research Station

The performance of several rice varieties was studied at the Bandarawela Research Station (Table 8). The farmers grew the traditional 4-4.5-month varieties such as H4 and MI 273. The test showed that no significant differences exist between the late and early varieties.

Table 8. Rice yields at the Bandarawela Research Station, Sri Lanka, 1978-79.

Variety	Maturity (days)	Yield (t/ha)
BG 334-1	142	7.1
BG 90-2	132	6.7
BW 248-1	126	7.1
H4	126	6.0
BG 401-1	116	6.6
BG 94-1	110	7.2
BG 304-1	110	7.4

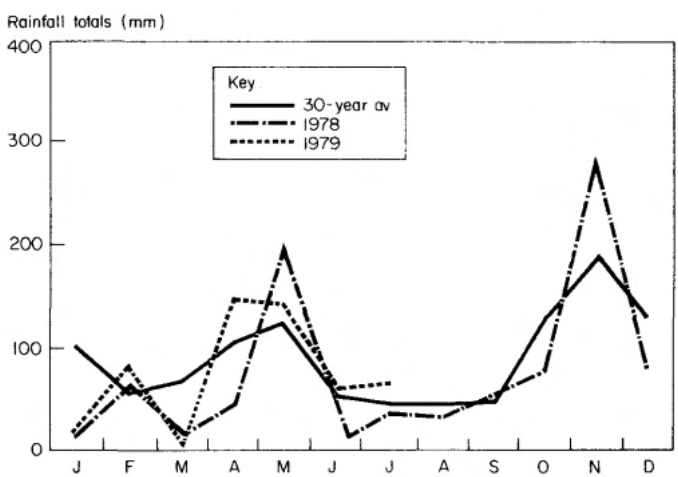
Potato, vegetables, cereal crops such as triticale and wheat, and garlic were also included in the program to ascertain the possibility of including them in the cropping patterns.

THE MAHAWELI PROJECT

Mahaweli, the largest irrigation project in Sri Lanka, involves the development of 400,000 ha of irrigated rice lands in the Dry Zone. Of this, almost 40% are existing paddy lands and some settlements are 40 years old. Each farmer was allocated 2.02 ha of paddy lands, 1.21 ha of upland, and a house. The more recent allotment size for a farmer is 0.81 ha of paddy lands and 0.20 ha of highland for homestead. The agroecological environment is similar to that of Walagambahuwa.

The cropping systems activities at Mahaweli were initiated with a program to monitor resource utilization at three sites of different farm sizes, farm communities, and age of settlements. The data collected in 1978-79 clearly demonstrated that:

1. The old settlements have a poor infrastructure for development in the production complex. Farms, whether 0.81 ha or 2.02 ha are equally efficient in performing operations irrespective of size. The farmers seem to be well aware of their resources and act accordingly. For instance, farmers with 2.02-ha used mostly tractor power, whereas farmers with 0.81 -ha used either the two-wheel tractor or mamoty.
2. The down-canal effect is well demonstrated in all the three sites. The resource use pattern down the canal is a pure function of the age of the farm, resource availability, and infrastructural development.



5. Annual rainfall pattern distribution at Angunakolapelessa, Sri Lanka.

Table 9. Rice varietal evaluation in Walawe, Sri Lanka, 1978-79.

Variety	Yield (t/ha)
Dry-seeded conditions with supplementary irrigation	
BG 90-2	4.29
BG 94-1	5.11
BG 34-6	5.16
62-355	4.21
Traditional methods (puddled and supplemental irrigation)	
BG 11-11 (red)	2.44
BG 90-2	4.04
A 66-2	2.81
Ponni	3.69

Table 10. Green gram varietal test, Walawe, Sri Lanka, 1978-79.

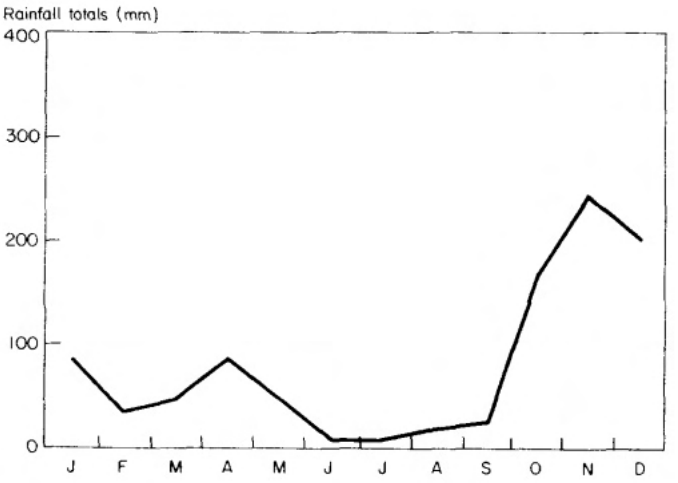
Variety	Yield (t/ha)
M1-4	1.0
H-104	0.51
Type 51	1.64
Sel 76-236	1.41
MI-1	1.33
MI-2	1.28

THE ANGUNAKOLAPELESSA PROJECT

The Angunakolapelessa project is in the southern Dry Zone in the Walawe Irrigation Scheme. Because the Government's policy is to develop this area as a cotton belt, the anticipated cropping patterns are:

- Rice - cotton in highlands, and
- Rice - rice in lowlands.

The rainfall distribution and the soil groups in the area are similar to that of the northern Dry Zone (Fig. 5). The soil problems that exist are largely salinity due to



6. Annual rainfall pattern distribution at Mannar, Sri Lanka.

long-term excessive irrigation effect.

In the upper part of Walawe — Uda Walawe — which is the upper end of the irrigation network, the practice of doublecropping rice has greatly reduced the anticipated double-cropping of rice in the lower end of the irrigation network — lower Walawe region. Therefore double-cropping has to be discouraged in the upper part of Walawe in the long run.

Cropping system activities are testing alternative crops on the research farm as well as in farmers' fields. Some results of the experiments conducted are shown in Tables 9-10.

THE MANNAR PROJECT

The Mannar project is in the northwestern coastal belt, an important rice-producing area. The project is in one of the drier parts of the Dry Zone with a rainfall distribution similar to that of Paranthan (Fig. 6). The rice lands are irrigated by the giant tank and tube wells. Late cultivation is a constraint to double-cropping. Salinity buildup from excessive irrigation from the tube wells is also a constraint to increasing agricultural production.

Cropping systems activities have focused on early cultivation to make maximum use of rainfall for wet-season crops, and monitoring of irrigation water from the tube wells for the possible buildup of salinity.

DISCUSSION

Khan: I am not clear on what you meant by well-drained and improperly drained conditions. I am also surprised at the apparent higher potato yields in improperly drained soils. Could you quantify *improperly drained* condition?

Fernando: Well-drained, imperfectly drained, and ill-drained classes are the accepted distribution of land down the catena with respect to hydrological condition. Imperfectly drained land is the intermediate where the water table depth fluctuates at an intermediate depth. When you examine a profile you shall see signs of mottling.

The reported higher potato yields in the imperfectly drained soils is not true. The table shows similar marketable tuber yields in both classes.

Brady: Is there a clear understanding between the cropping systems research program and the decision makers in the agricultural sector in Sri Lanka?

Fernando: There is a perfect understanding between the cropping systems research program and the policy makers on the one hand, and between cropping systems research workers and extension workers on the other. Some results of the program have been extended to several districts of the dry zone of Sri Lanka through extension in the minor tank village settlements.

The Deputy Minister of Agricultural Development and Research has shown a keen interest in some of the concepts we have developed in the cropping systems program and has requested all extension officers in the Department of Agriculture to adopt the methodologies in their respective districts. Farmers in some districts, for example those in the Kurunegala district, have shown acceptance of these results.

Cropping pattern testing in Nepal

M. L. Malla, A. H. Manzano, R. N. Mallick, D. C. Pathic,
M. G. Van Der Veen, and S. B. Mathema

Nepal's agriculture is highly intensive, a situation that creates strong interactions among various elements on a farm, and makes on-site evaluation of new crop technology necessary. Cropping systems research in farmers' fields started in Nepal in summer (monsoonal season) 1977. Initially, Parsa (Central Development Region) and Pumdi Bhumdi (Western Development Region) were selected. Three more sites — Chauri Jahari (Far Western Development Region), Lele (Central Development Region), and Khandbari (Eastern Development Region) — were added. Four of the sites are in the hills and one is on the plains (Fig. 1). Priority was given to hill sites where 60% of the population live and farming is at the subsistence level.

In the initial phase of the program, the existing predominant cropping patterns at the sites were identified, new cropping patterns were designed, and field trials were

1. Cropping systems sites of Nepal.

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initiated to

- test available technology,
- identify constraints faced by the farmers in adopting these technologies, and
- get acquainted with farmers' practices so as to make the necessary adjustments to the technology generated and recommended in the country for increased productivity of the small farms.

This paper summarizes the results in the initial 2 years of cropping pattern testing.

METHODOLOGY

Determination of land categories

At all the sites, the farmers' fields were grouped according to land type (upland or lowland), water availability, and fertility level. The number of categories varied from site to site, but the maximum was four.

Number of patterns

The number of patterns per land category also varied from site to site, but generally two or three cropping patterns covered most of the cultivated area in each category.

Arrangements with participant farmers

Free inputs (seeds, fertilizers, pesticides) were supplied to the farmers who supplied all labor for crop management. At harvest, samples were taken from each field for yield evaluation. The sample product was returned to the farmers once the sample had been processed and proper data recorded.

Replications per pattern

Each pattern was tested in four fields in each category. Each field (about 0.1 ha) belonged to one or more farmers.

Data collection

Rainfall, maximum and minimum temperature, and relative humidity data were collected daily at all sites. Field characteristics were given by the description of each category. Soil samples were chemically analyzed before each cropping pattern component crop was planted. The land category gave information about production potential. This last, in turn, was determined by the use of compost, water availability, slope, plot shape, size, etc.

Crop records described the management of each crop, its agronomic performance, crop type, crop variety, previous crops, land preparation schedule, use of compost, planting dates, seed treatments, planting methods, fertilization practices, and pest control. At harvest time, records on number of productive tillers, degree of lodging, and plant height were taken. Crop yields were estimated by taking 2 samples of 5 or 10 m^2 in each field.

CROPPING PATTERN TESTING

Pumdi Bhumdi

Site description. Pumdi Bhumdi lies in the midhills of the western development region. The site is 8 km west of Pokhara airport, in Kaski district. Lands in the area

are at elevations of 750-1,270 m. Average annual rainfall is about 4,000 mm. Rice and maize receive 95% of the total rainfall, and winter crops receive about 5%. Hail damage on crops is a serious problem, which generally occurs from mid-September to mid-November, from mid-February to mid-March, and occasionally in May and June.

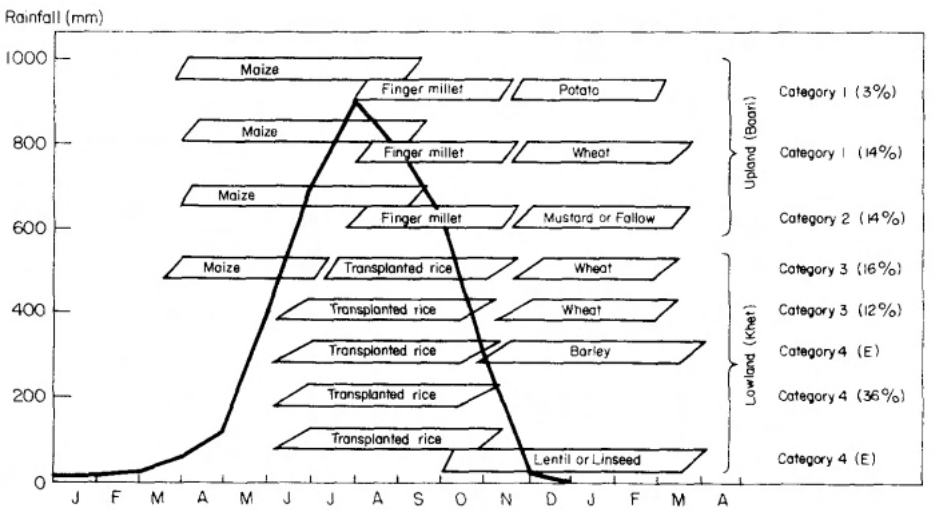
An intricate water diversion system built by farmers catches nearly all village runoff water for use in the paddies as supplemental irrigation. The system holds erosion to a minimum, and moves nutrients from animal and human wastes dropped in village walkways and public areas into the paddies.

Farm size in Pumdi Bhumdi is small — an average of 0.75 to 0.45 ha. More than 85% of the landholdings are less than 0.75 ha, and less than 10% are larger than 1 ha.

Cropping patterns tested. In 1977 19 cropping patterns were designed and tested in the Pumdi Bhumdi site. A large number were designed to introduce minor crops (especially grain legumes) and fodder crops in the cropping systems. Initial results indicate that the inclusion of grain legumes like lentils, pea, mungbean, soybean, and fodder crops like oats demanded additional management techniques that the farmers were not in a position to adopt. Additional information on varietal performance, planting dates, land preparation, insect control, crop population ratios, and labor demands had to be obtained through researcher-managed trials.

Focus of the research in the area was on improved productivity of the more common cropping patterns. Introducing improved techniques for component crops in double - and triple-cropped areas and testing new cropping patterns in areas where a single crop was grown received priority.

Figure 2 shows the existing predominant cropping patterns in each land category and the percentage of the area devoted to each pattern. Cropping pattern technology is given in Table 1.



2. Predominant and recommended (E) cropping patterns in different land categories, and rainfall distribution, Pumdi Bhumdi, Nepal.

Table 1. Present and potential cropping pattern technology in Pumdi Bhumdi, Nepal, 1977-79.

Cropping pattern [a]	Variety	Fertilizer (kg NPK/ha)	Seed rate (kg/ha)	Compost
Category 1 – Uplands with high production potential				
Maize/finger millet -wheat				
1. F) Maize	Local	–	120,000/40,000	Yes
Finger millet	Local	No	–	No
Wheat	Local	No	75	Yes
FI) Maize	Improved	45 kg/ha	120,000/40,000	Yes
Finger millet	Local	No	–	No
Wheat	RR 21	60 to 80 kg N/ha	150	Yes
Maize/finger millet - potato				
2. F) Maize	Local	No	120,000/40,000	Yes
Finger millet	Local	No	–	No
Potato	Local	40-80-0	200	Yes
FI) Maize	Local	No response	–	Yes
Finger millet	Local	Nontested	–	No
Potato	Kufri-Jyoti	40-80-30	–	Yes
Category 2 – Uplands with low production potential				
Maize/finger millet - mustard				
3. F) Maize	Local	No	60,000/40,000	Yes
Finger millet	Local	No	–	No
Mustard	Local	No	–	No
FI) Maize	Khumaltar yellow	30-30	53,000 plants/ha	Yes
Finger millet	Local	No	–	No
Mustard	Local	30-30	–	No
Category 3 – Lowlands with high production potential				
Rice - wheat - maize				
4. F) Rice	Gurdi	12-0-0	–	Yes
	Gurdi/Mansara	12-0-0		
Wheat	Local	No	75-80	Yes
Maize	Local	No response to low dosages	120,000/40,000	Yes
FI) Rice	IET 1444	45-0-0	40	Yes
Wheat	RR 21	75-40-0	150	Yes
Maize	Local	No economic response	120,000/40,000	Yes
Rice -wheat - fallow				
5. F) Rice	Gourdi	No		No
Wheat	Local	No	75-80	Yes
FI) Rice	Taichung	45-04	40	Yes
Wheat	RR21	7540-0	150	Yes
Fallow				
Category 4 – Lowlands with low production potential				
Rice - fallow - fallow				
6. F) Rice	Thima	No	–	Yes
FI) Rice/lentil				
Rice	CH 45	45-0-0	40	Yes
Lentil	Pusa	No	40	No
7. F) Rice	CH 45	45-0-0	40	Yes
Linseed	Pusa	No	20	No
	Local			
FI) Rice - barley	CH 45	45-0-0		
Barley	Bonus	30-30-0		

[a] F = farmers' present pattern, FI = farmers' improved pattern, / = relayed.

Results. Total yield, percent increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns are presented in Table 2. The results are summarized:

1. Four land categories were identified: category 1, upland with high production potential; category 2, upland with low production potential; category 3, lowland with high production potential; and category 4, lowland with low production potential.
2. The production potential of the different fields is determined, first, by water availability and, second, by soil fertility which is related to soil type, intensity of erosion, and compost use.
3. Land use intensity and percentage of total area in each of the four categories follow:

Table 2. Total yield production, percentage increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns, Pumdi Bhumdi, Nepal, 1978-79.

	Cropping pattern [a]	Total production (t/ha)	Increase (%)	Change in cash costs (Rs/ha)[b]	Change in net revenue (Rs/ha)[b]	Benefit-cost ratio
	Category I — Upland with high production potential					
1.	F) Maize (L) /finger millet (L) - wheat (L)	4.70				
	FI) Maize (I) /finger millet (L) -wheat (I)	6.74	43	322	5,594	17.4
2.	F) Maize (L) /finger millet (L) - potato (L)	3.50[c] 12.4				
	FI) Maize (I) /finger millet (L) -potato (I)	5.4[c] 13.2	54 6	88	5,026	57.1
	Category 2 — Upland with low production potential					
3.	F) Maize + finger millet (L) - mustard	2.39				
	FI) Maize (I) /finger millet (L) - mustard	2.82	4	681	372	0.45
	Category 3—Lowland (khet) with high production potential					
4.	F) Rice (L) - wheat (L) - maize (L)	5.24				
	FI) Rice (I) - wheat (L) - maize (L)	6.90	33	878	2,447	2.8
5.	F) Rice (L) -wheat (L) - fallow	3.24				
	FI) Rice (I)-wheat (L) - fallow	5.40	35	938	2,007	2.14
	Category 4 — Lowland with low production potential					
6.	F) Rice (L)- fallow - fallow	1.60				
7.	E) Rice (I)/lentil	3.60	125	294	5,888	20.0
8.	E) Rice (I)/linseed	2.77	73	294	3,294	11.2
9.	E) Rice (I) -barley	4.30	168	875	4,823	5.5

[a]F = farmers' pattern, L = local variety, FI = farmers' improved pattern, I = improved variety, E = recommended pattern. [b]US$1 = 11.90 rupees. 'Yield of maize and finger millet.

Category 1, 3 crops/year, 17%
Category 2, 2 crops/year, 15%
Category 3, a. 3 crops/year, 14%
b. 2 crops/year, 12%
Category 4, 1 crop/year, 38%

4. Cropping patterns in Category 1 and 2 (uplands) are maize based. In category 1, the predominant cropping pattern was maize relayed with finger millet and followed by wheat. In category 2, the predominant cropping pattern was maize relayed with finger millet and followed by mustard. In all cases, beans (soybean, mungbean, other beans) were mix-cropped with maize.
5. Increasing production in lands of category 1 lies mainly in replacing local varieties with improved varieties and improved management.
6. The total production in the predominant cropping pattern in lands of category 1 (maize/finger millet - wheat) could be increased 43% by replacing the local varieties of maize and wheat with the improved variety of maize, Khumaltar Yellow, and the improved variety of wheat, RR 21. This increase represented a change in net revenue of Rs 5,594/ha (US$1 = Rs 11.90) with an added cost of only Rs 322, or a benefit-cost ratio of 17:1. The added cost included the costs of fertilizers and insecticides used in the pattern.
7. Level of cash inputs for improving the performance of existing patterns in soils of category 1 was low.
8. Possibilities for increasing crop production in lands of category 2 are low. Farmers who own these lands have very limited resources. They do not own animals for power and compost production. Soil fertility is low, soils are eroded, and their capacity to retain moisture is very low.
9. Lowlands occupy about 60% of the total cultivated area of Pumdi Bhumdi. Cropping patterns are rice based.
10. In lowlands in category 3, the predominant patterns were rice - wheat -maize and rice - wheat - fallow. Compost use determined the land's organic matter content and in general its production potential. Supplemental irrigation was available during the monsoon.
11. In the cropping pattern rice - wheat - maize, the turnaround time was limited. In some cases, the harvest of crops that had not reached full maturity created difficult postharvest management and reduced final yields.
12. Total grain production with local techniques in lands of category 3 was 5.24 t/ha. Introduction of improved techniques raised the total production to 6.9 t/ha, a 33% increase. The change in net revenue was Rs 2,447/ha, that in cash costs was Rs 878.
13. Improved rice varieties Taichung 176, IET1444, and CH45 matured earlier than most local varieties. That allowed more turnaround time in the triple- and double-cropped area and a more efficient use of residual soil moisture for growing a relay crop in the single-crop area, or an additional crop in sequence.
14. Taichung 176 was suitable for lowlands in category 3 with permanent water supply for supplemental irrigation during the monsoon season. Under those conditions, Taichung 176 produced 3.40 t/ha, whereas the local varieties produced 2 t/ha.

15. The rice variety IET1444 was suitable for lowlands in category 3 with some limitations for supplementary irrigation during the monsoon season. (It yielded 500 kg/ha less than Taichung 176, but 900 kg/ha more than the local varieties yielding only 2 t/ha.)
16. CH45 was suitable for lowlands in category 4. It did not yield much higher than the local variety, but allowed better use of the residual soil moisture for growing a relay crop and offered real potential for escaping hail damage.
17. The potential for increasing production in lands of category 4 lies in the a) replacement of the local varieties with improved ones, b) possibility of relaying a crop into rice, and c) possibility of planting a drought-resistant crop like barley or sorghum immediately after rice harvest.

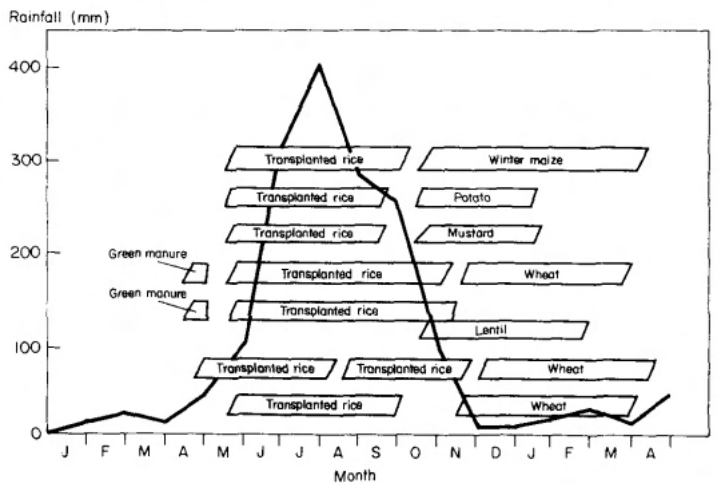
Parsa (irrigated area)

Site description. Dhobini-Langari is in the plain of Nepal about 30 km west of Birgunj in Parsa district. The lands are relatively flat and are irrigated from the Gandaki Canal of the Narayani Zone Irrigation Development Project. An average of 1,500 mm of rain falls at the site yearly. Peak rainfall occurs in June through September, with an average of 200 mm.

The average landholdings range from 0.5 to 1.2 ha. Close to 50% are less than 0.34 ha, and 4 to 36% are larger than 6.8 ha.

Almost all the fields in the area are lowlands with available irrigation. The land has been classified into two classes, high production potential and low production potential, based on observations on crop performance and information given by the farmers.

Cropping patterns. The cropping pattern studies in the irrigated area of Parsa started in monsoon season 1977. Five patterns were tested in lands with high production potential and one pattern was tested in lands with low production potential. Present and experimental cropping patterns are given in Figure 3. The



3. Predominant and experimental cropping patterns, and rainfall distribution, Parsa (irrigated area), Nepal.

crop technology used for the different crops is presented in Table 3.

Results. Basic data on agronomic and economic performance of the tested cropping patterns are given in Table 4. Results at this site were:

1. Two land categories (high and low production potential) were identified, but a more precise land classification is needed. Two or three crops are grown in lands with high production potential, but only one crop is grown in lands with low production potential. Soil analysis indicated that available nutrients, nitrogen, phosphorus (Bray I), and organic matter were all low.
2. The total production for the cropping pattern rice - rice - wheat can be increased 95% with the use of improved varieties and improved management. Major increases in production were due to the replacement of the local rice variety in the first crop by an improved one. An improved variety in the second crop did not contribute significantly to increased yield of the pattern. There is a need to identify an improved variety of rice to be planted as a second crop.
3. The rice variety CH45 produced 3.3 t/ha when fertilized with 40-20-20 kg NPK/ha. Other improved varieties, Chandina and Parwanipur 1, produced similar yields (3.4 and 3.0 t/ha), but only with a higher level of fertilizer (75-20-20 kg NPK/ha).

Table 3. Present and potential crop pattern technology, irrigated area, Parsa, Nepal, 1977-79.

Cropping pattern	Variety	Fertilizer (kg NPK/ha)	Seed rate (kg/ha)
	Category 1 (high fertility)		
1. Rice - rice - wheat			
Rice	Parwanipur	75-20-20	40
	Chandina	75-20-20	40
	CH 45	40-20-20	50
	Local	10-0-0	50
Rice	Parwanipur	80-20-20	40
	Local (Handiful)	15-0-0	50
Wheat	RR 21	80-25-20	120
	RR 21 (farmers' field)	—	
2. Rice -wheat			
Rice	Parwanipur 1	80-40-20	40
	Masuli	0	40
	Local	0	50
Wheat	RR 21	60-40-30	120
	RR 21 (farmers' field)	30-30-0	120
Rice	High yielding variety	60-20-20	40
	Handiful	9-0-0	50
Wheat	RR 21	80-25-20	120
	RR 21 (farmers' field)	—	120
3. Rice - potato			
Rice	HYV (II)	80-20-20	40
	Local (Handiful)	9-0-0	50

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TABLE 3 CONTINUED

Cropping pattern	Variety	Fertilizer (kg NPK/ha)	Seed rate (kg/ha)
Potato	Kufri/Sinduri	60-30-30	800
Potato	Local (Dist.)	–	–
Potato	Local (Dist.)	80-40-80	800
Potato	Local (Dist.)	100-75-100	800
4. Rice - mustard			
Rice	HYV	80-20-20	40
	Local	9-0-0	50
Mustard	Type 9	60–40-20	–
	Local	60-40-20	20-30
	Local		
5. Rice - lentil			
Rice	HYV (II)	80-20-20	40
	Local	9-0-0	50
Lentil	Local	20-20-0	30
	Local	0-0-0	30
Category 2 (low fertility land)			
6. Green manure -rice - wheat			
Rice	Masuli (8)	40-0-0	40
	Local	9-0-9	50
	Handiful		
Wheat	RR 21 (1-8)	80-25-20	120
	RR 21 (farmers)	–	130

4. In all cropping patterns presently grown in lands with high production potential, total production can be increased 30% or more.
5. In the predominant cropping pattern rice - wheat - fallow, total production rose from 3.7 t/ha with local practices to 6.6 t/ ha with replacement of the local rice variety by Parwanipur 1 and improvement of farmers' management of wheat variety RR 21. The increase in net return in relation to the existing pattern was Rs 3,228/ha with an added cost of Rs 1,132.
6. Results indicate that local rice varieties planted in the normal season (late July to mid-August) should be changed to improved varieties such as the recently released Sabitri (IR2071-124-6) and Janaki (BG90-2).
7. The local varieties planted in the early season should be replaced with early improved varieties Laxmi (IR2061-628), Chandina, Durga (IFT2938), and Parwanipur 1. These varieties produce about double the yields of the local ones and leave more time for the second crop of rice.
8. Maximum change in net revenue (Rs 9,921/ ha) was obtained with the improved cropping pattern rice - potato. Adoption of improved technology may be limited by marketing problems and the difficulty of getting good quality seed potato. Any of the early season improved varieties can be planted in this pattern. The more suitable variety was Kufri Sinduri.
9. Total production of the cropping pattern rice - mustard was increased 41% by

Table 4. Total yield production, percentage increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns. Parsa (irrigated area), Nepal, 1977-79.

Cropping pattern[a]	Total production (t/ha)	Increase (%)	Change in cash costs (Rs/ha)[b]	Change in net revenue (Rs/ha)[b]	Benefit-cost ratio
Category 1 (high production potential)					
1. F) Rice (L) - rice (L) - wheat (I)	4.1				
FI) Rice (I) - rice (L) - wheat (I)	1.7	88	1,259	3,201	2.54
FI) Rice (I) - rice (I) - wheat (I)	8.0	95	1,784	3,129	1.75
2. F) Rice (L) -wheat (I) - fallow	3.1				
FI) Rice (I) - wheat (I) - fallow	6.6	78	1,132	3,228	2.85
FI) Rice (I) -wheat (I)	5.1	38	1,132	961	0.85
3. F) Rice (L) - potato (L)	2.3 + 7.5				
FI) Rice (I) - potato (I)	3.4 + 13.8	47-84	1,190	9,921	8.34
4. Rice (L) - mustard (L)	2.9				
Rice (I) - mustard (I)	4.1	41	607	1,456	7.40
5. F) Rice (L)/lentil (L)	2.8				
Rice (I)/lentil (L)	4.3	54	832	2,028	2.44
Category 2 (low production potential)					
6. F) Rice (L) -wheat - fallow	3.6				
FI) Rice (I) - wheat - green manure	4.5	25	852	411	0.56

[a]F = farmers', FI = farmers' improved, L = local variety, I = improved variety. [b]US$1 = Rs 11.90.

replacing the local rice variety with an improved one. Replacing the local variety of mustard with the improved Type 9 produced an increase of only 100 kg mustard grain/ha. There is a need for better yielding mustard varieties.

10. Production in the pattern rice/ lentil was increased 54% by replacing the local rice variety with an improved one and by using improved management on lentil. The increase in net return introducing the mentioned changes was Rs 2,028/ha.
11. Wheat and chickpea intercropping was found unsuitable because of farmers' water management techniques. Temporary flooding of wheat fields damaged the chickpea.
12. Intercropping of wheat and maize appeared promising, if maize is harvested for fodder,
13. Precise schedules for release of water for irrigation are necessary for proper planning of double- and triple-crop patterns in the area.
14. Major potential for improving present farmers'cropping patterns production lies in the replacement of the local varieties of rice with improved ones, and increasing land use intensity if water is available on time.
15. Research is needed for improved water management practices, a more precise land classification, better yielding varieties of rice and mustard, efficient use of fertilizer, and identification of farmers' constraints in the adoption of technology.

Parsa (partially irrigated and rainfed)

Site description. The research on partially irrigated and rainfed areas is in Sukchaina village of Parwanipur in Pars district. The site is between the Birgunj and Parwanipur Agriculture Stations. The altitude is 100 m and mean annual rainfall is about 1,200 mm.

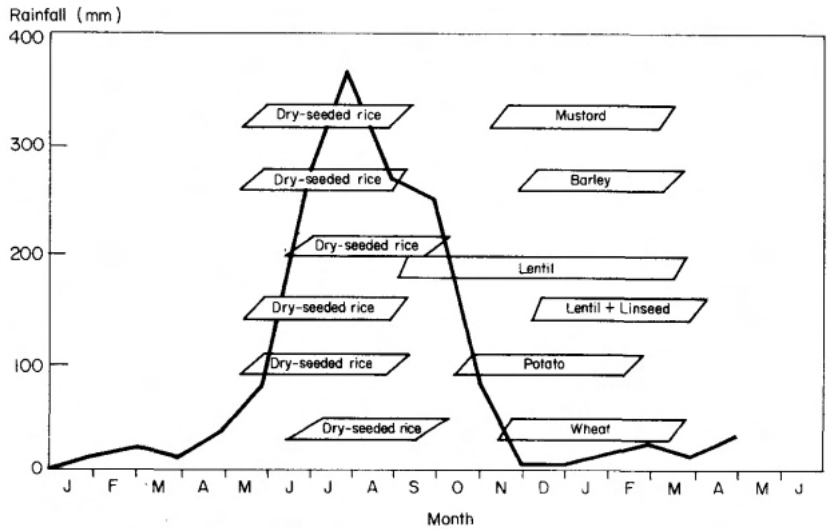
The average landholding is 1.92 ha/family. Rainfed rice is grown in 95% of the land and the remaining 5% is devoted to finger millet in the rainy season. High yielding rice (usually CH45) is grown in 25% of the cultivated area. Wheat is grown in 25% of the land and legume is grown in the other 15% during winter. The rest of the area remains fallow.

The areas were classified in two categories — rainfed and partially irrigated — but most of them were rainfed. Some fields are irrigated either by lift irrigation or by canal. Water availability is uncertain.

Cropping patterns tested. The predominant and experimental cropping patterns and rainfall distributions are presented in Figure 4. The technology for each crop of the patterns is given in Table 5.

Results. Total yield production, percent increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns are presented in Table 6. The results are:

1. The total grain production of the rice - wheat pattern can be increased 87% if improved varieties and technology are used. Improved technology in those patterns had a cash cost of Rs 834, which produced a change in net revenue of Rs 2,000/ha.
2. Total production of the rice - mustard pattern was increased by replacing the



4. Predominant and experimental cropping patterns, and rainfall distribution, Parsa (rainfed area), Nepal.

local variety of rice with the improved IET1444 and by using fertilizer (40-40-20 NPK) on the local mustard variety. The change in cash cost in this case was Rs 777 and the change in net revenue was only Rs 511. From both the economic and agronomic viewpoints, the rice - wheat pattern was superior to rice - mustard. The farmers' preference for these patterns depends on the soil production potential, compost availability, and residual or added soil moisture.

3. As in the preceding cropping patterns, improved technology can increase production in the patterns rice/lentil (lentil relayed in rice fields) and rice -barley. In both cases yields can be increased by more than 90%, with changes in net revenue of more than Rs 1,500.
4. The rice varieties CH45, Masuli, and experimental varieties IET1444 and B9C can be substituted for the local varieties. Yields of rice are increased by improving local agronomic practices. Line transplanting in partially irrigated fields and line seeding in upland fields increased yields over those from random transplanting in irrigated areas and broadcasting in uplands.
5. Research in rainfed areas needs to: a) test rice varieties for upland conditions; b) identify causes of physiological disorders in rice; c) identify disease-resistant lentil varieties; d) introduce new minor crops; e) recommend weed control in uplands; and f) select suitable varieties of groundnut and soybean for rotation programs.

Chauri Jahari

Site description. Chauri Jahari is in the southwest corner of Rukum district in the Far Western Development Region. The project area is generally flat at an altitude of

Table 5. Present and potential cropping pattern technology, Parsa (rainfed area), Nepal, 1977-79.

Cropping pattern [a]	Variety	Fertilizer (kg NPK/ha)	Seed rate (kg/ha)
1. Rice - wheat			
F) Rice (L)	Local	15-15	50
Wheat (L)	Local	0	120
FI) Rice (I)	CH 45	40-20-20	50
Wheat (I)	RR 21	75-20-15	120
2. Rice - mustard			
F) Rice (L)	Local	15-15	50
Mustard (L	Local	0	
FI) Rice (I)	IET 1444	40-20-20	50
Mustard (L	Local	40-40-20	50
3. Rice/lentils			
F) Rice (L)	Local	15-15	59
Lentils (L)	Local		30
FI) Rice (I)	B9C	40-20-20	50
Lentils (I)	P 43		40
4. Rice -barley			
F) Rice (L)	Local	15-15	50
Barley (L)	Local		110
FI) Rice (I)	B 9C	40-20-20	50
Barley (I)	HBL 56	30-30-20	110
5. Rice - wheat			
F) Rice (L)	Local	15-15	50
Wheat (L)	Local	0	120
FI) Rice (I)	Masuli	40-20-20	50
Wheat (I)	RR 21	75-20-15	120
6. Rice - potato			
ACP) Rice (I)	IET 1444	40-20-20	50
Potato (I)	Kufri Jvoti	60-60-30	800

[a] F = farmers', FI = farmers' improved, L = local variety, I = improved variety.

700 m and is surrounded by hills. The total cropped area is 600 ha. Of the 600 ha, 450 are uplands with slope ranging from 0.5 to 3%; the other 150 ha near the foothills are terraced lands. The Government completed a hill irrigation scheme in 1976 through the Chauri Jahari Tar Irrigation Project.

The site is a 4–6 day trek from the closest motorable road. It has a weekly plane service to Kathmandu and Nepalgunj. The average precipitation is about 1,100 mm. The peak rainfall period is in July. June, July, and August receive more than 200 mm rain, adequate to support a crop of dryland rice. The other months have very low rainfall that seriously limits crop production, especially during winter, where irrigation is not available. Freezing weather occurs in December, January, and February.

Table 6. Total yield production, percentage increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns, Parsa (rainfed area), Nepal, 1977-79.

Cropping pattern [a]	Total production (t/ha)	Increase (%)	Change in cash costs (Rs/ha)[b]	Change in net revenue (Rs/ha)[b]	Benefit-cost ratio
Category 1 – Rainfed					
1. F) Rice (L) - wheat (L) - fallow	2.51				
FI) Rice (I) -wheat (I)	4.70	87	834	2,022	2.42
2. F) Rice (L) - mustard (L)	2.14				
FI) Rice (I) - mustard (L)	4.13	93	717	511	0.66
3. F) Rice (I)/lentil (L)	1.69				
FI) Rice/lentil	3.36	99	270	1,863	6.9
4. F) Rice (L) -barley (L)	2.04				
FI) Rice (L) -barley (L)	3.84	88	664	1,520	2.29
Category 2 – Partially irrigated					
5. F) Rice (L) -wheat (L)	2.45.				
FI) Rice (I) -wheat (I)	4.68	91	834	1,958	2.35
6. F) Rice (I) - potato (L)					
FI) Rice (I) - potato (CPA)	3.4 + 10.7	49**	811	4,439	5.41

[a]F = farmers', FI = farmers' improved, I = improved variety, L = local variety. [b]US$1 = Rs 11.90. **Increase in potato yields only.

Hailstorms from February to May are a problem in some years and seriously affect the wheat crop.

The Chauri Jahari Tar Irrigation Project supplements the rainfall of the area. If irrigation is properly scheduled, the area could grow three crops a year, with spring maize or early rice in some places.

The average farm in Chauri Jahari varies from 0.5 to 1.15 ha. The most common landholding ranges from 0.25 to 0.50 ha, but some farmers have larger than 1 ha.

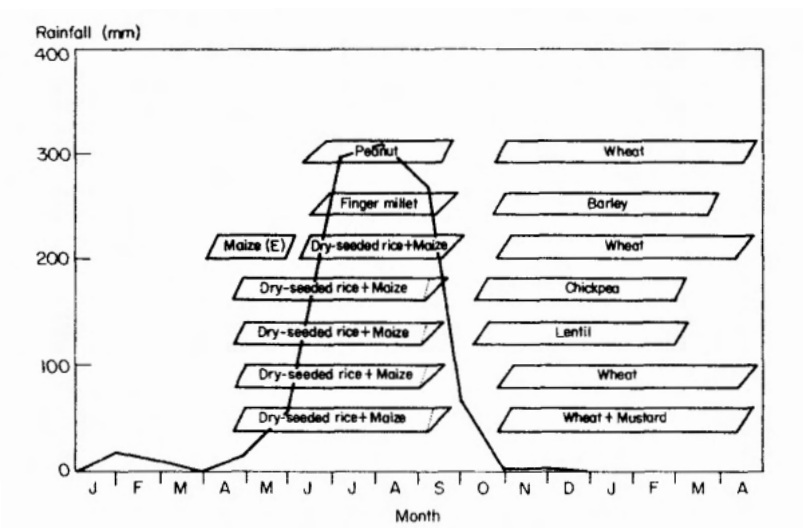
The village has an Agricultural Inputs Corporation sales depot and a cooperative to supply seeds, fertilizers, and chemicals. Some farmers get credit from the Agricultural Development Bank.

Cropping patterns tested. The predominant cropping patterns are rice based. In the uplands, rice is mix-cropped (+) with maize in the monsoon. Wheat is planted during winter in areas with irrigation or where soil residual moisture is high. In the lowlands, the predominant cropping pattern is rice - wheat. Some minor crops (lentil, chickpea, linseed) are also components of cropping patterns. The predominant and experimental cropping patterns and rainfall distribution are shown in Figure 5. Technology for the different cropping patterns is summarized in Table 7.

Results. The agronomic and economic performance of the predominant cropping patterns as managed by farmers and when improved technology is used is given in Table 8. The summary of the results follows:

1. The predominant cropping pattern in uplands of the area is rice + maize -wheat. Other cropping patterns covering only about 10% of the upland area are finger millet - barley, peanut - wheat, rice + maize - legume (lentil or chickpea).

2. A small area of leveled terraces is in the foothills close to and parallel to the main irrigation canal. Two crops rice - rice or rice - wheat are planted. A third



5. Predominant and experimental cropping patterns, and rainfall distribution, Chauri Jahari, Nepal. E = experimental cropping pattern.

Table 7. Present and potential cropping pattern technology at Chauri Jahari, Nepal, 1977-79.

Cropping pattern[a]	Variety	Fertilizer (kg NPK/ha)	Seed rate[b] (kg/ha)	Compost
Rice + maize - wheat				
F) Rice	Local	0-0-0	50	Yes
FI) Rice	IET 1444	60-30-0	50	Yes
F) Maize	Local	No	120,000/40,000	Yes
FI) Maize	Local	No	120,000/40,000	Yes
F) Wheat	Local	No	120	No
FI) Wheat	RR 21	80-40-30	120	No
Finger millet -barley				
F) Finger millet	Local	No	–	Yes
FI) Finger millet	Local	No	–	Yes
F) Barley	Local	0-0-0	110	Yes
FI) Barley	Ketch	30-30-0	110	Yes
Peanuts - wheat				
F) Peanut	Local	No	–	Yes
FI) Peanut	B4	30-30-20	–	Yes
F) Wheat	Local	No	120	Yes
FI) Wheat	RR 21	80-40-30	120	Yes
Rice + maize - wheat + mustard				
F) Rice	Local	0-0-0	50	Yes
FI) Rice	ET 1444	60-30-0	50	Yes
F) Maize	Local	No	120,000/40,000	Yes
FI) Maize	Local	No	120,000/40,000	Yes
F) Wheat	P1	No	120	Yes
FI) Wheat	RR 21	80-40-30	120	Yes
F) Mustard	Local	No	20-30	Yes
FI) Mustard	Type 9	No	–	Yes
Rice + maize -wheat vs rice + maize -wheat - maize				
F) Rice	Local	0-0-0	50	Yes
E) Rice	IET 1444	60-30-0	50	Yes
F) Maize	Local	No	120,000/40,000	Yes
E) Maize	Local	No	120,000/40,000	Yes
F) Wheat	Local	No	120	Yes
E) Wheat	RR 21	80-40-30	120	Yes
E) Maize	Local	60-40-20	120,000/40,000	Yes
Rice + maize - lentil				
F) Rice	Local	0-0-0	50	Yes
FI) Rice	IET 1444	60-30-0	50	Yes
F) Maize	Local	No	120,000/40,000	Yes
FI) Maize	Local	No	120,000/40,000	Yes
F) Lentil	Local	No	30	Yes
FI) Lentil	P2	20-20-0	30	Yes
Rice + maize - chickpea				
F) Rice	Local	0-0-0	50	Yes
FI) Rice	IET 1444	60-30-0	50	Yes
F) Maize	Local	No	120,000/40,000	Yes
FI) Maize	Local	No	120,000/40,000	Yes
F) Chickpea	Local	No	–	Yes
FI) Chickpea	Local	20-20-0	–	Yes

[a]F = farmers', FI = farmers' improved, E = experimental. [b]Figures for maize represent initial and final plant populations.

Table 8. Total yield production, percentage increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns, Chauri Jahari, Nepal, 1977-79.

Cropping pattern[a]	Total production (t/ha)	Increase (%)	Change in cash costs (Rs/ha)[b]	Change in net revenue (Rs/ha)[b]	Benefit-cost ratio
1. F) Rice (L) + maize (L) - wheat (L)	5.5				
FI) Rice (I) + maize (L) -wheat (I)	8.6	56	1,302	4,309	3.3
2. F) Finger millet (L) - barley (L)	4.6				
FI) Finger millet (L) -barley (I)	4.8	4	389	125	–
3. F) Peanut (L) -wheat (L)	6.5				
FI) Peanut (I) - wheat (I)	6.9	6	1,196	860	–
4. F) Rice (L) + maize (L) -wheat (L) + mustard (L)	5.9				
FI) Rice (I) + maize (L) - wheat (I) + mustard (I)	7.3	24	1,302	2,273	1.75
5. F) Rice (L) + maize (L) -wheat (L)	5.5				
E) Rice (I) + maize (L) -wheat (I) - maize (L)	12.8	133	1,302	10,987	8.44
6. F) Rice (L) + maize (L) - lentil (L)	5.2				
FI) Rice (I) + maize (L) - lentil (I)	6.8	24	777	2,870	3.69
7. F) Rice (L) + maize (L) - chickpea (L)	4.7				
FI) Rice (I) + maize (L) - chickpea (I)	5.9	26	777	2.235	2.88

[a]F = farmers', FI = farmers' improved, E = experimental. [b]US$1 = RS 11.90.

crop (maize) during spring is possible for harvest as green ears and the stalks used for fodder.

3. The areas along the river bank are intensively eroded. Soils are reddish with low organic matter content, and only one crop a year (sesame, finger millet, dryland rice, or maize) is grown.
4. Total production in the predominant pattern (rice + maize - wheat) was increased 50% when local varieties of rice and wheat were replaced with improved varieties of rice (IET1444) and wheat (RR21), and improved technology was utilized. Improved technology increased the yield of wheat 180% and that of rice, only 12%.
5. All areas in Chauri Jahari remain fallow from early April to mid-June. In this period a crop of maize (early variety) can be grown in areas where irrigation is available.
6. The introduction of maize as a third crop increased the total grain production to 130% over the production of the farmers' cropping pattern. Farmers' adoption of this technology was, however, limited because of the intensive care necessary to avoid damage by jackals and grazing cattle.
7. In the crop association, rice + maize, the maize yield was increased to 500 kg/ha by row planting rather than broadcasting, which is the farmers' practice.
8. Row planting of wheat (behind the plow) at a seeding rate of 120 kg/ha increased wheat yields 175% over that with the farmers' method with a saving of 40% in seed requirements.
9. Triticale is a promising crop for the area. Mean yields of 6 t/ha were observed in variety trials.
10. The lentil varieties Pusa 2 and P-43 showed good adaptation to the area and yielded 3.9 and 3.1 t/ha.
11. Research needs in Chauri Jahari are mainly a) water management, b) erosion control, c) efficiency of fertilizer use, d) crops interaction and competition, and e) introduction of minor crops.

Lele

Site description. Lele is in Lalitpur district in the Central Development Region, 15 km south of the Khumaltar Agriculture Research Farm. Total population is 5,130. The cultivated area is about 700 ha. Fifty percent of the landholdings are less than 0.50 ha. A high percentage of the farms are too small to provide enough food for the family.

The average annual rainfall is about 2,025 mm. Eighty-six percent occurs from June to October. The onset of heavy rains varies significantly from year to year, making it difficult to determine the optimum planting dates of maize and rice. Frost generally occurs from December to March, restricting the growing of crops during winter in lands at higher elevations. Hailstorms sometimes occur from March to May.

The predominant soil textures are silty and silty clay. Soil color varies from reddish yellow to dark brown. Physical and chemical properties of the soil vary widely. Soil pH values range from 4.8 to 5.5. The organic matter content varies from

1.8 to 2.8%. Levels of nitrogen and phosphorus are low to medium. Potassium content is generally high.

For cropping pattern testing the fields were classified as upland, lowland rainfed, and lowland irrigated.

The upland (category 1) receives water from rainfall only. Soils are yellow brown. Intensive erosion occurs in the fields in the upper portion of the hills. The predominant cropping pattern is maize + beans - mustard.

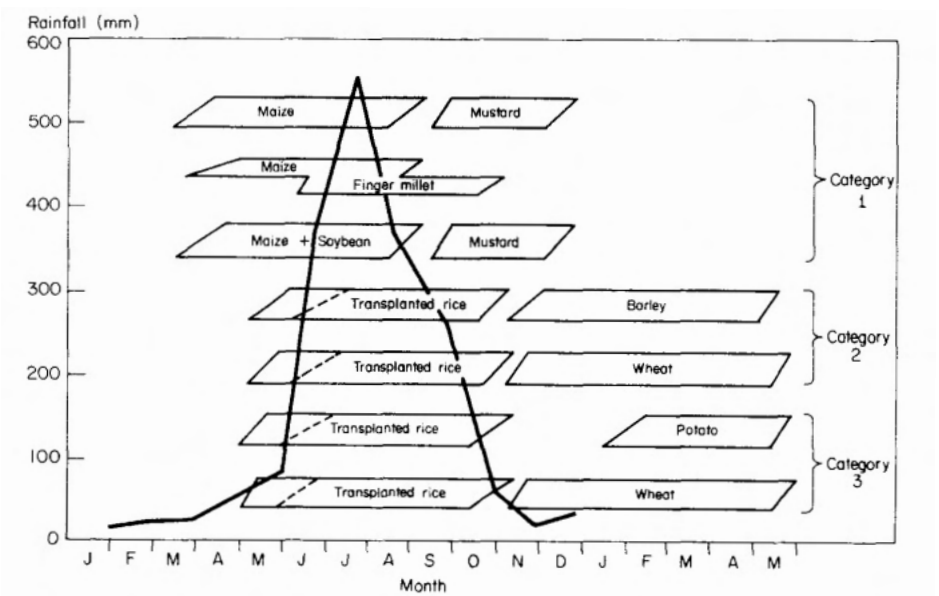
The rainfed lowland (category 2) has leveled terraces that receive rainfall and runoff during the rainy season. Soil residual moisture varies with the amount of water caught for rice cultivation during the rainy season. In areas with higher soil residual moisture, 2 crops/year are grown; in others, only one crop is possible.

In the irrigated lowland (category 3) irrigation from a Lele stream is available all year. Soils are dark brown with silty clay texture and have high production potential. Some terraces have drainage problems that limit the yield of winter crops. The predominant cropping pattern is rice - wheat.

Croppingpatterns tested. The predominant cropping patterns in each of the land categories and the rainfall distribution are presented in Figure 6. A summary of the technology assigned to the different patterns is presented in Table 9.

Results. The agronomic and economic performance of the tested cropping patterns is given in Table 10. Results are:

1. The land use intensity in Lele is:
   - Category 1 - 2 crops/year on 42%
     3 crops (mixed plus winter)/ year on 27%
   - Category 2 - 2 crops/year on 2%
   - Category 3 - 2 crops/ year on 29%



6. Predominant cropping patterns in the different land categories, and rainfall distribution, Lele, Nepal.

Table 9. Present and potential crop pattern technology, Lele, Nepal, 1978-79.

Cropping pattern[a]	Variety	Fertilizer (kg NPK/ha)	Seed rate[b] (kg/ha)	Compost
Maize + soybean - mustard				
1. F) Maize	Local	0-0-0	120,000/40,000	Yes
FI) Maize	Khumaltar yellow	60-30-0	120,000/40,000	Yes
FI) Maize	Khumaltar yellow	60-30-0	120,000/40,000	Yes
FI) Maize	Local (white)	30-15-0	120,000/40,000	Yes
2. F) Soybean	Local (white)	0-0-0	–	Yes
FI) Soybean	Hill	0-0-0	–	Yes
FI) Soybean	Local	0-0-0	–	Yes
FI) Soybean	Hill	0-0-0	–	Yes
3. F) Mustard	Local	0-0-0	20-30	No
FI) Mustard	Type 9	30-15-0	–	No
Rice -wheat (rainfed)				
4. F) Rice	Local	0-0-0	50	No
FI) Rice	Taichung	80-20-0	40	No
5. F) Wheat	RR 21	30-0-0	120	No
FI) Wheat	RR 21	60-30-0	120	No
Rice - barley (rainfed)				
6. F) Rice	Local	0-0-0	50	No
FI) Rice	CH242	80-20-0	40	No
FI) Rice	CH 2	80-20-0	40	No
7. F) Barley	Local	0-0-0	110	No
FI) Barley	Bonus	60-30-0	110	No
Rice -wheat (irrigated)				
8. F) Rice	Improved	50-0-0	40	No
FI) Rice	Taichung	80-20-0	40	No
FI) Rice	CH 2	80-20-0	40	No
FI) Rice	CH 242	80-20-0	40	No

[a]F = farmers', FI = farmers' improved. [b]Figures for maize represent initial and final plant populations.

2. On upland the production of the predominant cropping pattern maize + beans - mustard can be increased 180% by replacing the local varieties of maize and mustard with the improved maize variety Khumaltar Yellow, and the improved mustard Type 9. Using improved technology gives a benefit-cost ratio of about 7:1.
3. The local variety of soybean was intercropped with the improved maize Khumaltar Yellow. The improved soybean varieties Hill and Hardy did not fit in the cropping pattern because they matured late and were susceptible to insect attack.
4. Total production in the rainfed lowland was increased 100% in the pattern rice - wheat, and 65% in the pattern rice - barley. This land category (2) is only 2% of the total cultivated area in Lele, but the results here are relevant to land that is common in most of the hill areas of the country.

Table 10. Total yield production, percentage increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns, Lele, Nepal, 1977-79.

Cropping pattern[a]	Total production (t/ha)	Increase (%)	Change in cash costs (Rs/ha)[b]	Change in net revenue (Rs/ha)[b]	Benefit-cost ratio
Category 1 — Upland					
1. F) Maize (L) + soybean (L) - mustard (L)	2.17				
FI) Maize (I) + soybean (L) - mustard (L)	6.18	180	802	5,962.50	1.43
FI) Maize (I) + soybean (I) - mustard (I)	5.64	160	551	5,781.80	10.49
FI) Maize (L) + soybean (I) - mustard (L)	4.5	107	301	3,530.40	111.73
Category 2 — lowland, rainfed					
2. F) Rice (I) +wheat (I)	3.33				
FI) Rice (I) -wheat (I)	6.9	107	889	5,387.20	6.06
F) Rice (I) - barley (L)	4.90				
FI) Rice (I) - barley (I)	8.1	65	1101	8,771.00	1.97
Fl) Rice (I) -barley (I)	7.1	44	1101	7,039.00	6.39
Category 3 — Lowland, irrigated					
4. F) Rice (I) -wheat (I)	5.07				
FI) Rice (I) -wheat (I)	8.40	63	—	—	—[c]

[a]F = farmers', Fl = farmers' improved, I = improved variety, L = local variety. [b]US$1 = Rs 11.90. [c]Economic data to be analyzed.

5. Lands of category 3 have better production potential. The present level of technology used by farmers in the predominant cropping pattern rice - wheat is higher than technologies in other areas of Nepal; however, production was still increased by planting improved varieties of rice — Taichung 176, Chainung 242, and Chainan 2 — and raising farmers' fertilizer levels. In the pattern testing, total rice production increased from 4.3 t/ ha with the variety planted by farmers (undetermined Taiwanese varieties or mixtures) to 5.6 t/ha with Taichung 176 and 5.07 t/ha with Chainung 242.

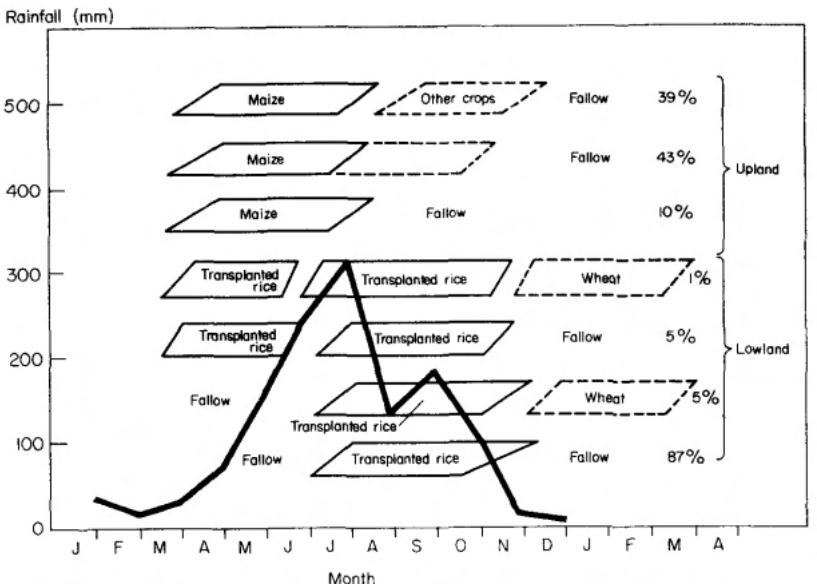
Khandbari

Site description. Khandbari in the midhills of the Eastern Development Region is 11 km north of Tumlingtar Airport, Sankhuwasabha district. Altitude varies from 450 to 1,500 m. Available full season data on rainfall are only for 1 year. The total rainfall is 1,200 mm; 80% occurs from July to September.

The total cultivated area is about 840 ha. Seventy-eight percent of landholdings is less than 1 ha. The most frequent size is in the range of 0.25-0.5 ha. Eighty-seven percent of the lowland remains fallow after a single rice crop. Maize-based cropping patterns are grown in the uplands, which represent 52% of the cultivated area.

Predominant soils are silty loam. Oxisols are present on low hill slopes. The pH ranges from 4.9 to 6.4, total nitrogen is low to medium, phosphorus is low to high, and potash content is high.

In Khandbari, as in Pumdi Bhumdi and Lele, lands are generally classified as lowland and upland. Different environments exist within these types. Altitude and water availability determine the cropping pattern in the lowland. In lowlands at an



7. Predominant and experimental cropping patterns, and rainfall distribution, Khandbari, Nepal.

Table 11. Present and potential cropping pattern technology, Khandbari, Nepal, 1978-79.

Cropping pattern[a]	Variety	Fertilizer (kg NPK/ha)	Seed rate[b] (kg/ha)
Uplands: maize +beans			
1. F) Maize	Local	0	120,000/40,000
Beans	Local	0	–
FI) Maize	Khumaltar yellow	60-30-30	20
Bean	Local	–	–
Lowlands: rice (L) - fallow - fallow			
2. F) Rice	Local	0	50
FI) Rice	Taichung 176	60-30-0	50
3. Rice - rice			
F) Rice	Tauli		50
Rice	Tauli		50
FI) Rice	Chandina	40-30-0	50
Rice	Local		50
4. FI) Rice	Taichung 176	40-0-0	50
Wheat	RR 21	60-0-0	120
FI) Rice	Chandina	40-0-0	50
Rice	Tauli		50
	Local		50
Wheat	RR 21	60-0-0	120

[a]F = farmers', FI = farmers' improved, L = local variety. [b]Figures for maize indicate initial and final plant populations.

elevation below 650 m, a double crop of rice is possible with irrigation. These lands offer the best potential for cereal crop production. In the lowlands at medium elevation in the hills, water is limited and only one rice crop is grown. These lands are at elevations from 650 to 1,300 m.

Cropping patterns tested. The cropping patterns identified in Khandbari are presented in Figure 7. Cropping systems studies were concentrated on the three predominant cropping patterns maize + bean - finger millet, rice - fallow - fallow, and rice - wheat - fallow. Wheat was tested as a third crop in the third pattern. Technology tested is summarized in Table 11.

Results. The agronomic and economic performance of the tested cropping patterns is summarized in Table 12. Results are:

1. In the area in which a single crop of rice a year is grown, the yield can be increased 70% by replacing the local varieties with the improved variety Taichung 176. With an improved variety and improved cultural practices, a change in net revenue of Rs 3,721/ha was obtained.
2. In areas where two crops of rice are planted (lowland irrigated), the yield of the pattern can be increased by replacing the local varieties with an improved variety as the first crop. Present improved varieties are not suitable as the second crop.

Table 12. Total yield production, percentage increase in yield, and economic performance of farmers' improved cropping patterns in relation to existing patterns, Khandbari, Nepal, 1977-79.

Cropping pattern[a]	Total production (t/ha)	Increase (%)	Change in cash costs (Rs/ha)[b]	Change in net revenue (Rs/ha)[b]	Benefit-cost ratio
Category 1 – Uplands					
1. F) Maize (L) + soybean (L)	2.83				
FI) Maize (I) + soybean (L)	4.83	71	634	2,866	4.52
Category 2 – Lowlands					
2. F) Rice (L)	2.3	70	551	3,721	6.75
FI) Rice (I)	3.9				
3. F) Rice (L) - rice (L)	4.6				
FI) Rice (I) -wheat (I)	5.1	11	640	143	–
FI) Rice (I) - rice (L) - wheat (I)	1.5	63	690	6,531	9.47

[a] F = farmers', FI = farmers' improved, I = improved variety, L = local variety. [b] US$1 = Rs 11.90.

3. In areas with irrigation (from natural springs), a rice - rice - wheat pattern is possible.
4. The total grain production in the cropping pattern rice - rice - wheat was 60% higher than in the pattern rice - rice. This represents a change in net revenue of Rs 6,531 /ha and a change in cash cost of Rs 690.
5. Research needs for this site are: a) identification of grain legume varieties (lentil, soybean, chickpea) suitable for the environment, b) land classification (land categories), and c) introduction of minor crops.

DISCUSSION

Price: The scope and structure of the analysis of cropping pattern tests are excellent and appear to be a good example for others to follow. The benefit-cost ratio appears to reflect cash costs alone. Even so, the neglect of labor would have little effect on the analysis where the improved practices are primarily levels of material inputs or variety, which involve little additional labor costs, except for harvesting. However, if the improved technology includes the introduction of additional crops or improved tillage, manual weed control or other labor intensive practices, the B-C ratio as presented may be overstated. Is the neglect of labor of any consequence in the analysis of your cropping pattern tests in Nepal?

Malla: In most cases the assumption of little or no differences in labor input is all right. However, we started collecting labor and power inputs in parcels under farmer management in each crop and will be in a position to compare labor input data for farmers' practices and for trials.

Aquino: What are the insect and weed management practices used in your cropping pattern testing?

Malla: To control insects, we used the granular insecticide endrin on maize and sprayed malathion or sumithion against rice bugs and borers. Timely control of weeds is by human labor at all cropping pattern testing sites.

Aquino: What method of crop establishment did you use particularly in your rice - rice pattern?

Malla: In the rice - rice pattern, we transplanted both crops. For the second crop we used a local variety. But we also tried Masuli for the second crop by the retransplanting method at Parsa (irrigated). Retransplanting Masuli gave a yield of 3.2 t/ha, which is higher than yields of the late-maturing local varieties.

Saing: In all cropping system experiments, you have compared farmers' method with improved technology. In this case, I'd like to know the impact points that contribute to higher yields of crops used in the patterns.

Malla: The use of newly improved varieties such as maize, wheat, chili, and new technology such as spacing, insect control, and the use of recommended dosage of fertilizers are the main impact points for increased yields of crops used in the patterns in Nepal.

Saing: In one of your slides, mix-cropping of paddy with maize was observed. Doesn't maize affect the rice yield?

Malla: Intercropping rice with maize is the traditional method adopted by farmers. We have to make observations on whether the maize plant affects the rice yield by shading.

Kasmo: The percentage of yield increase rarely exceeds 200, but the values of the B-C ratios are surprisingly high. Is it due to the high price of the product or to the relatively cheap cost of the additional inputs used for the improved patterns?

Malla: In this case we have not calculated the cost of labor for land preparation, planting, weeding, and harvesting operations. Only the costs of fertilizer and pesticides were taken as input costs. Therefore the benefit-cost ratio is higher than the percentage of yield increase.

Cropping systems research in Agusan, Bukidnon, and Capiz Settlement Projects

E. C. Quisumbing, A. A. Gomez, R. V. Labios, and B. P. Sagun

The Ministry of Agrarian Reform (MAR), in close coordination with several participating agencies is implementing the second Rural Development-Land Settlement Project through a loan assistance from the World Bank. The settlements selected for the project are in the provinces of Agusan del Sur, Bukidnon, and Capiz. They have reasonable productive potential and are of efficient size to warrant a more intensive application of technical, financial, and human resources. Present land use is rainfed agriculture with crop intensities depending mainly on annual rainfall distribution.

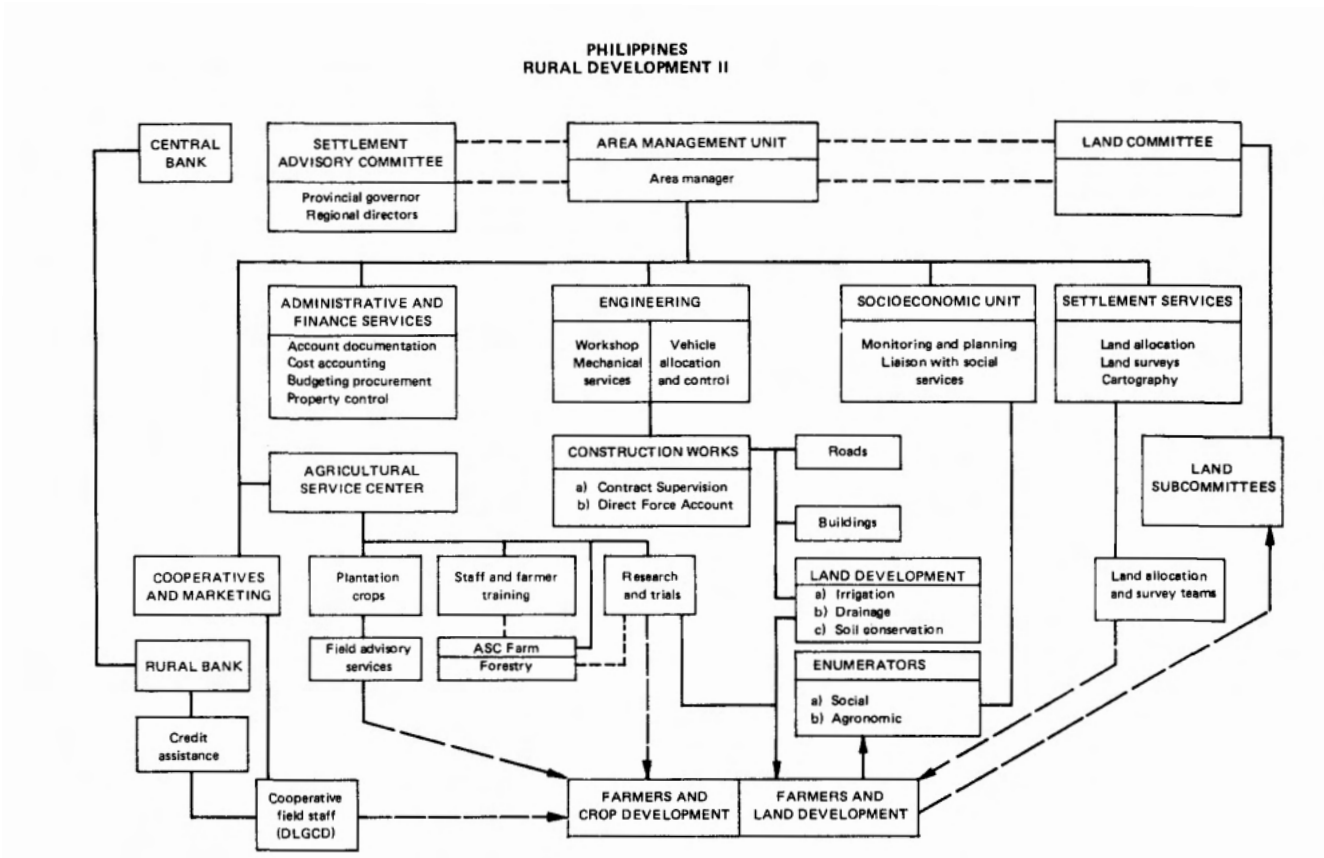
In each settlement, the project established an Agricultural Service Center (ASC), which serves as technical headquarters for agricultural research, extension, and training (Fig. 1, 2). The center is headed by a senior agronomist who acts as the director. The research unit has a research coordinator, agronomist, agricultural economist, crop protection specialist, soil technologist, and four to five barangay (settlement) assistants. Research is done in close, continuous contact with settlement farmers, with the backing of basic research institutions for guidance, coordination, staff training, etc. The unit has strong linkages with other units in the center on any agricultural development in the area.

THE RESEARCH METHODOLOGY

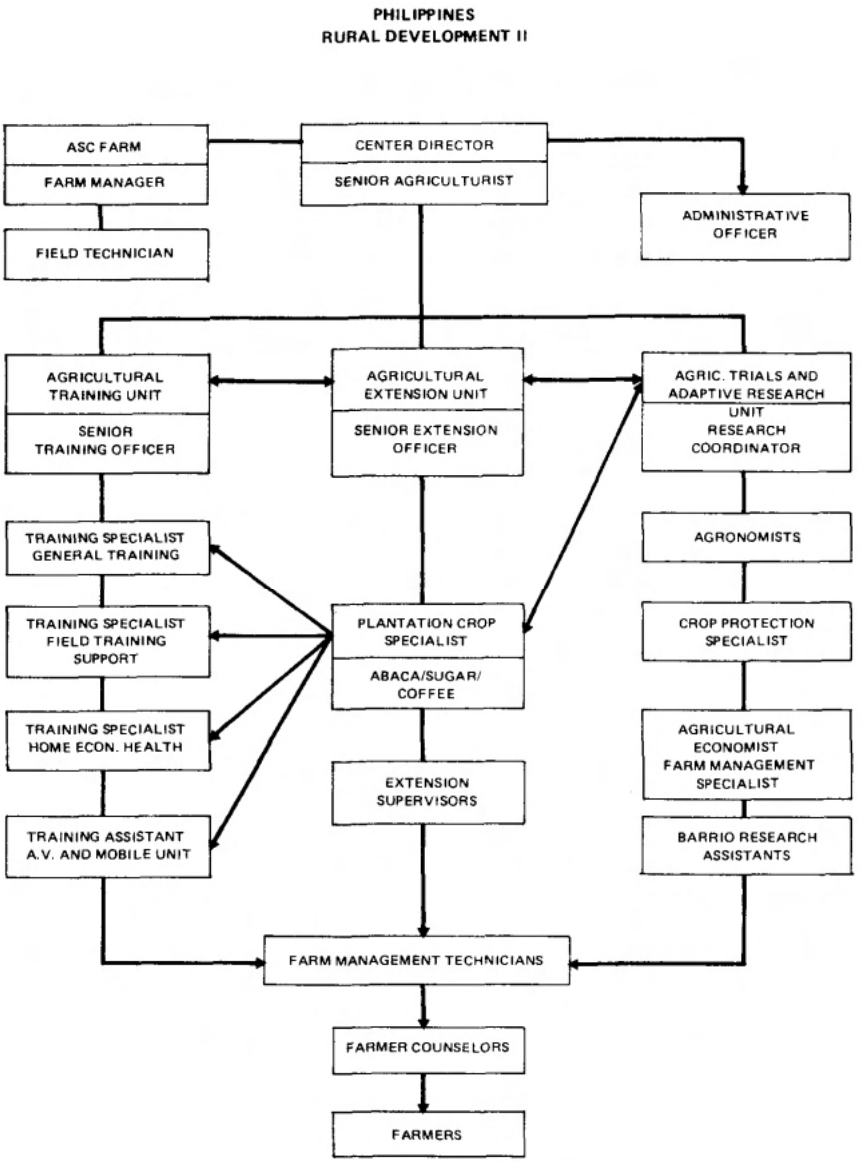
After an initial survey of existing resources, farming systems, and socioeconomic conditions, a number of sites representing major ecological and agroeconomic zones within each settlement were selected by the research staff. Emphasis was on annual crops in rainfed and partially irrigated areas where potential for improvement was high.

For cropping pattern studies within the settlement, two distinct areas — upland and lowland — were identified. No single barrio (village) within each settlement could be identified solely as lowland or upland. The lowland areas were further divided into plains and side slopes.

Deputy director, National Food and Agriculture Council; chairman, National Multiple Cropping Program; ABC research coordinator, and Agusan research coordinator, Philippines.



1. Organizational chart of the Second Rural Development-Land Settlement Project in Agusan, Bukidnon, and Capiz, Philippines.



2. Organizational chart of the Agricultural Service Center for settlement projects in Agusan, Bukidnon, and Capiz, Philippines.

Two types of farmer cooperators — agronomic and economic — were selected from the target barrios of each settlement. Agronomic cooperators were used for cropping pattern studies superimposed with investigations on component technologies; economic cooperators were used for studies that were primarily concerned with the economic analysis of farmers' existing management practices.

The agronomic cooperator farmer provided about 0.1 ha of land and its maintenance and the project provided the material inputs. All produce was given to the farmer, but no yield guarantees were given in case of crop failure. In the case of new crops, however, a guaranteed price for the produce was provided if there would be no ready local market for it. To minimize risks to the cooperating farmer, most of the initial verification trials were conducted at the ASC.

All cropping pattern studies were repeated three to four times across farms. For each test pattern, a record of daily operations was collected from the farmers during the study as bases for evaluating the adaptability of the pattern. Likewise, daily field operations of economic cooperators were monitored. Three to four rain gauges and light traps were set up in strategic places in farmers' fields to monitor the rainfall pattern and insect pests in the area.

Aside from pattern testing, applied research on different component technologies was conducted at the ASC farm and in farmers' fields. The management of all farm operations of the ASC was the responsibility of the researcher concerned. In the case of research in farmers' fields, the different treatments for components of production under investigation were superimposed on the farmers' cropping pattern.

CROPPING PATTERN TESTING

Site description

Table 1 shows the general description of the settlement sites. All share several common features, namely: large farm size, large forested or bush areas predominantly present in the rugged terrain (about 50% of the total area), a cultivated area dominated by upland areas with varying slopes, and good drainage.

Rainfall is generally high (more than 2,000 mm/year) with at least 6 months receiving more than 200 mm and only 2-3 months (February-April) with less than 100 mm. Relative humidity is high and temperature is favorable for crop production all year.

The predominant soil types are clay and clay loam with relatively low pH especially in the hilly portion.

Rice and maize are the common crops planted. Bukidnon has the biggest area for maize (12,000 ha) and Capiz for rice (7,000 ha). The other important crops are sugarcane for Capiz; and abaca, falcata, and rubber in the hilly portions of Agusan del Sur.

Yields of crops in the settlement sites are generally low. Rat infestation is a problem in newly opened lands. Because of poor roads and poor access to market, farm gate prices are low (₱0.10 to ₱0.30 less than the town price) and in the more remote parts of the settlements, farmers practice subsistence farming. Consequently, family income is roughly 25% of that usually recorded for urban areas.

Cropping patterns tested

Cropping pattern testing at the three sites started at the onset of the 1979 rainy season (April-May). The cropping patterns were based on the 15- or 20-year average rainfall data in the area and on the benchmark survey of existing farmers' patterns (Fig. 3, 4, 5). Figures 6, 7, and 8 show the designed patterns in Agusan, Bukidnon, and Capiz.

Table 1. General description of 3 settlement sites, Second Rural Development-Land Settlement Project, Philippines.

Item	Agusan del Sur	Bukidnon	Capiz
Location			
Longitude	125.5°	124.5°	122.5°
Latitude	8.5°	8.0°	11.0°
Area covered (ha)			
Total land area	16,500	36,000	25,000
Cultivated area	4,000-5,000	18,000	11,200
Wetland rice	950	1,200	2,500
Dryland rice	800	4,000	4,500
Maize	1,000	12,000	1,000
Abaca	2,000[a]	–	–
Sugarcane	–	–	1,700
Minor crops	–	800[b]	1,500[c]
Rainfall (mm/yr)			
Total yearly rainfall	3,251	2,776	2,567
No. of wet months >200 mm	10	6	8
No. of dry months <100 mm	0	2	3
Altitude (m)	10-200	500-1,100	10-400
Soil pH	4.6 to 5.2	4.77	4.8-5.4
Soil texture	Clay and clay loam	Clay and clay loam	Clay loam
Farm size (ha)	5.5	6.4	3.0
Yield (t/ha) of important crops			
Wetland rice	1.10	2.50	2.81
Dryland rice	1.00	1.50	1.25
Maize	0.72	1.25	1.15
Population (1976)	10,200	49,151	26,205
Families (no.)	1,700	11,773	4,600
Av annual income/family (₱)	1,900 ($259)	1,344 ($183)	2,800 ($381)

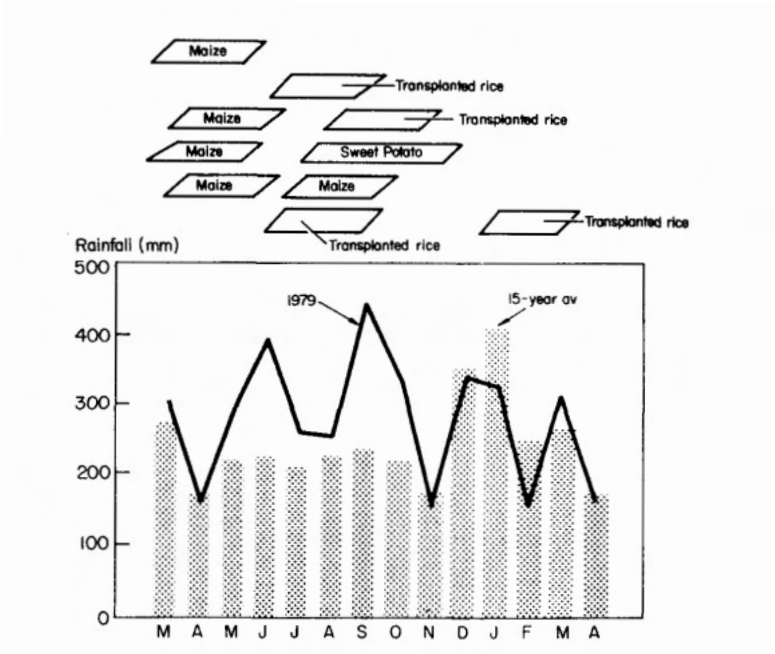
[a]Includes root crops, banana, falcata, and rubber. [b]Includes root crops, coffee, cassava, sweet potato, and mungbean. [c]Includes root crops, mungbean, peanut, and banana.

The component technology used for the different crops in the patterns is shown in Tables 2, 3, and 4. These practices were derived from 1978 experiments or from the existing recommendation of nearby agricultural institutions and from consultation with the IRRI cropping systems specialists who backstop the research component of the project.

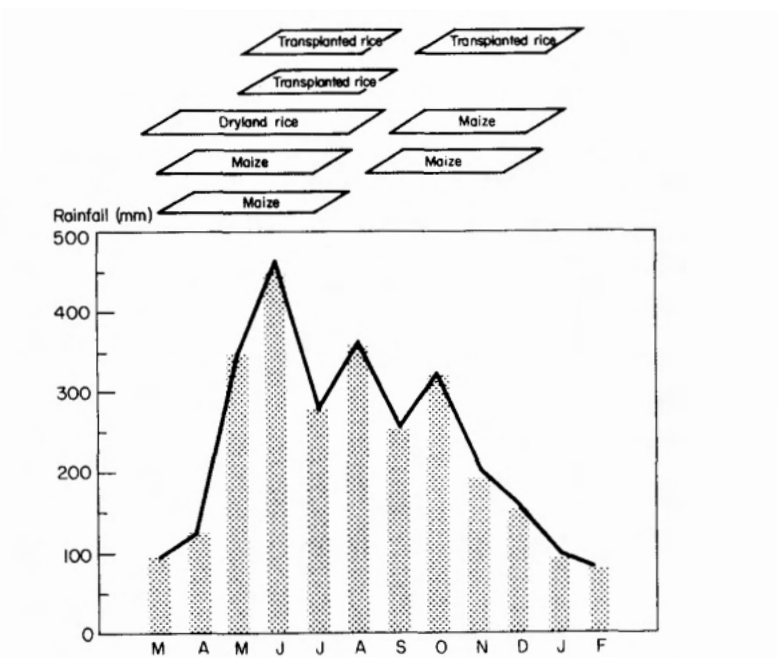
Agronomic and economic performance of cropping patterns

Agusan Settlement Site. The yield, costs, and returns of six experimental cropping patterns for the Agusan del Sur site are shown in Table 5. Only two crops are included. The third crop is still on the field.

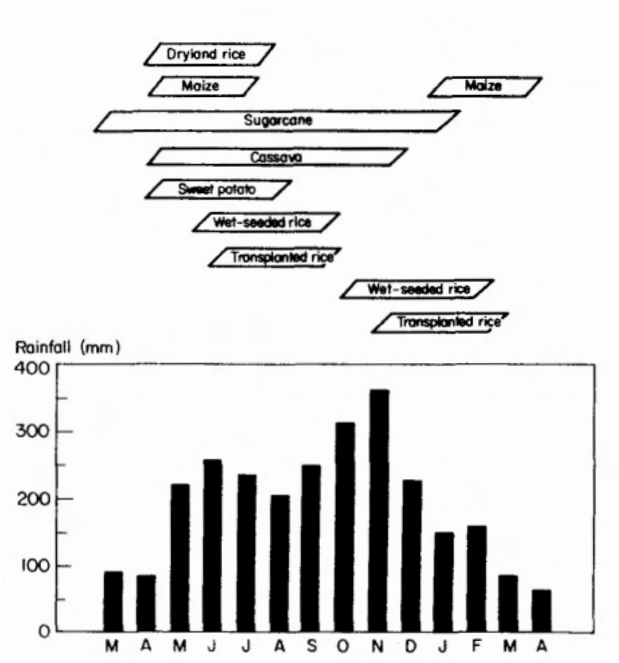
Maize yield was high when the crop was planted during the onset of the rainy season and when planted as sole crop in the pattern. Mungbean planted early also gave higher yield than that during the rainy season. Because of rat infestation, rice gave zero yield when planted early. Most of the rice crop was planted during the middle of the rainy season.



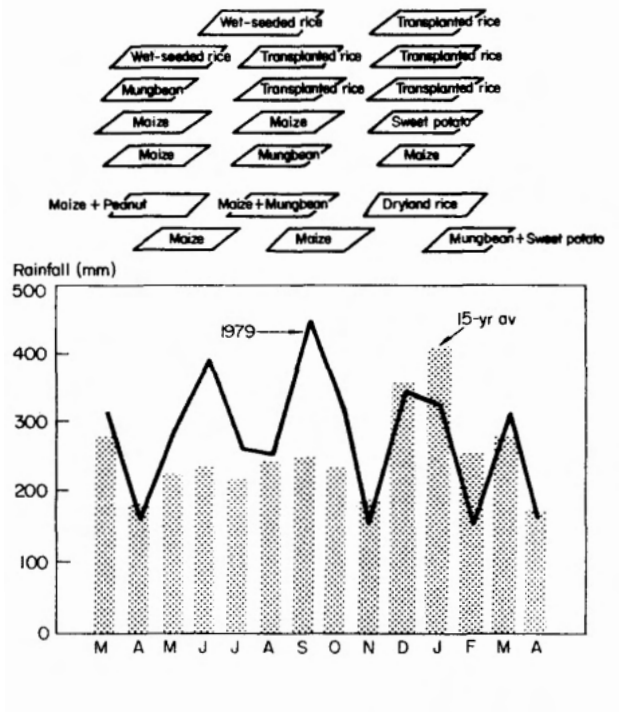
3. Existing cropping patterns graphed against the 15-year average monthly rainfall and 1979 monthly rainfall distribution, Agusan del Sur Settlement, Philippines.



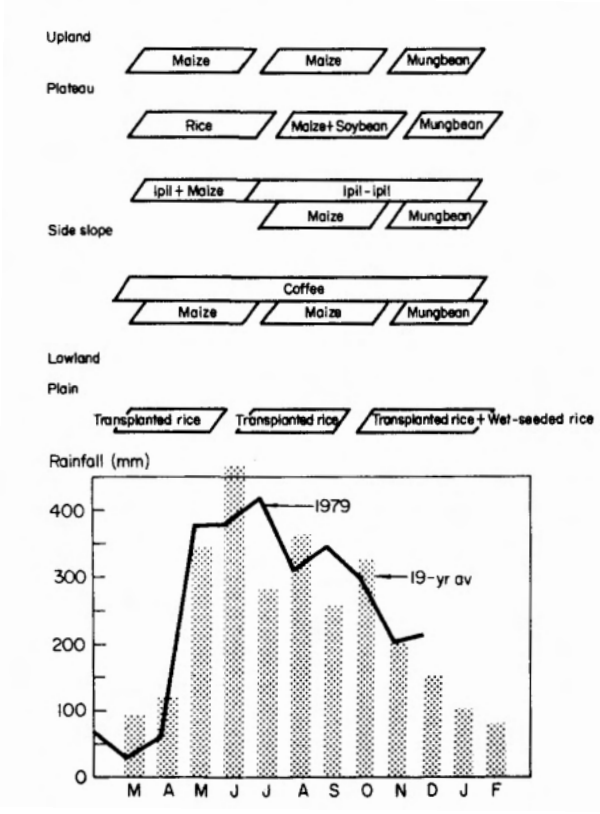
4. Traditional cropping patterns of Bukidnon Settlement, Philippines, graphed against the 15-year average monthly rainfall distribution.



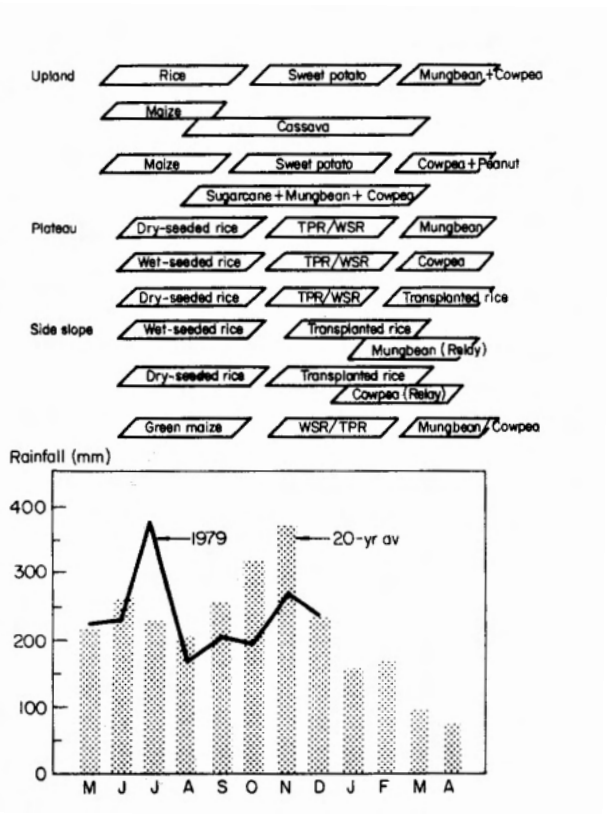
5. Existing cropping patterns graphed against the 20-year average monthly rainfall, Capiz Settlement, Philippines.



6. Alternative cropping patterns to be tested, graphed against the 15-year average monthly rainfall and 1979 monthly rainfall distribution, Agusan del Sur Settlement, Philippines.



7. Alternative cropping patterns to be tested, graphed against the average monthly rainfall distribution, Bukidnon Settlement, Philippines.



8. Alternative cropping patterns to be tested, graphed against the 20-year average monthly rainfall and 1979 monthly rainfall distribution, Capiz Settlement, Philippines.

Table 2. Recommended agonomic practices for cropping pattern testing, Agusan del Sur Settlement, Philippines, crop year 1979-80.

Crop	Variety	Spacing (cm)	Seeding rate (kg/ha)	Fertilizer rate (kg NPK/ha)	Insect control		Weed control
					Chemical	Rate (kg a.i./ha)	
Wet-seeded rice	IR36	Broadcast	120	60-30-0	Furadan 3G + FC Sevin EC	1.0 0.75	Butachlor EC + spot weeding
Transplanted rice	IR36	25 × 25	60	60-30-0	Furadan 3G + Sevin ET	1.0 0.75	Butachlor granule + rotary weeding
Dryland rice	C171-136	25 × 20	120	60-30-0	EC	–	Butachlor EC 1.0 kg a.i./ha
Maize	Improved Tiniguib	75 × 40	18	60-40-0	Furadan 3G + Sevin	0.5 0.75	Interrow culti-vation
Mungbean	CES 1D-21	50 × 30	30	10-40-0	Azodrin	0.50	Interrow culti-vation
Sweet potato	C-35-1	50 × 30	2-3 seed piece/hill	40-40-0	No spraying recommended		Interrow culti-vation
Peanut	CES 101	50 × 20	2-3 seeds/hill 100 kg/ha	10-40-40	No spraying recommended		One interrow cultivation

Table 3. Recommended agronomic practices for cropping pattern testing, Bukidnon Settlement, Philippines, crop year 1979-80.

Crop	Variety	Spacing (cm)	Seeding rate (kg/ha)	Fertilizer rate (kg NPK/ha)	Insect control.		Weed control
					Chemical	Rate (kg a.i./ha)	
Transplanted rice	IR36	20 × 20 (wet) 15 × 18 (dry)	60 100	40-30-0 40-30-0	Furadan 3G	1.0	Butachlor 1.5 kg a.i./ha, spot weeding
Dryland rice	C171-136	Broadcast	100	60-30-0	Furadan 3g + Sevin	1.0	2 hand weeding 15 and 35 DAE
Maize	Early DMR Comp. #2	75 × 50	3 seeds/hill (15.4 kg /ha)	60-30-0	Furadan 3G + Sevin	1.0	2 interrow cultivation
Mungbean	CES 1D-21	50 × 20	3-4 plants/ hill	15-45-45	Furadan 3G + Azodrin	0.50 0.75	1 interrow culti-vation

Table 4. Recommended agronomic practices for cropping pattern testing, Capiz Settlement, Philippines, crop year 1979-80.

Crop	Variety	Spacing (cm)	Seeding rate (kg/ha)	Fertilizer rate (kg NPK/ha)	Insect control[a]	Weed control
Transplanted rice	IR36	20 × 20	2-3 seedlings 60 kg/ha	80-30-30	Furadan 3G 1.0 fb foliar spray ET	Butachlor granule fb spot weeding
Wet-seeded rice	IR36	Broadcast	120 kg/ha	80-30-30	Furadan 3G 1.0 fb foliar spray ET	Butachlor EL fb spot weeding
Dryland rice	C171-136	20 cm between furrows	120 kg/ha	90-30-30	Furadan 3G fb foliar spray ET	Butachlor EL fb spot weeding
Maize	BPI Var. 1 Glutinous	75 × 50	2-3 seeds/hill 18 kg/ha	60-60-60	Furadan 3G 1.0 + Azodrin	1 interrow cultivation
Mungbean	CES 1D-21	HT-50 cm bet. rows ZT-10 cm bet. hills	2-3 seeds/hill 30 kg/ha	20-40-45	Foliar spray of recommended insecticide	1 interrow cultivation fb spot weeding
Cowpea	EG # 2	50 × 20	2-3 seeds/hill 40 kg/ha	20-40-45	Foliar spray of recommended insecticide	1 interrow cultivation
Peanut	CES 101	50 × 20	100 kg/ha	20-40-45	No spraying recommended	1 interrow cultivation
Sweet potato	C-35-1	75 × 30	2 seed pieces/hill	60-60-90	No prophylactic treatment	1 interrow cultivation
Cassava	Local	100 × 75	1 seed piece/hill	50-50-50	No spraying recommended	1 interrow cultivation

[a] fb = followed by.

Table 5. Yield, cost of production, and net returns of 6 experimental cropping patterns tested in Agusan Settlement,[a] Philippines, crop year 1979-80.

Cropping pattern[b]	Fields (no.)	Yield (t/ha)		Variable costs (₱/ha)		Gross returns (₱/ha)	Net returns (₱/ha)	Return to cash (₱/ha)
		First crop	Second crop	Material	Labor			
Maize - mung - maize	4	2.50	0.26	871	1,178	3,246	1,130	3.45
Maize - maize - mung	3	3.64	2.15	941	1,108	5,210	3,160	5.34
Maize - peanut - maize + mung - dryland rice	3	1.18 + 1.05	1.06 + 1.19	840	1,310	10,178	8,027	12.12
Mung - TPR - TPR	2	0.70	6.80	909	1,450	10,820	8,461	11.90
WSR - TPR	1	0	7.60	1,254	1,475	9,114	6,385	7.27
WSR - TPR - TPR	3	0	6.51	1,760	1,821	7,807	4,226	4.43

[a] Only 2 crops are included, the third is not yet harvested. US$1 = ₱7.35. [b] TPR = transplanted rice, WSR = wet-seeded rice.

Table 6. Yield, cost of production, and net returns[a] of 6 experimental cropping patterns tested in Bukidnon Settlement, Philippines, crop year 1979-80.

Cropping pattern[b]	Fields (no.)	Yield (t/ha)		Variable cost (₱/ha)		Gross returns (₱/ha)	Net returns (₱/ha)	Return to	
		First crop	Second crop	Material	Labor			Cash (₱)	Labor (₱)
TPR - TPR - TPR	3	5.50	[c]	963	441	6,050	4,650	6.28	3.43
TPR - TPR - WSR	3	5.25	[c]	963	447	5,775	4,365	5.99	3.39
DLR - maize - mung	5	2.80	3.80	1,831	967	6,536	3,738	3.57	3.03
Maize - maize - mung	4	3.50	3.40	1,228	1,127	6,210	3,855	5.05	3.37
Maize - mung	4	3.30	0.72	1,266	1,210	5,850	3,375	4.62	3.42
Coffee + maize - coffee + maize	4	2.75	[c]	593	531	2,475	1,351	4.17	2.69

[a]US$1 = ₱7.35. [b]TPR = transplanted rice, WSR = wet-seeded rice, DLR = dryland rice. [c]Data not yet analyzed, third crop not harvested.

Table 7. Yield, cost of production, and net returns of 7 experimental cropping patterns tested in Capiz Settlement,[a] Philippines, crop year 1979-80.

Cropping pattern[b]	Fields (no.)	Yield (t/ha) of first crop	Variable cost (₱/ha)		Gross returns (₱/ha)	Net returns (₱/ha)	Return to	
			Material	Labor			Cash (₱)	Labor (₱)
DSR - TPR - CP	2	3.3	685	530	2,249	1,034	2.27	3.59
WSR - TPR - mung	7	5.6	958	754	3,829	2,116	3.00	5.00
DLR - SP - mung	3	3.2	1,102	667	2,201	342	1.13	3.40
TPR- TPR/WSR - TPR	2	6.4	765	732	4,410	2,913	4.76	5.97
DSR - TPR/WSR - mung	1	4.5	916	522	3,120	1,682	2.41	5.91
WSR - TPR - CP	12	5.1	956	721	3,535	1,858	2.69	4.41
Maize - SP - CP/peanut	3	1.9	671	735	2,030	625	2.02	6.88

[a]Includes only one crop. Data for the second crop have not been analyzed and the third crop has not been harvested. US$1 = ₱7.35. [b]DSR = direct-seeded rice, TPR = transplanted rice, DLR = dryland rice, WSR = wet-seeded rice, SP = sweet potato, CP = cowpea.

Among the patterns tested, maize intercropped with peanut followed by maize intercropped with mungbean, and mungbean followed by transplanted rice gave the highest return. The lowest return was from maize followed by mungbean. Yield of mungbean was affected by heavy rain during the flowering stage.

Bukidnon Settlement Site. Table 6 shows the summary of cost and returns of the two crops in the cropping pattern at the Bukidnon site. Some of the second crop for each pattern have not yet been harvested and analyzed. The low return of the maize mungbean was due to higher labor cost for harvesting and processing of mungbean.

Capiz Settlement Site. As shown in Table 7 only the first crop in the cropping pattern was analyzed. Among the first rice crops, established in the pattern, transplanted rice (TPR) gave the highest yield and dry-seeded rice (DSR) the lowest. The low yield of DSR was due to weeds.

TPR gave the highest returns and DSR the lowest. However, among the first crops established, dryland rice (DLR) gave the lowest return because of higher material inputs, especially seeds and fungicides. DLR was severely attacked by leaf blight. Maize yield was also low because of a typhoon during the flowering stage of the crop.

Problems in increasing cropping intensity of rice land

The three project settlements had common problems during the 1979 cropping pattern trials. Those were shortage of fuel for farm power and for transport of farm inputs; poor road maintenance especially during the rainy months; flooding of the experimental fields; and lack of transportation for regular visits to the experimental field. Rat infestation was common in Agusan and Bukidnon and caused substantial yield loss of rice and maize. Leaf blight in DLR was serious at the Agusan and Capiz sites. "Aguingay" (*Rottboellia exaltata*) was a serious weed problem in Bukidnon and Capiz.

DISCUSSION

Pookpakdi: It seems that at the Agusan site your moisture supply is good. What is the possibility of using a high-value crop like soybean or some other vegetable?

Sagun: The Agusan del Sur settlement site has welldistributed rainfall throughout the year and is seldom visited by typhoons, conditions that are very favorable for the growth of field legumes and vegetable crops during certain times of the year. We get good yields from most of the soybean, mungbean, and cowpea entries. Fruit and leafy vegetables were also promising. The main reasons, however, why farmers are not growing them are: a) farm gate prices, especially those for vegetables, are very low, b) farm-to-market roads that would have facilitated transportation are still inadequate in the three settlements.

Pookpakdi: Can you comment on the use of ipil-ipil in the system? What about cutting or preventing them from growing deep roots? I feel that if ipil-ipil is left planted in the soil for a long time, it will be difficult to prepare the land for a subsequent crop.

Sagun: Ipil-ipil (*Leucaena* spp.) as a component of the cropping pattern tested in the settlement site is intended primarily to control soil erosion in undulating areas. Its leaves are also used as organic fertilizer and animal feed. Ipil-ipil is planted in strips that follow the contour of the land and is cut at regular time intervals at a desired height. The leaves are then

spread between maize rows as fertilizer. Some are used as animal feed. The regular cutting to a desired height may also prevent extensive root development that could probably interfere in land preparation. There are ongoing studies in the Bukidnon and Capiz settlements.

Pookpakdi: Why do you have a low yield in wetland rice? Is there a possibility of using promising varieties?

Sagun: The variety commonly used at the settlement sites is IR36. Low yields in farmers' fields have most of the time been due to heavy rat infestations, especially at the Agusan site. Another reason is probably the large farm size, about 6 ha/ settler in Agusan and Bukidnon. The farmer-settler has to attend to other farm activities, which vary in many areas. That prevents the farmer from doing the intensive type of farming necessary to obtain high rice yields.

Santiago: How many years of experimentation in the project areas have you had before you arrived at the recommended agronomic practices for cropping patterns in the ABC projects? Do you feel that this experimentation time is enough for us to feel confident of the recommendations?

Sagun: The component technology we recommended for the alternative cropping patterns has been tested in national experiment stations. We feel that the technology component generated by these institutions is already sufficient. Our role as a research team in the settlement sites is to conduct adaptive research to identify the appropriate crop variety and the optimum level of component technology (fertilizer rate and pesticide level) economically and socially acceptable to the farmer-settler. The length of time is not really enough if these were basic experiments. But in the settlement sites, we have to feel confident of our results so we can proceed with pattern testing. Moreover, we feel that the results of superimposed trials are even more appropriate and refined than the national recommendations and other recommendations generated elsewhere.

Ismail: You have abundant rainfall and erosion could be a serious problem in the undulating dryland. Do you plan to study land development and management to solve this problem?

Sagun: Soil erosion has been a problem in settlement sites and is more serious in the highland areas with steep slopes. We have come up with some solutions:

- Terminate special timber licenses issued to loggers by the Bureau of Forest Development;
- Upland areas with more than 18% slope must not be allocated to settlers but instead reforested and declared as permanent timberland. About 2,000-3,000 ha in all settlement sites should be developed for timberland; and
- Promote the planting of agro-forestry crops such as rubber, ipil-ipil, and coffee at the sites.

Mathema: The data in Table 7 show that the TPR in pattern 4 yielded higher than other patterns and gave the highest net return in the Capiz Settlement area, even when compared with results in Bukidnon Settlement, although both areas used the same variety (IR36). What could be the reasons?

Sagun: The settlement sites may be similar in some aspects but may differ in various factors. For instance, even if the variables in all the sites are the same, there is always one distinct variable — the farmer and his management capability.

Zandstra: Bukidnon cannot be compared to Capiz with regard to soil and climate.

The IRRI-BPI cropping systems research project in Pangasinan and Iloilo

R. A. Morris, H. C. Gines, R. D. Magbanua, R. I. Torralba, and A. Sumido

Within South and Southeast Asia, rice-growing areas with potential for cropping intensification have relied, and will continue to rely for several decades, solely on rainfall or a combination of rainfall and partial irrigation, which extends the rice-growing season by 1 or 2 months. Little research has been directed specifically at rainfed and partially irrigated rice production practices, however, and even less research has been focused on problems during the transition from a rice crop to a nonrice crop and back to a rice crop. For rainfed areas, where little is known about the feasibility of new agronomic practices, adaptive research to fit elements of new technology into viable improved cropping systems is required.

Cropping systems research methods have been formulated to rapidly develop improved rice-based cropping patterns that are within the management capability of small South and Southeast Asian farmers in rainfed sites. The methods have found greatest application in support of agricultural development projects, and are excellent exposers of high-priority research problems. The research methods consider four factors:

1. variability in physical and socioeconomic environments which, by creating many small agroecological zones, hampers extrapolation of research findings;
2. farm family and community resource base limitations that govern adoption potential;
3. local technical knowledge; and
4. the short supply of manpower needed to staff field-level agricultural research and development projects.

Variability occurs as comparatively abrupt changes not only in the physical factors of land and climate in South and Southeast Asia, but also as changes in social and economic orders. Market accessibility, as generally determined by local road systems, is a major economic factor. Social variability is often pronounced, with changes in predominant ethnic groups occurring over short distances, and different socioeconomic classes within an agricultural community, e.g., owner-operators, share-tenants, landless laborers, and absentee landlords.

Cropping systems agronomist; senior research assistant and former Pangasinan outreach site coordinator; research assistant and Iloilo outreach site coordinator, Multiple Cropping Dept, IRRI; and BPI technicians, Pangasinan and Iloilo projects.

Any investigation of cropping systems must consider the farm family and community resource bases. Therefore, a cropping systems study is not simply one of agronomic adaptation, but one of economic viability. Economic evaluation must consider both limited resource bases and risk factors.

Physical and socioeconomic variability, and resource base limitations can be easily recognized through farmer-cooperator collaboration and by employment of local personnel in project operations. Local knowledge can be blended with modern technology to synthesize a set of modern practices that is viable under local conditions.

Anyone who staffs a research site in a remote area faces manpower problems. Even if qualified personnel were available, budget allocations are seldom sufficient to hire all the trained and experienced researchers that one would like for a site research program.

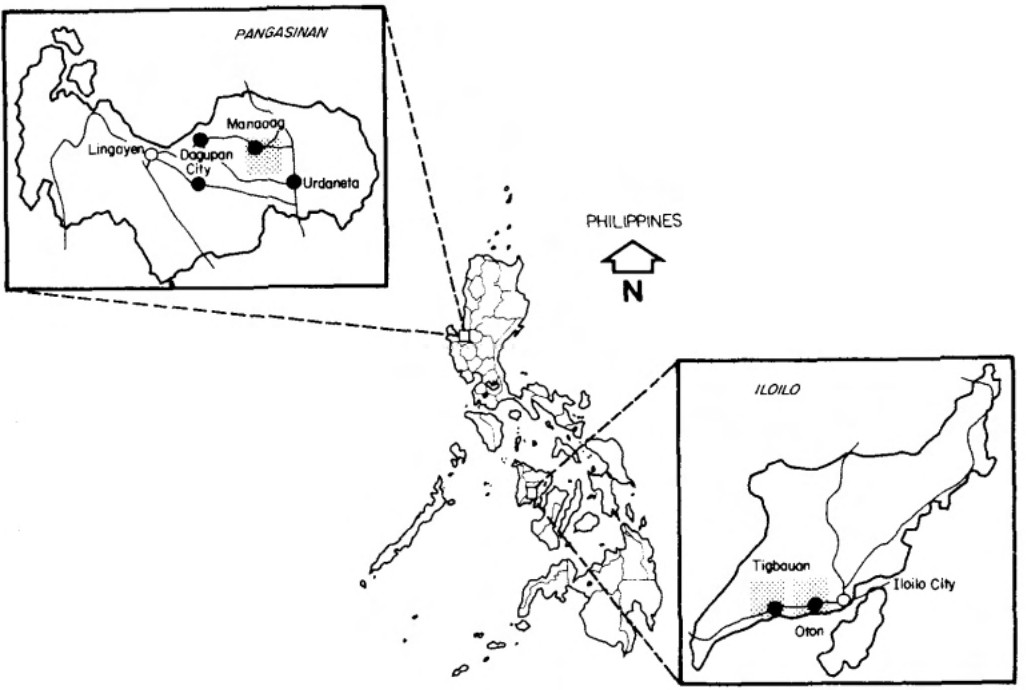
The recognition of physical and socioeconomic variability and resource base and manpower problems has prompted a systems approach to site research. A systems approach draws attention to linkages between various components of a cropping system, and between such components and the environment. The approach increases comprehension of a functioning system and promotes efficient communication among the researchers in a multidisciplinary team.

The primary objective of the Pangasinan and Iloilo cropping systems research projects was to evaluate proposed cropping systems research methods. A secondary objective was to develop more productive, but economically viable, rice-based cropping patterns for small farmers in rainfed and partially irrigated areas. The two sites were cooperatively supported by the Philippine Bureau of Plant Industry (BPI) and IRRI. Their location is shown in Figure 1. The sites were selected because they were predominantly rainfed or partially irrigated with the extent or duration of irrigation being minimal. Site research started in April 1975, was phased down in early 1979, and was terminated in February 1980.

RESEARCH METHODS

An overview of the cropping systems site-related research methods is shown in Figure 2. Although the scheme shows activities to be organized somewhat sequentially, many were operational throughout the life of the project. Designing and testing activities were iterative, with designs improved annually. In component technology research, important management variables were identified for experimentation the first year, but many key management variables were not recognized initially and were investigated in subsequent years. Target areas should have been more exactly defined initially but even if they had been, delineation would have required updating as the requirements of promising patterns became apparent and as knowledge of the area accumulated during the project.

Typical site staffing patterns and organization arrangements are shown in Figure 3. The site staff is central and linkages to IRRI and the BPI are indicated. Information flowed in many directions. Researchers designed patterns to be grown on a farmer's field. Each pattern was discussed with the farmer-cooperator, and, if necessary, adjustments were made. Design successes and failures were reported, and



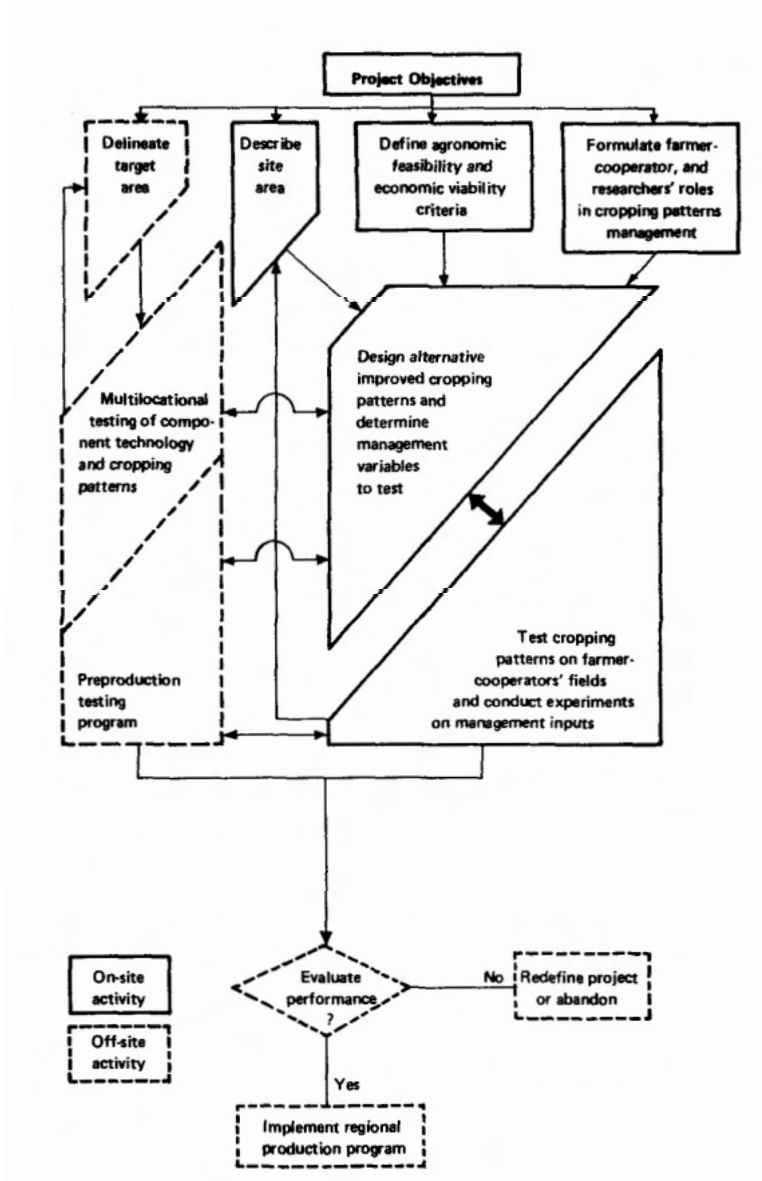
1. The IRRI-BPI Iloilo and Pangasinan, Philippines, cropping systems research sites, 1975-80.

means of overcoming design weaknesses were discussed and formulated at annual meetings. However, many problems were discussed informally among staff members, at all levels and between disciplines, as they became apparent during the crop year and adjustments were made as necessary.

Farmers' fields ranged from 300 to 1,500 m^2; the typical size was about 1,000 m^2. Each farmer-cooperator provided land plus labor and power for cultural operations. The project researcher provided seeds, fertilizers, insecticides, herbicides, sprayers if necessary, and advice.

During the cropping period, agronomic aides visited the fields daily to observe field conditions, note operations in progress or completed since the last visit, and log the date, nature, and duration of operations. Records were also kept on the quantity of material inputs used, and notes were made of crop status related to water depth, lodging, insect damage, weed incidence, and other factors affecting yield. The economic cooperators who provided the project with farm and household data received no compensation for their time. An economics aide visited the cooperator's house three times a week to review and edit forms on which data were recorded.

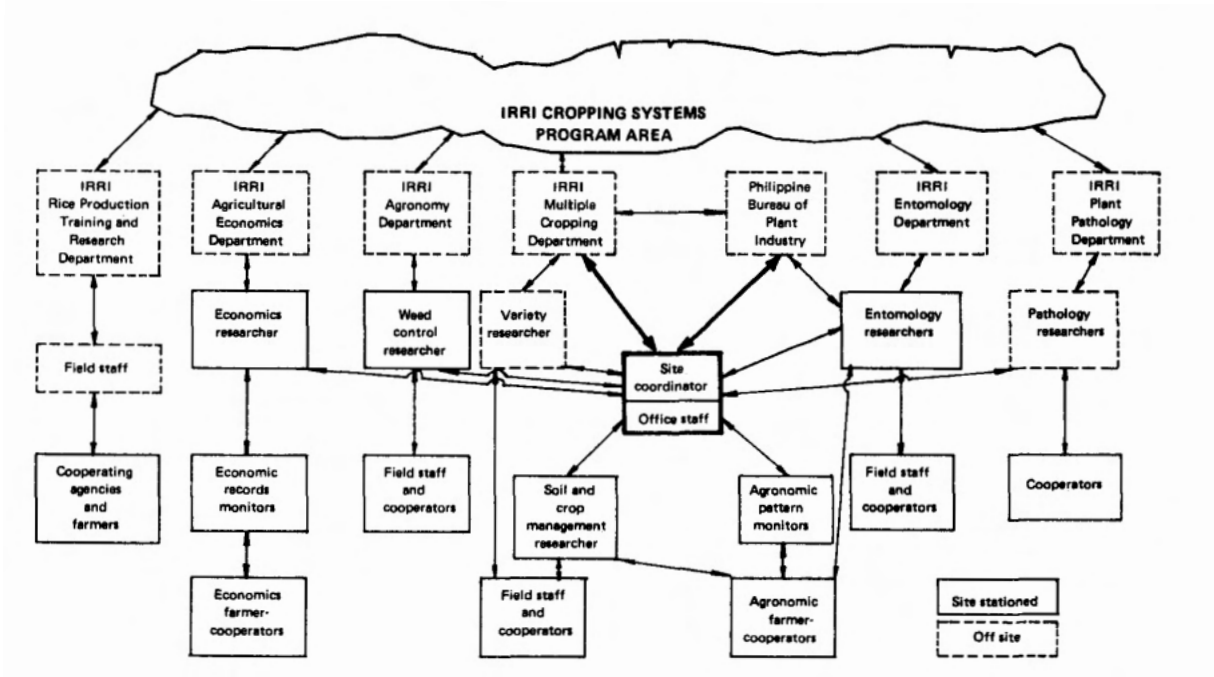
At the start of each crop year, physical data for each field were recorded. A simple soil profile description included the depth and texture of each horizon to about 100 cm. The pH of each horizon was determined with a field test kit and moist color was recorded with a simple 5-color classification. Field area was measured and other



2. Cropping systems site-related research methods as applied to a regional program.

field information such as bund height and width was recorded. Expected seasonal irrigation availability, if any, was registered. The physical information was used primarily to examine the classification of fields and interpret data.

Maximum and minimum temperature, pan evaporation, and solar radiation were recorded daily at the site level, but rainfall was recorded daily from individual gauges located near each village. Product prices at various market levels were recorded over



3. Site staffing patterns and organization.

the year to determine general and seasonal trends. Input prices including the cost of materials, hired labor, and hired animals for custom operations were also canvassed periodically or taken from economic cooperator records.

Agronomic and economic data were used for three main purposes: 1) cost and returns analyses of existing and alternative cropping patterns, 2) identification of weak points in the patterns (eg, long turnaround time between crops, delayed planting of dry-seeded rice, weed control problems on dry-seeded rice, and unreliable upland crop establishment), and 3) adaptation to general environmental determinants: physical reliability in the case of agronomic data (particularly rainfall and land variability) and market absorption potential and farm resource availability (particularly labor and cash) in the case of economic data. The data were also used to evaluate risk levels, both directly on the basis of yields, and indirectly on the basis of rainfall probabilities.

SITE DESCRIPTION

Most soils at the Pangasinan site fall within the Eutropept great group. Soil pH ranged between 6.7 and 7.9, with a raw mean of 7.4. The modal surface soil texture was clay loam.

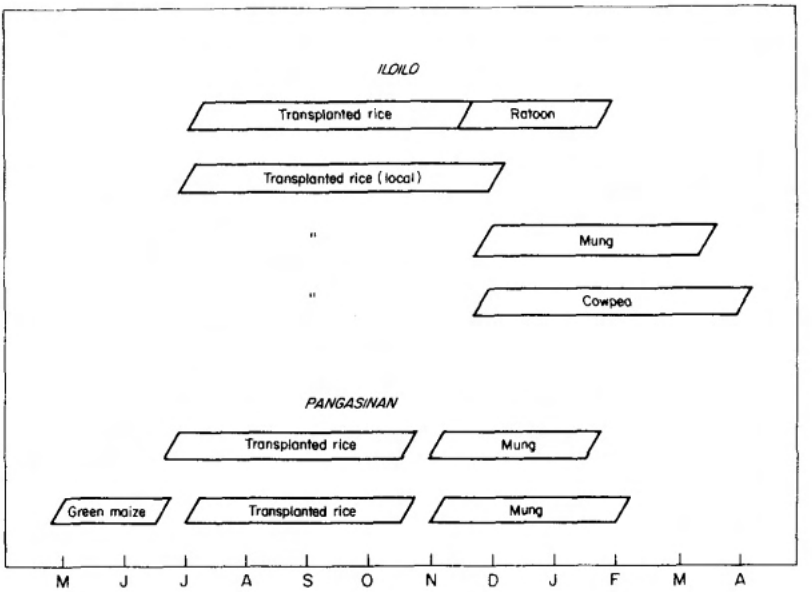
Normally there were 3-4 months with total monthly rainfall exceeding 200 mm (including 1 month during which rainfall exceeded 500 mm) and 5-6 months with less than 100 mm total rainfall per month.

Cropping systems researchers divided the Pangasinan site into several complexes (IRRI 1976). The Pangasinan land system[1] was composed of flat plains and a levee backslope of an alluvial subsystem. A major division between complexes was based on deep (levee backslope) versus shallow (plain) water table depth. Further divisions were based on soil texture differences, water sources, and relative elevation. The landscape appears rather level, grading away slightly from the river levee to occasional deeply dissected creeks into which waterways drain. Differences in relative elevation of less than 1 m caused slight but significant differences in production potentials.

Farm size in the study area ranged from 0.4 to 8.5 ha (av of 2.2 ha). Each farm averaged 3.9 parcels, each averaging 0.6 ha in size. The average farm size of agronomic cooperators was 1. 1 ha. Eighty-one percent of the farmers were share-tenants, 12% were owner-operators, and the remainder were leaseholders.

More than 50% of the area was usually planted to rice - upland crop patterns, with the rice - mung pattern being dominant. In the common patterns (Fig. 4), rice is transplanted in July or August and harvested in October or November. The field is then plowed and planted to broadcast mungbean in late November or early December. Farmers in the Lipit-Pao section plant maize at the start of the rains, followed by transplanted rice, and then mungbean. Because of the shallow water

[1] Used rather loosely here, the term land system denotes a naturally recurring pattern of land units. A land unit is an area that is homogenous with respect to landform. soil characteristics, and hydrological features. Land use, agronomic practices, and crop performance should be relatively uniform within a land unit.



4. Predominant traditional cropping patterns in Iloilo and Pangasinan, Philippines, at time of project implementation.

table, the Caaringayan area is frequently inundated early in the wet season, which increases the risk for an early maize crop (Herrera et al 1976).

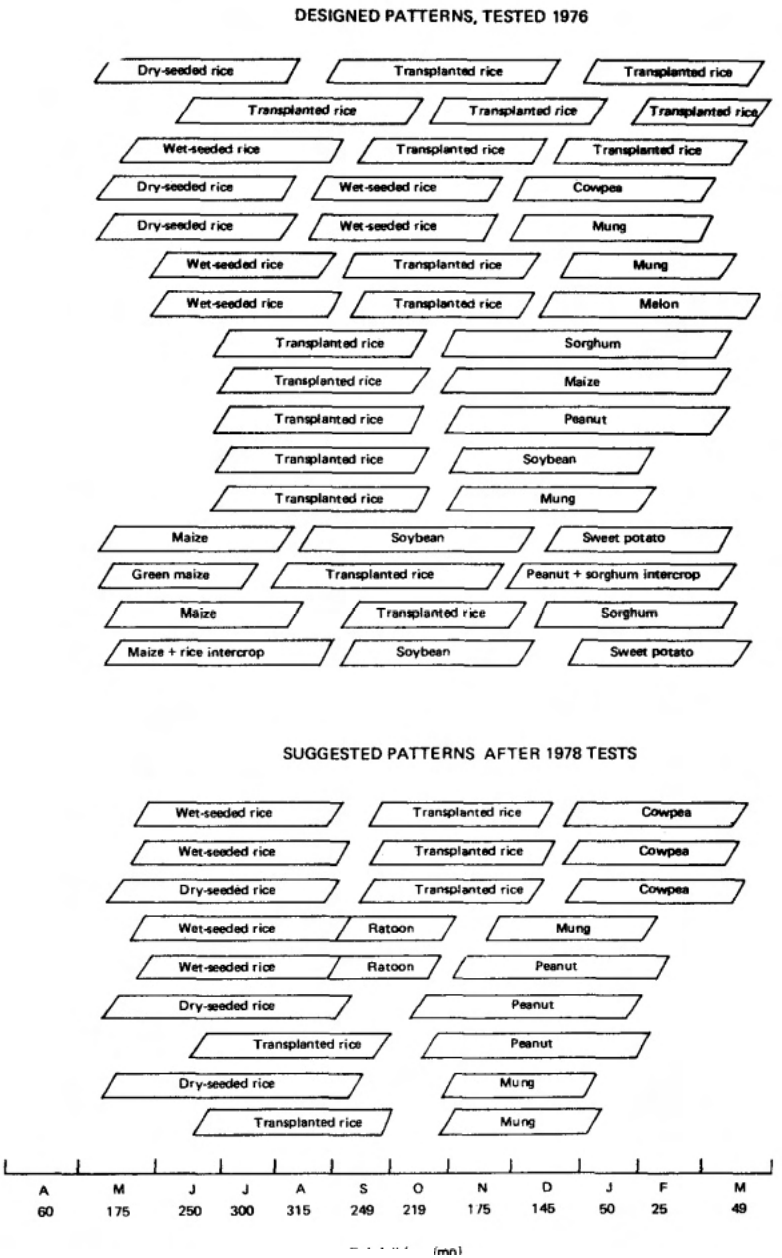
At the Iloilo site, soils within the Pelludert, Eutropept, and Tropfluvent great groups predominated. Soil surface materials were generally moderately to slightly acid clays or silty clays. Although the site area was primarily rainfed, in crop year 1976-77 a large number of land units received partial irrigation of varying durations beyond the normal end of the wet season.

In the upper section of the site, the rice fields are primarily on ramified interhill miniplains and lower colluvial slopes of an alluvio-colluvial subsystem. The land system in the lower section consists primarily of flat plains of 1-2% slope in a marine terrace subsystem. Rainfall at the site normally consisted of 5-6 months with total monthly rainfall exceeding 200 mm, and 3-4 months with less than 100 mm.

A single transplanted rice crop was the common pattern on 97% of the site area. Using low management practices, small areas of mungbean or cowpea and other crops were planted after rice. Farmer cooperators' farms averaged 1.5 ha in size, and were predominantly under a share-tenancy arrangement. Most farmers owned a water buffalo, which was used for tillage and short-distance haulage (Palada et al 1976).

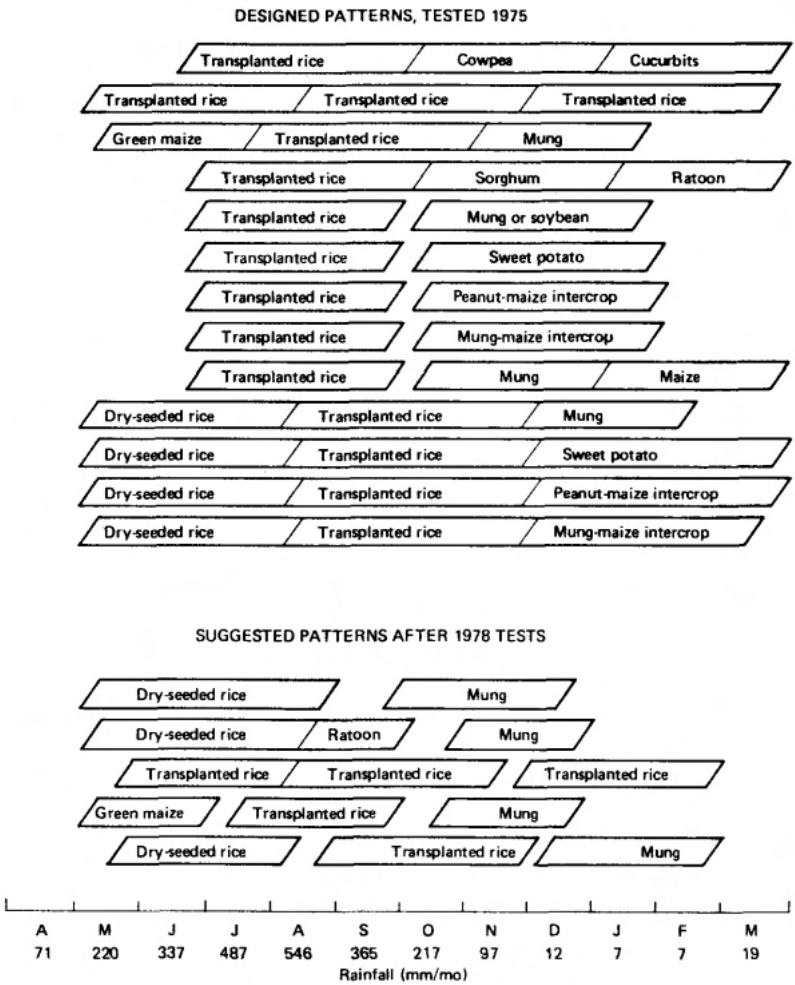
CROPPING PATTERN TESTING

The cropping patterns found agronomically adapted to Iloilo and Pangasinan after 4 years of field testing are shown in Figures 5 and 6. For Pangasinan, pattern specification considered water table depth, waterway and non-waterway locations,



5. Cropping patterns tested in 1976 and suggested patterns after 1978 tests. Iloilo, Philippines.

and irrigation condition (Table 1). In Iloilo, landscape position, soil texture, and irrigation condition were used (Table 2). The economic aspects of patterns are discussed by E.C. Price (this volume) in "Adoptions and impact of new cropping systems in Iloilo and Pangasinan."



6. Cropping Patterns tested in 1975 and suggested patterns after 1978 tests. Pangasinan, Philippines. Rainfall data based on Dagupan City records, 1954-78.

IDENTIFICATION OF PRODUCTION PROBLEMS

At both sites researchers quickly realized that the turnaround time between rice crops was significant, and delayed plantings of the second crop increased that crop's exposure to drought stress (Fig. 7). Experiments were conducted both at the sites and at IRRI on methods of reducing tillage requirements for the second crop. The results of an experiment at IRRI (Table 3) suggested that both the time between crops and the intensity of tillage could be reduced on the second crop. In Iloilo, where the turnaround time between rice crops appeared critical, farmer-cooperators were introduced to and encouraged to use portable threshers. An experiment at Pangasinan to determine if field duration could be shortened by using old seedlings showed that 40-day-old seedlings could be planted on the same date as 20-day-old

Table 1. Suggested cropping patterns for specified field conditions, IRRI-BPI Project, Pangasinan, Philippines.[a]

I. Deepwater table
1. Rainfed, non-waterway: DSR/TPR[a]-mung
2. Rainfed, waterway: DSR-ratoon[b]-mung
3. Partially irrigated: DSR-ratoon-mung
4. Partially irrigated: DSR-TPR-mung if DSR can be established early[c]; otherwise, suggested as DSR-ratoon-mung
5. Partially irrigated and with supplemental irrigation in March, GM-TPR-mung, or DSR-TPR-mung if supplemental irrigation will be used to flush-irrigate fields for early DSR establishment.

II. Shallow water table
1. Rainfed: DSR-ratoon-mung if early DSR; otherwise, DSR/TPR-mung
2. Rainfed: DSR/TPR-mung, if early DSR; otherwise, DSR-ratoon-mung
3. Partially irrigated: DSR-TPR-mung, if early DSR, otherwise, DSR-ratoon-mung
4. Partially irrigated: DSR-TPR-mung
5. Free-flowing well area: TPR-TPR-TPR

[a]DSR = dry-seeded rice, TPR = transplanted rice, GM = green maize. Partially irrigated assumes water availability late May/early June to December, but decreasing frequency from late October.

Table 2. Suggested cropping patterns for specified field conditions, IRRI-BPI Project, Iloilo, Philippines.[a]

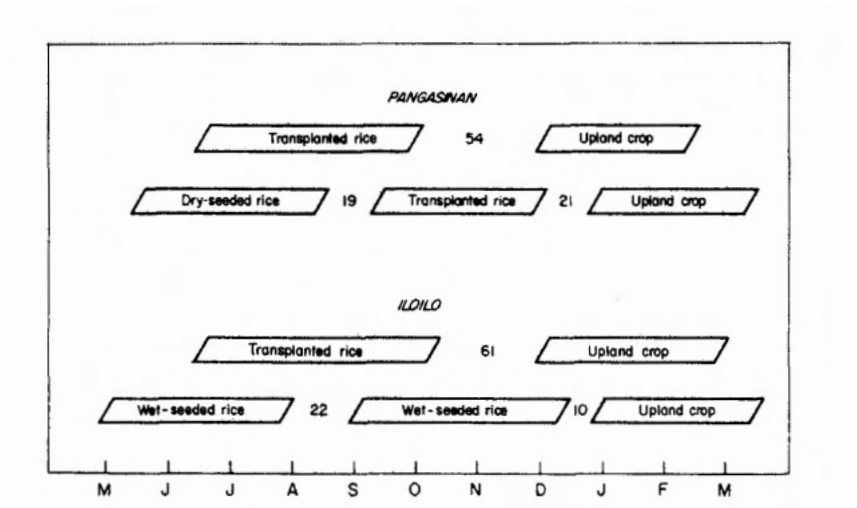
I. Side slope (all rainfed)
1. Medium texture: DSR/TPR-MG/CP
2. Light texture : DSR-P

II. Plateau
1. Rainfed, medium texture: WSR/TPR-MG/P
2. Rainfed, light texture : DSR/TPR-P
3. Partially irrigated[b], medium texture : WSR-TPR[c]-CP[d]
4. Partially irrigated, light texture : DSR-TPR[c]CP

III. Plain
1. Rainfed, medium texture : WSR-ratoon/fallow-CP
WSR-TPR[c]-CP
2. Rainfed, heavy texture : WSR-TPR[c]/WSR[e]-CP
3. Partially irrigated, medium texture: WSR-WSR-CP
4. Partially irrigated, heavy texture : WSR-WSR-CP

IV. Bottomland
1. Rainfed, heavy texture : WSR-WSRCP
2. Partially irrigated. heavy texture : WSR-WSR-CP

[a]DSR = dry-seeded rice, TPR = transplanted rice, MG = mung, CP = cowpea, P = potato, WSR = wet-seeded rice. [b]Partially irrigated assumes water availability late May/early June to early December, but decreasing frequency from late October. [c]30- to 35-day-old IR36 seedlings, 4-5/hill. [d]Zero tillage should be used where cowpea is recommended after 2 rice crops. [e]Use WSR as second crop if first crop was planted by 5 June.



7. Mean turnaround periods between crops in rice - upland crop and rice - rice - upland crop patterns. Pangasinan and Iloilo, Philippines, 1975-76 crop year. The figures indicate days from harvesting to planting.

Table 3. Average grain yield and labor[a] (for land preparation) as influenced by establishment method and land preparation technique, 1977-78 dry season, Los Baños, Philippines.

Land preparation technique	Grain yield (t/ha)			Labor[b] (h/ha)
	Wet-seeded rice	Transplanted rice	Mean	
Traditional 1 plowing plus 2 harrowings, over an 11-day period	3.7[c]	5.0	4.4	146 a
Two vaned roller passings over a 3-day period	3.7	5.5	4.6	86 b
Two vaned roller passings over a 5-day period	4.1	4.3	4.3	105 b
Two rototiller passings over a 3-day period	4.7	5.3	5.0	89 b
Stubble cutting by hand plus 0.4 kg a.i. paraquat/ha for 1 day	4.6	3.9	4.3	56 c
Mean	4.2	4.8	4.5	
	CV_a = 27%, CV_b = 19%		CV = 31% for labor input	

[a]Does not include transplanting or seeding operations. [b]Means followed by a common letter were not statistically different at the 5% level.

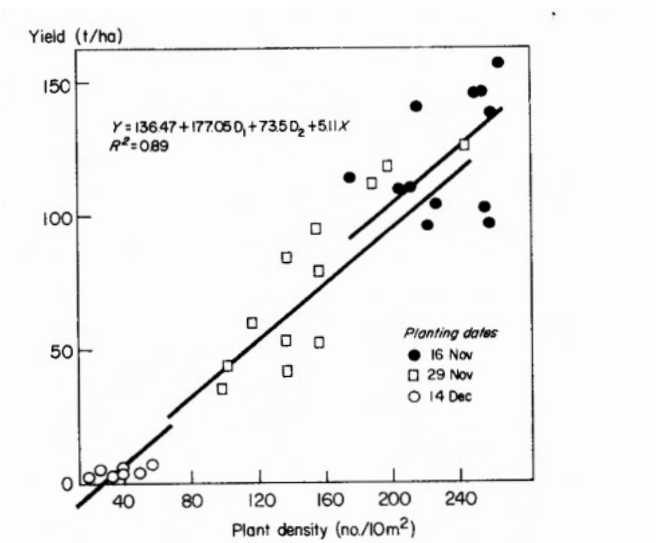
seedlings, but harvested about 2 weeks early, with only a 0.1 t/ha yield depression. Use of the older seedlings allowed the following crops to be planted earlier.

The long turnaround time between rice and upland crops appeared to be due more to wet field conditions than to lack of capability or power for tillage. The establishment of crops after rice was recognized as a problem: early establishment often led to stand losses due to excess moisture, but as illustrated by an experiment in Pangasinan, late establishment also led to poor germination and stands, and low yield (Fig. 8).

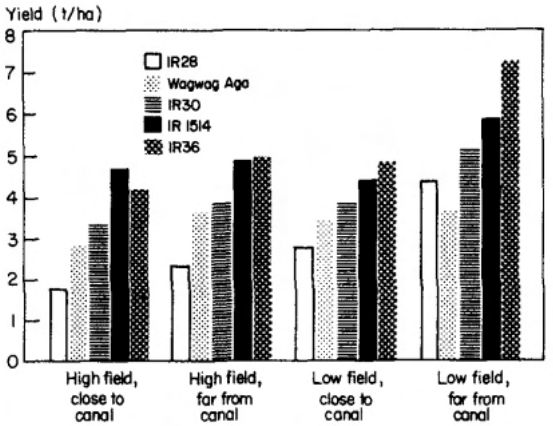
The potential of a rice ratoon as a means of using the water often available for 5 to 6 weeks after a rice crop has been harvested was recognized in Iloilo (Palada et a1 1976). Extensive work on ratooning has been undertaken at IRRI to increase the yield potential of the ratoon crop (IRRI 1980). Experiments have indicated that high ratoon yields were associated with high tiller numbers and large panicles and grains or both.

In Pangasinan, poor varietal adaptation of DSR hampered the agronomic performance of DSR-TPR-UC patterns. A comparison of five varieties grown under four field conditions showed that IR36 was as good as or superior to all others, and it was used in future tests (Fig. 9). Weed problems on dry-seeded rice crop were also recognized as important, and research was directed at overcoming them. Research on weed control is discussed by K. Moody (this volume) in "Weed control in dry-seeded rice."

Climatological studies undertaken to support cropping systems research programs were refined because of the recognition that future crop intensification would depend significantly on the effective use of early and late wet season rainfall, i.e., rainfall during the dry-wet and wet-dry monsoon transitions. Return periods were determined for periods in each of these two transitions when rainfall is critical but highly variable.



8. Effect of planting date on plant density and grain yield of mungbean, Pangasinan, Philippines, 1979.



9. Rough rice yield of 5 rice varieties dry-seeded in 4 land positions, Pangasinan, Philippines, 1976.

Because the importance of land and soil factors was not initially recognized, scarce resources were expended on land which was not of primary importance and for which suitable new technology did not exist. Land classification and stratification was therefore introduced. Upland fields in Iloilo were deleted and the focus of research on fields near free-flowing wells in Pangasinan was reduced.

The wide range of upland crops in the original patterns made pattern comparisons difficult and questionable. Furthermore, the diverse cultural requirements of the crops made it difficult to determine the farmers' ability to cope with technology requirements throughdata examination. There were too few replications of patterns with upland crop components.

Experience showed that too many fields were used at both sites initially. Although inexperienced aides could collect large volumes of data, sound summarization and interpretation required an individual with the ability to organize a data management system at the site office, and who could devote time to analyses and interpretation. In part, the use of many crops, patterns, and cooperators in 1975 must have reflected the subconscious idea that pattern testing should be judged by degree of adoption. Reduction in the number of farmer-cooperators, stratification by land and irrigation class, critical selection of a few well-designed patterns, and elimination of crops which had little market demand, reduced the data summarization and interpretation workload and increased the timeliness and focus of analysis and interpretation.

Initially component technology inputs were specified at high, protective rates. These high-cost component technology packages overlooked the fact that the farmers had cash constraints and wished to avoid risk. Insufficient attention was given to reducing total cost of all inputs to a level in line with the financial position and risk avoidance strategy of farmers. Methodical procedures developed recently aid agronomists, entomologists, and economists in specifying component technology for each crop in the pattern.

Although the sites were located in collaboration with government agencies little detail was given to describing the target areas for either site. The target area for

Pangasinan was examined recently (IRRI 1980) and the delineation of the Iloilo target area is in process. A procedure for delineating target areas has been outlined. It focuses on three factors which determine field water regimes: rainfall patterns (with emphasis on transition periods), soils (and their associated landforms), and irrigation systems. Public agencies (weather bureaus, soil survey agencies, irrigation administration agencies) are sources of the physical data. Although the procedure requires subjective evaluation, it appears to be a useful first approximation. Information on the target area should be useful to agencies responsible for designing and implementing regional production programs based on the results of cropping systems studies.

SUMMARY AND CONCLUSIONS

Cropping systems research methods, formulated to develop improved rice-based cropping patterns for rainfed and partially irrigated farms in South and Southeast Asia, were used in on-farm research projects in Iloilo and Pangasinan from April 1975 through February 1980. These on-farm projects were collaboratively implemented by IRRI and the BPI, with evaluation of cropping research methods as a primary objective and development of more productive, but economically viable rice-based cropping patterns for local farmers as a secondary objective.

Formulation of the research methods considered four factors: 1) variability in physical and socioeconomic environments which, by creating many small agroecological zones, hampers technology extrapolation; 2) farm family and community resource base limitations that govern adoption potential; 3) local technical knowledge; and 4) the short supply of manpower needed to staff field-level agricultural research and development projects. To improve research focus and aid communication between members of an interdisciplinary team, the research methods were formulated in a systems framework.

Cropping patterns were tested over the first 4 years of the project in iterated design-test-redesign-retest cycles. Agronomic and economic data collected during each cycle were used in cost and returns analysis of alternative cropping patterns, identification of weak points in the patterns, and evaluation of patterns against physical factors and farm and community resources. Through the analyses, cropping patterns were specified to fit various land, irrigation, and soil textural strata within each site.

Data analysis uncovered constraints to intensification, among which were long turnaround times between successive rice crops and between a rice crop and a following upland crop (caused by low tillage capacity and low threshing capacity in the first case and excess moisture in the second case), and delayed establishment of early direct-seeded rice (caused by low tillage capacity). Data analysis also suggested an opportunity for intensification by rice ratooning during periods too wet for upland crops but too short for a full-duration rice crop.

Several adjustments in the projects were of methodological interest. Increased emphasis was given to stratification of fields on the basis of factors controlling the field water regime, viz., landform, soil texture, and irrigation class. To consolidate research focus, the number of fields was reduced and several upland crops were

deleted as candidates for cropping patterns. Reduction in number of test fields, stratification by land and irrigation class, selection of a few well-designed patterns, and elimination of crops which had little market demand reduced the data interpretation workload and increased the timeliness of analysis and interpretation. Procedures to delineate target areas with physical conditions similar to those of the research site were outlined and used to identify areas in the Central Luzon Valley where cropping patterns tested in Manaoag are likely to be agronomically adapted.

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Cropping systems research in Thailand

D. Chandrapanya, T. Charoenwatana, A. Pookpakdi, and G. Banta

Three universities and four departments in Thailand have active cropping systems research in farmers' fields and at research sites. The following four research sites represent rainfed conditions of the Northeast and the Central Regions of the country. The first three sites are in the Northeast and the fourth is in the Central Plain.

Thailand has a land area of about 51.4 million ha of which 16.81 million is cropped land, 19.04 million ha is forest area, and the rest is grassland, current fallows, unclassified, and nonagricultural land. Cropland is divided into four major categories: paddy land, 11.37 million ha; field crops, 3.78 million ha; fruit crops, 1.62 million ha; and vegetables, about 36,000 ha.

Thailand is mainly an agricultural country. About 80% of the population are engaged in farming, and the major exports are agricultural commodities. The dependence on agriculture is so great that even minor fluctuations of weather affect the national economy. Only 17.2% cropland (2.4 million ha) is under irrigation. Eighty percent of rice and almost the entire maize, cassava, kenaf, food legumes, and other upland crops are rainfed. Consequently, the country's social and economic development is predicated on rainfed agriculture.

To further illustrate the importance of rainfall to rice production in the country, statistical records showed that in 126 years (1831-1957) rice yield was considered normal in only 62 years. Some crop damage was recorded in the other 64 years —drought occurred in 60 years and flood in 4 years. Even without years of slight to moderate drought, rice production was seriously affected in 43 out of 126 years; that is, rice production was adversely affected once in 2 years and severely affected once in 3 years.

UBON

Ubon site in the eastern part of Northeast Thailand is a rainfed area of about 500,000 ha. By road, it is about 700 km from Bangkok. The area has three seasons: the monsoon rainy season (May-September), the cool season (November-February),

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and the warm season (March-April). Rain falls regularly during the early monsoon, but is cut off sharply toward the end of the rainy season.

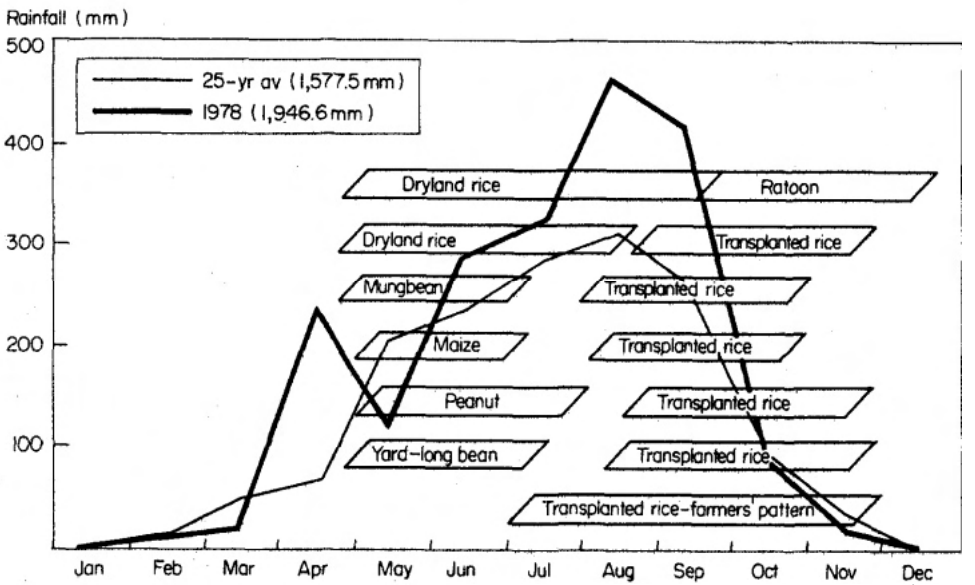
In 1978, the second year of the rainfed rice-based cropping systems research at Ubon, six cropping patterns were proposed:

1. Yard-long bean - rice (RD6) - peanut
2. Peanut - rice (RD6) - mungbean
3. Glutinous maize - rice (RD7) - peanut
4. Mungbean - rice (RD7) - sweet maize
5. Rice (RD7) - rice (RD6)
6. Rice (RD5) - ratoon

The first crop would be planted immediately when the first rains come, in the middle of April. The third crop would be planted after rice harvest, and so would have only residual moisture (Fig. 1).

The 24 farmers from 4 villages were divided into 4 groups. Each group had six farmers, each to grow one pattern. The test plot was about 800-1,200 m^2.

Soils at the experimental sites belong mostly to Roi-Et and Ubon series. They are sandy loam to loamy sand to sandy. Soil fertility is low, with about 1% or less organic matter; pH values range from 4.5 to 5.5 for the Roi-Et series and 5-5.5 for the better drained Ubon series. Cation exchange capacity value is 1.2 meq/ 100 g on the average. Farmers usually grow 1 crop of rice and get grain yields of about 1.5 t/ha on the average 5-ha farm. The abrupt cessation of precipitation at the end of the monsoon in some years results in low yield.



1. Rainfed cropping patterns tested in farmers' fields and rainfall data at Ubon site, Thailand, 1978.

Rainfall

The total rainfall in 1978 was 1,946.6 mm — 369.1 mm above the 25-year average.

First crop

Planting date was 22 April-8 May. Spacing (cm) was as follows:

- Yard-long bean 50 × 100
- Peanut 25 × 33
- Maize 25 × 100
- Mungbean 33 × 50

Rice was drilled in rows 33 cm apart, at a seeding rate of 60 kg/ha.

Fertilizer N-P_2O_5-K_2O in kg/ha was applied:

- Yard-long bean 19-38-38
- Peanut 0-38-38
- Maize 69-63-94
- Mungbean 19-38-38
- Rice (RD7) 50-38-38
- Rice (RD5) 75-38-75

Harvesting was on the given dates:

- Yard-long bean 24 Jun-25 Jul
- Peanut 21 Jul-11 Aug
- Maize 12 Jul
- Mungbean 19 Jun- 13 Jul
- Rice (RD7) 25 Aug-6 Sep
- Rice (RD5) 26 Sep-6 Oct

Second crop

Transplanted rice (RD6 and RD7) was the second crop. It was spaced 25 × 33 cm and fertilized at the rate of 50-38-38 kg N-P_2O_5-K_2O / ha. The seedbed was prepared 17 June-22 July and transplanting was done after harvest of the first crop when the field had water (18 July-31 August). All the second crop was harvested during 28 October-29 November, allowing a growing period of 135 days.

For ratoon, fertilizer at 75-38-38 kg N-P_2O_5-K_2O/ ha was applied and harvest was on 22 December. The total growing period was 82 days.

Third crop

The third crop was planted at the beginning of December after harvesting the rice crop. Although the crops germinated, all died at the later stages and there were no yields.

Yields for each pattern are shown in Table 1.

Results

1. In the second year, growing of crops before and after rice was tested at Ubon. The crops before rice were promising because they had sufficient moisture at the beginning of the wet season; those after rice failed because of lack of moisture in the later stages of development.
2. Upper or intermediate-level rice fields are suitable for crops before rice. In case of

Table 1. Yields of the first and second crops[a] of rice-based cropping systems at Ubon in Thailand, 1978.

Pattern		Yields (t/ha)	
First crop	Second crop	First crop	Second crop
Yard-long bean	Rice (RD6)	2.09	2.10
Peanut	Rice (RD6)	1.41[b]	2.28
Glutinous maize	Rice (RD7)	28,438[c]	3.04
Mung	Rice (RD7)	0.24	1.81
Rice (RD7)	Rice (RD6)	1.52	2.41
Rice (RD5)	Ratoon	0.76	0.58

[a]The third crop failed. [b]Dried pod weight. [c]Marketable ears.

heavy rain at the beginning of the wet season, the excess water can be drained from such fields.

3. Yard-long bean, peanut, maize, and mungbean have been tested as crops before rice. Yard-long bean has been grown for 2 years. Maize, peanut, and mungbean were tried for the first time. Maize and peanut gave good yields, but mungbean yields were low.
4. Rice yields in each pattern were satisfactory. It is evident that growing one crop before rice will not affect the subsequent rice planting.
5. There is a possibility of 2 rice crops in 1 year under rainfed conditions. At the beginning of the wet season a photoperiod-insensitive variety can be direct seeded. After its harvest in August, a photoperiod-sensitive variety can be transplanted.
6. Although the grain yields of both the main and ratoon crops were low, the pattern looks promising. Seeding the main crop (photoperiod-insensitive variety) at the start of the wet season and harvesting it in the middle of the wet season will leave water for the ratoon crop. Because RD5 did not yield well, some new varieties will be tested next year.
7. The lower areas are suitable for the rainfed rice -rice pattern (also rice - ratoon).

PIMAI

Pimai site is in the lower western part of Northeast Thailand, about 300 km from Bangkok. The site represents the rainfed area of about 850,000 ha that has potentials for increasing cropping intensity. It has three seasons: the monsoon rainy season (May-October), the cool season (November-January), and the warm season (February-April). Rainfall distribution is bimodal with occasional drought periods during the early monsoon.

In 1978, the second year of cropping systems research under rainfed conditions in farmers' fields at Pimai, four patterns were tested: sesame - rice, mungbean - rice, peanut - rice, and sweet maize/peanut - rice.

Soils in the area derived from semirecent and old alluvium and range from light to heavy clay composed of low humic gley, gray Podzolic, and alluvial soils. During the rainy season, farmers grow a crop of rice in the lowland paddies and cassava, kenaf, and others in the upland fields. Average farm size is about 5 ha. Rice cultivation is risky because of erratic rainfall during the early monsoon. The total rainfall in 1978 was 1,204.5 mm.

First crop

The first crop was planted 10 May-13 May. Spacing was as follows:

- Sesame, 12.5 kg/ha (broadcast)
- Mungbean, 20 × 50 cm, 3-4 plants/hill
- Peanut, 20 × 50 cm, 2-3 plants/hill
- Sweet maize/peanut intercrop (40 × 100 cm for maize and 20 × 50 cm for peanut)

Fertilizer N-P_2O_5-K_2O in kilograms per hectare was applied as described:

- Sesame, 5 treatments: 0-0-0, 37.5-37.5-37.5, 75-0-0, 75-75-0, and 75-75-75
- Mungbean, 0-0-0, 0-37.5-0, and 19-37.5-37.5
- Peanut, fertilizer same as for mungbean. For cultural practices the treatments were 1) no weeding and hilling up, 2) weeding after 20 days of emergence and no hilling up, 3) weeding after 20 days of emergence and hilling up, and 4) no weeding but hilling up included. Each treatment received fertilizer of 19-37.5-37.5.
- Maize/peanut, 62.5-62.5-0, including insect control treatments of 1) Furadan 3G 1 kg a.i./ha (at planting) and monocrotophos 1 kg a.i./ha (30 days after emergence), 2) Furadan 3G 2 kg a.i./ha (at planting) and endosulfan 1 kg a.i./ha (30 days after emergence), 3) Temmik 10G 1 kg a.i. /ha (at planting) and monocrotophos 2 kg a.i./ha (30 days after emergence), 4) Temmik 10G 2 kg a.i./ha (at planting) and endosulfan 2 kg a.i./ha (30 days after emergence), 5) check, and 6) economic threshold monocrotophos 2 kg a.i./ ha.

No yield was obtained for sesame and peanut because of flooding. Mung was harvested 25 July, maize on 2 August, and peanut on 17 August.

Second crop

Rice (KDML 105) was transplanted as the second crop between 4 August and 13 September and fertilized at the rate of 37.5-37.5-37.5 kg NPK/ha. Harvest was between 17 November and 21 December.

Results

Sesame - rice. Sesame grew well after planting, but at 2 weeks before harvest the plots were flooded and no grain yields were obtained. If the plots had been on higher levels, the crop could have been successful although the growing period was long. The rice crop after sesame gave yields of 1,394-1,8 19 kg/ha. The grain yields were not statistically different, indicating no residual effect of fertilizer used in the first crop (Table 2).

Mungbean - rice. Mungbean yields were low because of poor drainage. A fertilizer rate of 19-37.5-37.5 kg NPK/ha gave the best yield (0.28 t/ha). The grain yield of rice after mungbean showed no residual effect of fertilizer (Table 3).

Peanut - rice. Peanut at the flowering stage was badly damaged by leaf roller. Spraying with monocrotophos resulted in recovery of about 70%, but this was damaged by flood just before harvest. One plot gave a very low yield. Yields of the rice crop were 0.61-1.29 t/ha.

Sweet maize/peanut - rice. The first maize crop gave good yields because the number of pests was low. Leaf roller and flooding, however, caused poor peanut

Table 2. Grain yields of rice grown after sesame.[a] Pimai, Thailand, 1978.

Fertilizer rate (kg NPK/ha) on sesame	Rice[b] (t/ha)
0-0-0	1.75
37.5-37.5-37.5	1.39
75-0-0	1.69
75-75-0	1.82
75-75-75	1.78

[a]No yield data for sesame, which was damaged by floods. [b]Av of 4 plots fertilized at the rate of 37.5-37.5-37.5 kg NPK/ha.

Table 3. Grain yields of mungbean and rice. Pimai, Thailand. 1978.

Fertilizer rate (kg NPK/ha) on mungbean	Mungbean[a] (t/ha)	Rice[b] (t/ha)
0-0-0	0.16	1.76
0-37.5-0	0.23	1.52
19-37.5-37.5	0.28	1.47
Rhizobium	0.19	1.49

[a]Av of 5 plots. [b]Av of 4 plots fertilized at the rate of 37.5-37.5-37.5 kg NPK/ha.

yields. The short growing period of maize allowed harvest before the flood. Peanut in the control gave the lowest yield (0.26 t/ha). Grain yields of the rice crop were 1.441.93 t/ha (Table 4).

Discussion

1. Sesame, mungbean, peanut, and maize were tested as a crop before rice in rainfed fields in low areas. Fields in upper areas should be considered to avoid floods.
2. Mungbean and maize have a short growing period (74-82 days) and have potentials as a crop before rice. Both suffered less damage from flood than peanut and sesame.
3. The higher maize/peanut intercrop plots were not flooded. Maize shading reduced the weed populations in the peanut rows. One reason for the lower peanut yields was the heavy soil of the site. Some of the peanut pods were left in the soil.
4. The long growth duration of sesame and peanut allowed damage by flooding. The sesame variety with a short growing period (70-80 days) will be ideal. Planting on higher plots will also help in obtaining good yields from the two crops.
5. The average grain yield of rice for 1978 was low because of the higher level of water during transplanting. Flood damaged some rice plots.

KHON KAEN UNIVERSITY

Northeast Thailand has an area of about 17 million ha. More than 80% of its population of about 15 million are engaged in agriculture. The average farm of 3.3 ha supports a family of 7. Per capita income is estimated as 40% of the national average. The major income of the family comes from crop production, which is

Table 4. Yields of maize/peanut - rice. Pimai, Thailand. 1978.

Treatment [a]	First crop [b]		Second crop [c] (rice)
	Maize (marketable ears/ha)	Peanut (fresh pod wt, t/ha)	
1	14,181	0.70	1.83
2	11,675	0.72	1.64
3	8,681	0.70	1.68
4	8,143	0.74	1.80
5	10,893	0.26	1.44
6	7,331	0.53	1.93

[a] See fertilizer description for first crop, maize/peanut. [b] Av of 4 plots. [c] Av of 2 plots fertilized at the rate 37.5-37.5-37.5 kg NPK/ha.

limited by erratic rainfall and unproductive soils. Soils are sandy and low in water-holding capacity and have low fertility. The rainy season lasts for 6 months - May to October. About 80% of the 1,200-mm annual precipitation occurs at irregular intervals and at variable intensity during the rainy season. Rainfall in the dry season is negligible and irrigation is necessary for crop production. The potential irrigable land is less than 1% of cultivated areas.

The current cropping systems are mainly a monoculture of rice, kenaf, and cassava. Rice is a subsistence crop, which occupies more than two-thirds of the cropped land. The paddy fields lie in lowlands and in middle or even high terraces. The upper paddy fields lie idle in most years because of insufficient water for rice production. It was estimated that more than a million hectares of paddy fields lie idle annually. Kenaf and cassava occupy the major portion of uplands. It appears that the farmers' crop productivity could be improved by increasing cropping intensity.

The research project on cropping systems at Khon Kaen University is financed by the Ford Foundation. It aims to develop cropping systems suitable for rainfed cultivated areas in Northeast Thailand.

Methodology

The cropped land in the Northeast falls under three types: upland, upper (middle terrace) paddy, and lowland (low terrace) paddy areas (Fig. 2). The proposed cropping systems for the types follow:

Upland area

1. Cassava/field crops intercropping
2. Kenaf - field crops double-cropping
3. Double-cropping of field crops

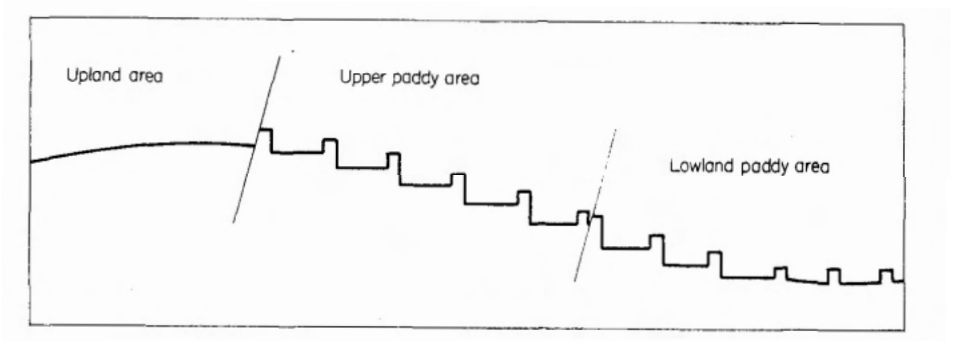
Upper paddy area

4. Double-cropping of field crops
5. Field crops before or after rice
6. Late single field crop

Lowland paddy area

7. Field crops before or after rice

The proposed cropping systems were tested both on the university farm and in farmers' fields. A standard experimental design with several replications was used on the university farm. Five villages with different socioeconomic background were test



2. Types of cultivated land in Northeast Thailand.

sites; all are in Khon Kaen province and are one hour away by car from Khon Kaen University. The village experiments were classified by level of management into three types:

1. Trials were conducted by project staffs in rented farmers' fields and plots were arranged in standard experimental design with replications.
2. Trials were conducted by the farmers in their own fields under researcher supervision. The project provided all inputs, e.g. seeds and insecticides to the farmers. The experimental plots were large, i.e. 1 rai (1,600 m^2) and arranged in demonstration type without replication.
3. Trials were managed by the farmers in their own fields. The project provided credit for necessary inputs. The farmers paid back in seeds.

Results

The research work started in late 1975. Results reported in this paper summarize the work done during the first 3 years on promising cropping patterns.

Cassava/field crops intercropping. Field crops used for intercropping on the university farm in 1975 were peanut, soybean, mungbean, and dryland rice. In 1976 and 1977 cowpea, sorghum, and maize were added to the trial. Based on 2 years' performance, only peanut, mungbean, cowpea, and soybean were selected for further testing in 1978.

Sorghum, maize, and dryland rice on infertile sandy soils were easily damaged by several insects and diseases, and suppressed by drought stress. Stands could not be established unless fertilizer was applied. Table 5 shows the results in 1977 and 1978. Cassava yield was poor in 1975, but increased in later years. Yields of legumes, particularly soybean and mungbean, were poor in 1976 and 1978 because of drought stress during the grain-forming period. Poor cowpea yield was due to a virus. Mungbean and cowpea that normally matured during the heavy rain period were damaged by fungus diseases. In 1977 legume yields were good because rainfall was favorable. Cassava - peanut gave the highest return. This pattern also produced consistent yields, which may be due to the greater number of nodules in peanut than in other legumes.

In farmers' fields, the interplanted crops in 1976 and 1977 were peanut, soybean,

Table 5. Yield, value, and net income[a] from solid cassava and different patterns of cassava/field crops intercropping at Khon Kaen University, Thailand. 1977-78.

Cropping pattern	Yield (t/ha)				Value (baht/ha)		Cash input (baht/ha)		Net income (baht/ha)	
	1977		1978							
	Cassava	Others	Cassava	Others	1977	1978	1977	1978	1977	1978
Sole cassava	24.54	–	24.24	–	9,819	18,181	1,781	863	8,038	17,407
Cassava/peanut	26.76	1.77	20.00	0.60	21,313	17,938	3,494	2,094	17,819	15,844
Cassava/soybean	22.91	1.10	20.81	0.30	14,675	17,013	2,181	1,175	12,494	15,838
Cassava/mungbean	22.89	0.74	18.38	0.05	12,869	13,981	2,181	1,163	10,688	12,819
Cassava/cowpea	21.78	1.99	15.37	0.20	16,688	12,513	2,169	1,175	14,519	11,338

[a] US$1 = Baht 20.50.

Table 6. Yields of cassava/field crops intercropping experiments in farmers' fields in Khon Kaen, Thailand, 1977 and 1978.

Cropping pattern	Yield (t/ha)											
	Village 1				Village 2				Village 3			
	1977		1978		1977		1978		1977		1978	
	Cassava	Others	Cassava	Others	Cassava	Others	Cassava	Others	Cassava	Others	Cassava	Others
Sole cassava	18.81	–	9.56	–	8.78	–	6.31	–	4.52	–	10.85	–
Cassava/peanut	15.86	0.41	9.21	0.75	4.83	269	2.80	0.84	3.89	275	6.01	0.63
Cassava/soybean	18.78	–	9.48	0.11	8.44	–	3.43	0.02	6.08	106	–	–
Cassava/mungbean	17.70	0.11	6.89	0.66	4.83	25	2.68	0.14	5.05	119	8.92	0.15
Cassava/cowpea	10.61	0.15	5.28	0.85	5.44	–	1.16	0.86	3.25	125	4.25	0.43

mungbean, cowpea, sorghum, maize, and dryland rice. Only four legumes — peanut, soybean, mungbean, cowpea — were tested in 1978.

Results for 1977 and 1978 are shown in Table 6. Results were similar to those obtained on the university farm. Cassava yield varied from site to site. Sole cassava outyielded intercropped ones. Among the intercrop combinations, cassava/ soybean showed the best yield. Peanut appeared to be more stable than other crops. The major pest of peanut was subterranean ants. Bean fly was the main insect pest of soybean, cowpea, and mungbean.

Results from the trials at both sites suggest that the promising combinations have cassava with peanut or mungbean or cowpea. They are well adapted to poor soils and drought conditions. Cowpea, however, has no market in Thailand and is grown mainly as green manure.

Kenaf - field crops double-cropping. Kenaf is drought tolerant and requires little care. It was grown with close spacing and occupied the full growing season. The trial tested the possibility of growing field crops after kenaf in rainfed conditions.

The field crops tested included mungbean, peanut, cowpea, soybean, yambean, sorghum, pearl millet, and watermelon. In 1975 when field crops were planted at the end of October — the normal cutting time for kenaf — growth was poor and yields were unsatisfactory. In 1976, planting time of field crops were adjusted by cutting kenaf 3-4 weeks earlier. Growth of field crops was better, but yields were still low. The trial designed to determine the effect of early cutting of kenaf showed that early cutting reduced fiber yield (Table 7). The yield of field crops that followed was also low, and net income from them was not profitable enough to compensate for the fiber loss due to early cutting.

Double-cropping of field crops in the upland area. Various double-cropping combinations of field crops were tested on both the university farm and the farmers'

Table 7. Fiber yield of kenaf cut at different dates and yield of second crops. Khon Kaen, Thailand, 1977.

Kenaf		Second crop		
Date of cutting	Fiber yield (t/ha)	Date of planting	Crop	Yield (t/ha)
31 Aug 1977 (129 days)	1.77	17 Sep 1977	Millet	0.26
			Mungbean	0.03
			Cowpea	0.31
			Peanut	x
			Watermelon	x
			Other crops	-
15 Sep 1977 (144 days)	2.14	27 Sep 1977	Mungbean	0.09
			Cowpea	0.26
			Watermelon	x
			Other crops	–
			All crops	–
30 Sep 1977 (159 days)	2.43	11 Oct 1977	All crops	–
15 Oct 1977 (174 days)	2.84	30 Oct 1977	All crops	–

LSD (.05) = 556.3, CV (%) = 12, x = negligible yields.

fields. First crops tested were peanut, soybean, mungbean, cowpea, maize, sesame, sorghum, and dryland rice. Second crops were peanut, soybean, mungbean, cowpea, sorghum, yambean, watermelon, roselle, pearl millet, and sesame. Results for 1978 are presented in Table 8.

Yield of crops varied from year to year depending on environmental conditions. As first crop, peanut produced satisfactory and stable yields over the years. Cowpea performed well especially in 1978. Yields of second crops were generally low. Peanut, cowpea, and mungbean gave satisfactory yields. Peanut after peanut gave a rather low yield because its planting was late and growth was suppressed by inadequate soil moisture. Where planting could be earlier, higher yield was obtained from peanut grown after cowpea or mungbean. Cowpea yield was also consistent from year to year.

Similar cropping patterns were tested in farmers' fields in five villages. Results were similar to those from the university farm (Table 9). Peanut and cowpea produced satisfactory and consistent yields across sites when grown as the first crop. Mungbean yield varied from site to site. Yields of the second crops were low and vaned from site to site. The main factors accounting for the inconsistent results were soil heterogeneity, drought stress, and insect pests. Insecticide applications were at low levels to minimize the cash input, but that led to serious damage to certain crops like legumes. Promising patterns appeared to be combinations between peanut, mungbean, and cowpea.

Double-cropping of field crops in upper paddies. Cropping combinations tested were formed from four first crops and six second crops. First crops were peanut, mungbean, cowpea, and sorghum; second crops had soybean and yambean added to the list.

Results in 1978 appear in Table 10. Peanut as first crop performed well even in heterogenous soil. Mungbean performed well only on fertile soil with good water-holding capacity. Second-crop yields were generally poor mainly because of soil moisture at later stages of growth. Environmental conditions that permit early planting would lead to better second-crop yields. Delayed planting of second crops resulted in poor yield, particularly of peanut, which is a long-duration crop.

For this system, drainage management appeared to be the main problem. Planting of the second crops in poorly drained fields was frequently delayed. Soil moisture becomes limiting for long-duration crops, such as peanut when grown as the second crop.

Field crops before rice in upper paddies. Field crops grown before rice in 1977 were peanut, mungbean, cowpea, soybean, sorghum, and baby maize. However, 1978 trials excluded soybean, sorghum, and baby maize. The trials were conducted in bunded paddy fields rented from the farmers. The results are given in Table 11.

The system depended on rainfall distribution. Rainfall in 1977 was well distributed during the first half of the season, but ceased early at the end of September. The result was good yield of field crops but low paddy production. The reverse was observed in 1978 — dry first half and too wet or flood in the second half. Most field crops failed but the rice crop was excellent. Suitable crops for growing before rice appeared to be peanut, mungbean, and cowpea. The system will be successful if rainfall during the first half of the season is evenly distributed and heavy rain occurs

Table 8. Double-cropping of field crops in an upland area, Khon Kaen University farm, Thailand, 1978. [a]

First crop					Second crop						
Crop	Yield (t/ha)	Value (t/ha)	Cash input (baht/ha)	Net income (baht/ha)	Crop	Planting date	Yield (t/ha)	Value (baht/ha)	Cash input (baht/ha)	Net income (baht/ha)	Net income (baht/ha)
Peanut	0.87	4335	1831	2504	Peanut	10 Oct	0.31	1530	1831	301	2805
					Mungbean	10 Oct	0.26	1280	1069	211	2715
					Cowpea	10 Oct	0.64	2552	1044	1508	4012
Mungbean	0.78	3905	1263	2642	Peanut	1 Sep	0.79	3970	1831	2139	4781
					Mungbean	1 Sep	0.23	1125	1069	86	2728
					Cowpea	1 Sep	0.61	2424	1044	1380	4022
Cowpea	1.31	5224	1181	4043	Peanut	1 Sep	0.68	3405	1863	1542	5585
					Mungbean	1 Sep	0.36	1780	1069	711	4754
					Cowpea	1 Sep	0.56	2224	1044	1180	5223

[a] US$1 = Baht 20.50. Current prices: peanut, baht 5.00/kg; mungbean, baht 5.00/kg; cowpea, baht 4.00/kg.

Table 9. Double-cropping of field crops in an upland area, research-managed plots, Khon Kaen University farm, Thailand, 1978-79.

Village	First crop			Second crop			
	Date planted	Crop	Yield (t/ha)	Date planted	Yield (t/ha)		
					Peanut	Mungbean	Cowpea
Muong	18 May	Peanut	0.83	8 Sep	0.16	0.18	0.19
	18 May	Mungbean	0.51	7 Sep	1.06	0.19	0.06
	18 May	Cowpea	0.61	8 Sep	0.16	0.21	0.17
Jode	27 Apr	Peanut	0.61	28 Aug	0.07	0.03	0.27
	8 May	Mungbean	0.13	28 Aug	0.04	0.10	0.18
	8 May	Cowpea	0.57	28 Aug	0.04	0.31	0.36
Pasan	28 Apr	Peanut	1.20	26 Aug	0.88	1.00	0.73
	4 May	Mungbean	0.05	26 Aug	1.06	0.14	0.83
	4 May	Cowpea	0.94	26 Aug	1.17	0.63	1.21
Koksri	8 May	Peanut	1.53	30 Aug	0.54	0.50	0.70
	13 May	Mungbean	0.58	24 Aug	1.36	0.75	0.21
	8 May	Cowpea	0.73	25 Aug	1.31	0.63	0.74
Haad	8 May	Peanut	1.36	30 Aug	0.30	0.06	0.11
	10 May	Mungbean	0.69	30 Aug	0.28	0.05	0.06
	8 May	Cowpea	1.15	30 Aug	0.22	0.06	0.16

Table 10. Double-cropping of field crops in upper paddies, research-managed plots, Khon Kaen University farm, Thailand, 1978-79.

Village	First crop			Second crop			
	Date planted	Crop	Yield (t/ha)	Date planted	Yield (t/ha)		
					Peanut	Mungbean	Cowpea
Muong	20 May	Peanut	1.24	28 Oct	0.05	0	0.05
	21 May	Mungbean	0.40	28 Oct	0.11	0.04	0.03
	20 May	Cowpea	0.74	28 Oct	0.11	0.04	0.03
Jode	28 Apr	Peanut	0.76	24 Oct	0	0.21	0
	9 May	Mungbean	0.48	24 Oct	0	0.13	0.09
	12 May	Cowpea	0.80	24 Oct	0	0.12	0.04
Pasan	12 May	Peanut	0.44	19 Oct	0.53	0.20	0.89
	12 May	Mungbean	0.17	19 Oct	0.94	0.26	1.11
	12 May	Cowpea	0.45	19 Oct	1.03	0.28	0.69
Koksri	9 May	Peanut	1.09	13 Oct	0	0.12	0.20
	12 May	Mungbean	0.39	26 Oct	0	0	0
	9 May	Cowpea	0.35	13 Oct	0	0.21	0.19
Haad	27 May	Peanut	0.49	Soil too dry to plant second crop			
	27 May	Mungbean	0.44	16 Aug – Too wet and rice is transplanted			
	27 May	Cowpea	0.68	2 Nov	1.18	0.50	0.63

in September for rice production.

Field crops before rice in lowland paddies. Procedures were similar to those in upper paddies. Field crops were peanut, mungbean, cowpea, soybean, sorghum, and baby maize. Rice was the photoperiod-sensitive local variety. Results in Table 12 show only promising crops tested in 1978.

Table 11. Double-cropping of field crops with rice in upper paddies, research-managed plots, Khon Kaen University farm, Thailand, 1978.[a]

Pattern	Village	First crop					Rice					Net income (baht/ha)
		Date planted	Yield (t/ha)	Value (baht/ ha)	Cash input (baht/ ha)	Net income (baht/ ha)	Date planted	Yield (t/ha)	Value (baht/ ha)	Cash input (baht/ ha)	Net income (baht/ ha)	
Peanut - rice	Muong Jode	22 May	0.47	2345	1888	457	29 Sep	0.49	1235	94	1141	1598
		29 Apr	1.01	5030	1831	3199	19 Aug	2.59	6470	94	6376	9575
	Pasan	19 May	0.28	1405	1881	-476	17 Aug	3.20	8000	94	7906	7430
	Koksri	9 May	8.86	4310	1831	2479	4 Sep	1.42	3548	94	3454	5933
	Haad	30 Apr	0.24	1190	1250	-60	3 Sep	1.60	4000	94	3906	3846
Mungbean - rice	Muong Jode	22 May	0.44	2215	1125	1090	23 Aug	1.42	3548	94	3454	4044
		9 May	0.54	2720	1069	1651	15 Aug	2.30	5750	94	5656	7307
	Pasan	19 May	0.19	970	1119	-149	17 Aug	2.05	5125	94	5031	4882
	Koksri	12 May	0.12	595	1181	-586	23 Aug	1.78	445 3	94	4359	3773
	Haad	28 May	0.16	815	1075	-260	16 Aug	3.46	8655	94	8561	8301
Cowpea - rice	Muong Jode	22 May	0.65	2600	1100	1500	23 Aug	1.69	4235	94	4141	5641
		9 May	0.74	2952	1044	1908	15 Aug	2.54	6345	94	625 1	8159
	Pasan	19 May	-	-	1094	-1094	16 Aug	2.07	5173	94	5079	3985
	Koksri	9 May	0.07	276	1050	-774	2 Aug	3.16	7890	94	7796	7022
	Haad	28 Apr	0.13	500	1050	-550	17 Aug	2.54	6360	94	6266	5716

[a]US$1 = Baht 20.50.

Table 12. Double-cropping of field crops with rice in lowland paddies, research-managed plots, Khon Kaen, Thailand, 1978.[a]

Crop	First crop				Rice					Net income (baht/ha)
	Yield (t/ha)	Value (baht/ha)	Cash input (baht/ha)	Net income (baht/ha)	Date planted	Yield (t/ha)	Value (baht/ha)	Cash input (baht/ha)	Net income (baht/ha)	
Muong village, planting date 23 May										
Peanut	0.02	94	1888	-1794	18 Aug	1.59	3910	94	3876	2082
Mungbean	–	–	1125	-1125	18 Aug	1.58	3951	94	3851	2732
Cowpea	–	–	1100	-1100	18 Aug	1.01	2533	94	2439	1339
Jode village, planting date 10 May										
Peanut	–	–	1831	-1831	15 Aug	1.03	2563	94	2469	638
Mungbean	0.05	250	1069	-819	5 Aug	1.36	3408	94	3314	2495
Cowpea	0.08	324	1044	-720	11 Aug	1.61	4033	94	3939	3219
Pasan village, planting date 11 May										
Peanut	0	0	1831	-1831	7 Aug	1.89	4120	94	4626	2795
Mungbean	0.03	155	1069	-914	7 Aug	1.61	4015	94	3921	3007
Cowpea	0.14	576	1044	-468	7 Aug	1.53	3813	94	3719	3251I
Koksri village, planting date 10-14 May										
Peanut	–	–	1781	-1781	29 Aug	1.68	4203	94	4109	2328
Mungbean	0.17	845	1125	-280	22 Aug	3.76	9390	94	9296	9016
Cowpea	0.03	100	994	-894	21 Aug	1.78	4438	94	4344	3450
Haad village, planting date 30 May										
Peanut	0	0	944	-944	4 Aug	2.16	5390	94	5296	4352
Mungbean	0	0	969	-969	4 Aug	2.08	5188	94	5094	4125
Cowpea	0	0	1200	-1200	4 Aug	1.79	4485	94	4391	3191

[a]US$1 = Baht 20.50. Current prices: rice = baht 2.50/kg, peanut = baht 5.00/kg, mungbean -baht 5.00/kg, cowpea = baht 4.00Fg.

In 1977 the field crops gave satisfactory yields, but the rice crops were only fair. In 1978 flood damaged most field crops before rice, and the rice crop yield was low because of excessive water. The ideal rainfall pattern for this cropping system is similar to that for the upper paddy section. Promising legumes are mungbean and cowpea.

Field crops after rice in upper and lowland paddies. Several trials on growing field crops after rice in both upper and lowland paddies were conducted in farmers' fields. Method of crop establishment included broadcasting of seed in the field before rice harvest, and planting after rice harvest with or without land preparation. Planting without land preparation included planting in the stubble, planting in the field with rice straw cut at soil surface, and planting in the field with rice straw pressed to the ground. None of the test crops — peanut, soybean, mungbean, cowpea, sorghum, maize, pearl millet, yambean, sesame, sunflower, and roselle — produced any measurable yield despite management practices. Legume crops generally germinated and grew better than the nonlegume crops. However, all died before flowering because of inadequate soil moisture. For success in this system, rice varieties must be early maturing to allow the early planting of field crops.

CENTRAL DISTRICT OF THAILAND

The Multiple Cropping Research Project of Kasetsart University, Thailand, aims to develop a cropping systems technology that will increase cropping intensity on the rice farm and make more efficient use of available resources. Priority is given to areas where rainfall is the only source of water for crop production. Such areas constitute 70% of rice farms in Thailand (Carangal 1977). With an adjustment in cropping technology, it may be possible to grow crops before and after rice.

The outreach area

The Multiple Cropping Research Project selected Bangpae district in Rachaburi province, about 100 km southwest of Bangkok, as its outreach site. Bangpae district is 60 km away from Kasetsart University's Kampangsaen campus, proposed nucleus agricultural research and training center of the university. The district is between a sugarcane area in the west and an intensive vegetable-producing area in the east, but most farms grow rice as their only crop. Farmer income is generally low — 3,500-4,600 baht/person annually (Table 13).

Table 13. Average family size and income classified by farm size, Bangpae district, Rachaburi province, Thailand, 1975.[a]

Farm size	Av no. of family members	Income (baht) per farm			Av income (baht) per family member
		Farm	Nonfarm	Total	
Small	4.38	1,416	16,416	17,831	4,071
Medium	6.04	11,667	9,685	21,352	3,535
Large	6.80	24,272	1,350	31,622	4,650
All	5.73	11,507	11,110	22,617	3,947

[a]US$1 = Baht 20.50.

Climate and soils

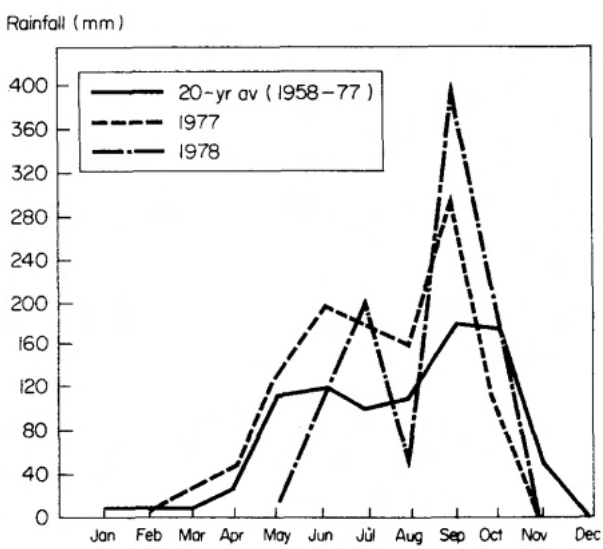
Bangpae is a rainfed area (Kasetsart Univ. / Min. Agric. Coop./ IDRC 1977). Rainfall normally begins in the middle of April and reaches a peak of 110-120 mm in June. It drops in July, then rises to a second peak in September, and ceases toward the end of October (Fig. 3). The amount is considerably low for crop requirements. In a few areas, irrigation water from constructed canals enables farmers to grow certain upland crops and vegetables.

The soil in Bangpae district is generally alluvial, with a clayey texture, high water-holding capacity, and poor aeration. pH ranges from 5.3 to 7.6, organic matter is 2.1-3.0%, available phosphorus is 20-60 ppm, and exchangeable potassium is 40-180 ppm (Kasetsart Univ./Min. Agric. Coop./IDRC 1977).

Existing crops and cropping patterns

Most farmers grow rice. About 85% of the rice area has broadcast rice, the rest has transplanted rice. In areas near the irrigation source, other upland crops such as mungbean, maize, and vegetables such as onion, garlic, and hot pepper, are grown on a small scale before and after rice.

In August the rice field receives a large amount of rainfall and water from the Maeklong river. During this period farmers transplant rice. However, flooding does not occur at the same time each year. In some cases, transplanted seedlings suffer from water shortage 1 or 2 weeks after transplanting; therefore, most farmers prefer to broadcast rice in the dry field in June before rainfall comes (Kasetsart Univ./ Min. Agric. Coop./ IDRC 1977). With sufficient moisture, seeds of rice germinate and grow high enough to extend the plants' top portion above the water when floods come in August. Broadcasting is popular but gives low yields because of nonuniform stand and weed competition.



3. Rainfall distribution in Bangpae district, Rachabud Province, Thailand.

Testing cropping patterns

The target of the cropping systems research of the Multiple Cropping Project is to establish three cropping patterns for rice farmers. Since rice has been grown widely at Bangpae district, we examined the possibility of growing additional crops before and after rice.

Testing patterns with crops before rice. The rainfall pattern of Bangpae (Fig. 3) indicates the possibility of growing a crop before rice. Some farmers have grown an early-maturing crop like mungbean, using the local variety Fag Khow in some limited areas (Pookpakdi 1979) and sowing seeds in April immediately after the first rain.

In a preliminary trial in 1977, mungbean and glutinous maize were superimposed in a trial with replications across villages. Different management practices for maize and mungbean were studied. Data for 1977 showed that mungbean could be harvested 60 days after planting, before the fields were flooded. The yield advantage of 135 kg/ ha was obtained from row planting compared to broadcasting ($p < 0.05$) (Table 14). However, neither fertilizer nor insecticide treatments gave any significant yield difference. Mungbean variety M7A gave a higher yield than the local variety in most plots because it had a higher number of pods per plant (Pookpakdi 1979). M7A also had less infection due to Cercospora leaf spot disease caused by *Cercospora canescens,* and powdery mildew caused by *Erysiphe polygoni.* The pods of M7A mature more uniformly than those of the local variety. Farmers normally harvested M7A only twice, compared with four times for the local variety (Pookpakdi 1979).

Table 14. Seed yield and some yield components of mungbean grown before rice in Bangpae district, Rachaburi province, Thailand, 1977.[a]

Treatment	Level of treatments	Seed yield (t/ha)	Pods (no./plant)	Seeds (no./pod)
Broadcasting[b]	Without fertilizer	0.29	11.0	11.6
	With fertilizer [c]	0.30	9.8	12.0
	Means	0.29		
Row planting[b]	Without fertilizer	0.41	10.0	11.8
	With fertilizer [c]	0.44	10.0	11.9
	Means	0.43	–	–
Insecticide	Without insecticide	0.47	no data collected	
	With insecticide [d]	0.56		
	Means	0.51		
Varieties	M7A	0.54	10.6	9.8
	Local variety	0.28	6.7	11.2
	Means	0.41	–	–

[a]Means of 4 replications. [b]For broadcast treatment, mungbean was seeded at the rate of 25 kg/ha; for row planting, furrows were made 60 cm apart after plowing and harrowing, and seed was drilled evenly in the furrow at the rate of 25 kg/ha. [c]Mixed fertilizer 14-14-14 given as basal application at the rate of 26.25 kg N, P_2O_5, and K_2O/ha. [d]Means of 3 insecticide treatments: Furadan 3 G at 1.5 kg a.i./ha applied twice at 3-wk intervals. Phosdrin 24% E.C. at the rate of 0.5 kg a.i./ha sprayed 3 times at 2-wk intervals; Lannate 18% W/V at the rate of 0.36 kg a.i./ha sprayed 3 times at 2-wk intervals.

Glutinous maize (*Zea mays* var. *amylacea*) was suitable before rice — the green cobs can be harvested 65 days after planting, before flooding occurs. A 53% increase in number of ears per hectare over the control was obtained from plots fertilized at the rate of 50 kg N/ ha split applied twice. Net income from the control and fertilized plots differed by baht 10,164.2/ha (Table 15). The trial planted to black gram gave poor results and was discarded.

In May 1978, a cropping pattern experiment involving mungbean M7A, soybean variety S.J. 2, sweet maize, glutinous maize. and two intercrop practices — mungbean intercropped with sweet maize and soybean intercropped with glutinous maize — was conducted with six replications. It examined the performance of crops grown in the short season before rice with respect to planting date, maturity, and yield performance.

The results revealed that mungbean was more suitable than soybean for the short growing season before rice. In 1978, rainfall which started early in May gradually increased until it reached the first peak in June. In such a case, farmers normally transplant rice in late July or early August, and an upland crop grown before rice must be planted in May and harvested in early July before flooding occurs. M7A mungbean, which matures 60-65 days after planting, was found suitable. Soybean can be grown for green pod production, but the local market is limited. Its long maturity period does not allow growing it for seed. Sweet maize, which can be harvested 60-65 days after planting, was also suitable. A drawback is the downy mildew disease, which was widespread and almost destroyed the crop in 1978. Even with supersweet DMR, a variety resistant to downy mildew, as much as 40% disease infection occurred in the test plots.

No data on glutinous maize were obtained; however, the 1977 results for that crop as well as similarity in growth habit and maturity between sweet and glutinous maize suggest that the latter has potentials. Yields of intercropped maize, soybean, and mungbean were low.

Rice crop performance. Rice is a stable crop in the cropping pattern; therefore, research examined the possibility of increasing rice yield by either introducing photoperiod-insensitive high-yielding varieties recommended by the Department of Agriculture or improving cultural management of local rice varieties, or doing both.

The photoperiod-insensitive rice variety RD7 and the photoperiod-sensitive Luang on transplanted in farmers' fields in 1977 were compared. The yield of RD7 increased from 1.96 t/ha in the plot without nitrogen to 2.71 t/ha in the plot receiving fertilizer at 125 kg of 16-20-0 NPK mixed fertilizer per hectare 1 day before transplanting plus topdressing of ammonium sulfate 45 days after transplanting. The local variety had no significant response to fertilizer application.

In 1978 trials, yields of broadcast and transplanted Luang on in 12 farmers' fields were similar (2.83 and 2.84 t/ha). Broadcasting was done in the third week of July, and transplanting took place in mid-August. In 1978, photoperiod-insensitive rice varieties were not grown because flooding occurred much earlier than usual and increased in depth abruptly in 1 or 2 days. Because water depth during flooding cannot be controlled, farmers prefer broadcasting to transplanting,

Weeds seem to be the most important problem of broadcast rice. In one weed experiment, a yield reduction of 35% was obtained when weeds could not be

Table 15. Yield and economic inputs and returns from glutinous maize plots receiving or not receiving fertilizer. Bangpae district, Rachaburi province, Thailand, 1977.[a]

Treatment	Ears (no./ha)	Fresh wt of ears (t/ha)	Gross income (baht/ha)	Cash inputs (baht/ha)	Net income (baht/ha)
Control	18,167	3.58	9,991.85	2,309.62	7,682.23
24 kg N/ha	26,250	6.64	19,687.50	5,615.36	14,072.14
50 kg N/ha	39,167	8.31	21,541.85	3,795.42	17,746.43

[a]US$1 =baht 20.50.

controlled. Therefore, our component technological researches for rice emphasized the need for weed control trials plus herbicide screening.

The 1977 rice data showed that photoperiod-sensitive rice varieties already used by farmers at Bangpae were suitable for the cropping patterns. Our data did not indicate any change in rice yield as a result of the change in fertility due to the growing of a previous upland crop.

Testing patterns with crops after rice. Superimposed experiments with mungbean, soybean, sweet maize, and glutinous maize were grown in farmers' fields in January 1978 immediately after rice was harvested. Soybean, sweet maize, and glutinous maize suffered from moisture depletion. Only mungbean survived and produced yields ranging from 400 to 700 kg/ ha.

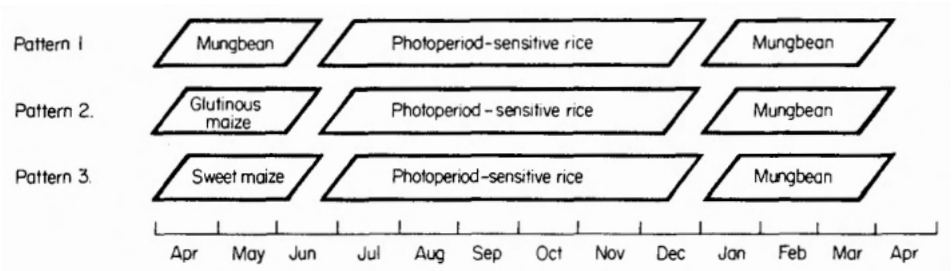
Although mungbean can be grown successfully after rice harvested in December, late planting of mungbean in February results in poor growth and low yield due to lack of moisture (Pookpakdi 1979). The growth of mungbean in January depends on soil moisture. Growing mungbean in rows in which the seedbed had been plowed and harrowed before planting did not produce any yield advantage over broadcasting. Broadcasting seeds immediately after rice harvest and plowing once by animal to barely cover the seeds with soil were suitable practices for mungbean after rice.

We tested cropping patterns using mungbean, soybean, sweet maize, glutinous maize plus two intercrop combinations in December 1978-January 1979, using the same experimental procedure as in tests of these crops before rice in 1978. The results confirm that, without irrigation, only mungbean can be grown after rice. However, late planting may result in lower yields (Table 16). Soil moisture was not enough for maize and soybean growth because both crops require more moisture than mung-

Table 16. Growing period, plant height, and seed yield of M7A mungbean grown after rice in crop year 1978. Bangpae district, Rachaburi province, Thailand.[a]

Planting date	Days to flowering	Days to maturity	Plant ht (cm) at flowering	Seed yield (kg/ha)
13 Dec 1978	36	60	26.5	781.6
21 Dec 1978	38	62	27.5	445.4
25 Dec 1978	38	59	24.5	609.2
8 Jan 1979	37	68	26.0	585.5

[a]Means of three replications.



4. Suitable cropping patterns for Bangpae district, Rachaburi ,Thailand.

bean did. Maize and soybean have a longer growing period; therefore, their water consumption over the growing period exceeds the amount provided by residual soil moisture.

CONCLUSION

Data for two crop years showed that suitable cropping patterns for Bangpae district would be mungbean - rice - mungbean, sweet maize -rice - mungbean, and glutinous maize - rice - mungbean (Fig. 4). The Multiple Cropping Research Project is evaluating these improved patterns in large-scale trials involving more farmer cooperators and larger plots. Detailed information on agronomic, soil, and other aspects of crop production will be collected.

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DISCUSSION

Syarifuddin: On the report of Khon Kaen University, Tables 5 and 6: Could you explain further why the 1978 cassava yields in farmers' fields were very low and lower than the 1977 yield? Was there any big increase in cassava price in 1978 from 1977?

Chandrapanya: Cassava yields in farmer's field were lower than yields on the university farms primarily because the university plots had been fertilized for sometime at high rates whereas in the farmer's field the rate was kept at a minimum.

Yes, the price of cassava root went up almost 100%.

Upasena: From your slides it seems that the performance of grain legumes before rice is poor. May I know the reasons. Is it because of excess moisture? If so, is it not possible to drain the field? Or is it due to some other reasons?

Chandrapanya: In northeast Thailand the stable rainfall occurs in August or September when farmers can transplant their rice. Rainfall water from May to July is inadequate and unstable, which results in poor growth and poor yield of grain legumes, i.e. peanut and mungbean, grown before rice. Excessive rainfall which is expected in July, again results in poor growth if the field is not well-prepared for drainage. In addition most paddy fields are saline, which has an adverse effect on many legumes. Legume before rice is considered risky but we feel it has potential.

Patel: In Thailand jute is grown in rotation with rice. But in your paper it seems it has not found its place as an item for export. Can you tell us if it is uneconomical to grow jute in your country or if it does not fit well in the different cropping systems.

Chandrapanya: Jute is grown in small areas in the provinces along the Mae Khong river bank, e.g. Nongkhai, which have high water level during the rainy season. Kenaf is grown in most of the northeast provinces and is considered the main crop in high-terrace land (not in paddy field). Products of either jute or kenaf are processed in our sack industry and are not a major export.

Carangal: Do the decision makers in your country really understand the cropping systems work? It is necessary for them to understand if we want our work to be successful.

Charoenwatana: For Thailand at this stage I should say "yes" because we are in the stage of setting up cropping systems research as a national program. I have a strong feeling it will get approved which means that the policy makers recognize the importance of the work. I should add that cropping systems research in Thailand is conducted both by universities and the Ministry of Agriculture. A national seminar is held in the country with all programs participating. The decision arrived at in the last national seminar suggested that we are ready to form a national program on cropping systems.

Rice-based cropping pattern testing in Korea

Seong-Ho Yun and Yong Hwa Shin

Korea is one of the densely populated countries (17 persons i ha in 1979) in the world. Accordingly, a national urgent goal is to increase food production on limited land. At present, the average cropping intensity index in paddy fields is 125; however, that can be raised to 145 if adequate rice-based cropping systems are developed.

Cropping systems in Korea have been studied mainly at three sites: the Crop Experiment Station, Wheat and Barley Research Institute, and Agricultural Sciences Institute in Suweon in the central northern part; Honam Crop Experiment Station in Iri in the southwestern part; and Yeongnam Crop Experiment Station in Milyang in the southeast.

At the nine Provincial Offices of Rural Development (PORD), cropping systems adapted to each region have also been tested in collaborative research with the Office of Rural Development (ORD).

Cropping in paddy fields is sequential the year round. Three cropping types are available:

- In summer, rice is transplanted in flooded fields and harvested in autumn in drained fields; then crops such as barley, wheat, and rapeseed are planted and harvested in late spring or early summer the following year;
- The paddy field is fallow in winter, but in the following year a spring crop, such as Irish potato, and other vegetables are sown and harvested simultaneously with the winter crop; and
- Rice - fallow.

Some existing rice-based cropping patterns such as rice - barley, rice - wheat, Irish potato - rice, and rice - forage crops, depend on regional environmental conditions. In the central-northern region, those patterns were tested at the Crop Experiment Station. However, they have not been recommended because of low crop yields and unprofitability of succeeding crops. Although the rice - barley pattern for home consumption has been traditional in the central-southern region, the trend is toward cash income patterns such as rice - malting barley, rice - rapeseed, and rice - vegetables.

This report presents the various regions' crop growth periods, yields, farm income, and changes in soil fertility due to sequential cropping.

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CROPPING PATTERN TESTING

Northern region

Cropping pattern testing for wetland rice was conducted in drained loamy soils at the Crop Experiment Station (CES), Suweon. Daily mean air temperature in winter is lower in Suweon than in Milyang and the consecutive frost-free period (1 70 days) is shorter than in Milyang by 30 days. This shorter growing period as well as severe winter is unfavorable to rice-based cropping systems in the northern region.

Although it is possible to introduce rice - barley (Yun and Ahn 1979) with Josaengtongil (early rice) and Olbori (early barley), a traditional pattern of rice - fallow has been maintained by use of high yielding long-season rice varieties with developed cultural practices. Because of the high yield of early transplanted rice in rice - fallow pattern, gross income is similar to that from a rice - barley pattern with a shorter season rice variety. At present, mechanical planters transplant younger rice seedlings and hand transplanting uses seedlings with 5-7 leaves. Thus, researchers have to test new cropping patterns adapted to new cultural practices.

The results of the cropping pattern tests at CES since 1976 are in Table 1. At the lower fertilizer and plant population, barley seeds were broadcast and incorporated into the soils by a power tiller; at heavier fertilization and higher plant population, the seeds were drilled. Irish potato presprouted in nursery beds for 25 days were transplanted in the field on 5 April. Barley and Irish potato were harvested on 15 June. Rice was transplanted on 20 June in flooded paddies and harvested on 25 September. Suweon 258, a high yielding long-season rice variety (indica × japonica) was sown in a semi-irrigated nursery bed with polyethylene film tunnel on 11 April, transplanted on 25 May, and harvested on 5 October. Rye was broadcast and incorporated into soils with a power tiller on 10 October, and harvested on 20 May the following year for silage. In general, rice yield was higher at heavier fertilization and higher plant population. A rice - fallow pattern widely practiced by farmers showed the highest yield largely because of intensive management for rice.

In the rice - fallow pattern with intensive management, brown rice yield was 7 t/ ha. The yield of the short-season rice variety Josaengtongil in the rice - barley or Irish potato - rice pattern was less than that of the long-season variety Suweon 258 in a rice - fallow pattern. Rice yields in the rice - rye and the rice - fallow patterns were similar probably because of the similar cultural practice for the same rice variety.

The late transplanting and intensive management of early rice varieties gave yields similar to those of late varieties at early transplanting with normal management. In conclusion, the rice - fallow pattern is the better choice.

Yield of barley was higher with drill seeding and heavier fertilization than with broadcast (Table 2). The yields of Irish potato at normal and at high levels of management did not significantly differ. Forage yield of rye increased at high seeding rate and heavier fertilizer application. Rice showed relatively stable income in any cropping pattern, but returns from barley and wheat lagged behind input cost in the patterns rice - barley and rice - wheat. Irish potato - rice and rice - rye patterns could guarantee stable returns from rice.

Irish potato cultivation gave the highest return for each management, but its labor requirement was also highest (Table 3).

Table 1. Average yield and sequence of crops in cropping pattern testing in the northern region, Crop Experiment Station, Suweon, 1976-78.

Cropping pattern	Rice			Crops before or after rice	
	Fertilizer N-P_2O_5-K_2O (kg/ha)	Population (hills/ha)	Yield of brown rice (t/ha)	Fertilizer N-P_2O_5-K_2O (kg/ha)	Yield (t/ha)
1. Rice - barley	150-100-120	277,778	5.2	110-60-60	2.2
	180-130-140	308,642	6.1	140-80-80	4.2
2. Irish potato[a] - rice	150-100-120	277,778	5.5	110-90-90	13.1
	180-130-140	308,642	6.0	120-100-100	14.8
3. Rice-rye (forage[a])	150-100-120	222,222	6.0	110-60-60	23.7
	200-120-180	308,642	6.8	140-80-80	33.8
4. Rice - fallow	150-100-120	222,222	6.0	–	–
	200-120-180	308,642	7.0	–	–

[a]Yield of Irish potato and fodder rye were on fresh weight basis.

Table 2. Average yield and cost, and return analysis for cropping patterns in the northern region, Crop Experiment Station, Suweon, 1976-79.

Cropping pattern	Yield (t/ha)		Gross return (US$/ha)		Input cost (US$/ha)		Net return (US$/ha)		
	Rice	Crop before or after rice	Rice	Crop before or after rice	Rice	Crop before or after rice	Rice	Crop before or after rice	Total
			Ordinary management						
Rice - barley	4.76	2.95	3202	836	2160	1764	1042	-928	114
Rice - wheat[a]	4.43	5.31	2980	1722	2160	1653	820	69	889
Irish potato - rice	4.92	12.19	3310	2389	2160	1998	1150	391	1541
Rice - rye	5.51	28.08	3707	1554	2296	1593	1441	-39	1402
Rice - fallow	5.61	–	3715	–	2296	–	1479	–	1479
			Intensive management						
Rice - barley	5.67	4.38	3814	1242	2288	1791	1526	- 549	977
Rice - wheat	5.79	3.72	3895	1206	2288	1680	1607	- 474	1133
Irish potato - rice	5.68	13.79	3821	2703	2288	2010	1533	693	2226
Rice - rye	6.17	35.68	4151	1975	2440	1620	1711	355	2066
Rice - fallow	6.46	–	4346	–	2440	–	1906	–	1906

[a]This pattern was tested in 1979 only.

Table 3. Labor requirement for barley and lrish potato in paddy fields in northern and central region (Shin et al 1977).

Cultural practice	Labor (h/ha)			
	Northern region		Central region	
	Barley	Irish potato	Barley	Irish potato
Plowing	53	160	86	122
Planting	96	670	164	643
Fertilization	18	10	32	24
Weed control	208	233	313	303
Insect and disease control	2	19	3	24
Water management	26	11	32	32
Harvesting	206	253	232	347
Postharvesting	32	21	28	4
Total	641	1,383	890	1,499

Of the crops succeeding rice, forage rye is the most profitable: its production cost is low and it can be harvested early with relatively high yield to allow transplanting of rice on time. Forage production is extremely important in Korea because the price of feeds is increasing. In the rice - barley pattern, fodder yield is low because barley has low tolerance for winter temperatures and wet paddy soil. However, its nutritive value as hay or silage is higher than that of rye when both crops are harvested at the same date (Table 4).

When rye is harvested early as green manure, about 10-15 t/ ha in fresh weight can be obtained and can be incorporated directly into the soil by a tractor.

Changes in soil fertility after the 2-year cultivation of crops in each cropping pattern are shown in Table 5. Available phosphorus pentoxide, silicon oxide, and calcium in the soil markedly increased in all cropping patterns, but after Irish potato harvest the silicon oxide content in normal cultivation plots decreased. Soil porosity increased after harvest of upland crops in all cropping patterns.

Cropping patterns tested at the Gyeonggi PORD are shown in Table 6. The yield of an early rice variety in double-cropping was lower by 18% than that of a longer-season variety in the rice - fallow pattern. However, the farmer's income from the rice - garlic pattern was similar to that from the Irish potato - rice pattern, although many garlic seed bulbs were required and suitable land was limited.

Central region

Seven cropping patterns were tested in a loamy soil (pH 6.0, organic matter: 1.9%) at the Chungbug PORD (Table 7). Rice - garlic, pea - rice, and Irish potato - rice patterns were promising.

In Chungnam PORD, the yield of rice in double-cropping patterns was lower than that of rice in the rice - fallow pattern. However, double-cropping may be feasible when high-value vegetables are introduced (Table 8).

Southwestern region

Rice - naked barley and rice - rapeseed patterns have long been used in the southwestern region. Recently, the rice - wheat pattern was tested at the Honam

Table 4. Yield of rice - fodder, barley and rye, and rice - fallow cropping patterns, Crop Experiment Station, Suweon, 1974-76.

Cropping pattern	Crop	Date		Yield (t/ha)			
					Fodder crop		
		Transplanting or sowing	Harvest	Rice	Fresh wt	Dry wt	Total digest-ible nutrients
Rice - barley	Rice	21 May	1 Oct	7.6	–	–	–
	Barley	10 Oct	10 May	–	30.8	4.7	3.6
	Rice	31 May	2 Oct	7.3	–	–	–
	Barley	10 Oct	20 May	–	38.4	6.9	5.3
	Rice	9 Jun	5 Oct	7.3	–	–	–
	Barley	10 Oct	30 May	–	35.4	9.9	–
Rice - rye	Rice	21 May	1 Oct	1.6	–	–	–
	Rye	10 Oct	10 May	–	35.4	6.8	3.9
	Rice	30 May	2 Oct	7.3	–	–	–
	Rye	10 Oct	20 May	–	43.8	10.1	5.6
	Rice	9 Jun	5 Oct	7.1	–	–	–
	Rye	10 Oct	30 May	–	36.1	11.6	–
Rice - fallow	Rice	21 May	1 Oct	7.1	–	–	–

Table 5. Soil fertility [a] 2 years after different cropping patterns. CIRC, Office of Rural Development, Suweon, 1978.

Fertilization	Cropping pattern	Soil depth (cm)	pH of H_2O (1:5)	Organic matter (%)	Available P_2O_5 (ppm)	Available SiO_2 (ppm)	Exchangeable cations (meq/100 g) K	Ca	Me	Solution Zn (ppm)	Pore (%) in soils
				After succeeding crop's harvest							
Normal	Rice - barley	0-10	++	±	+++	±	±	++	++	+	±
		10-20	++	+	+	–	–	+	+	+	±
	Potato - rice	0-10	+	+	+++	+	–	+	±	-	+
		10-20	+	±	±	+	+	±	±	-	+
	Rice - rye	0-10	+	+	+++	+	±	+	±	+	-
		10-20	±	–	±	+	–	±	-	+	+
	Rice - fallow	0-10	5.5	2.10	124	17	0.23	2.93	0.56	0.86	57
		10-20	5.8	1.94	18	19	0.15	3.51	0.65	0.55	53
Heavy	Rice - barley	0-10	+	±	±	–	±	+	–	+	+
		10-20	±	+	++	++	–	+	+	-	++
	Potato -rice	0-10	±	–	+	–	–	–	±	+	+
		10-20	±	±	+++	±	±	–	+	-	++
	Rice - rye	0-10	±	±	++	–	±	++	+	++	±
		10-20	±	±		±	–	+	+	±	±
	Rice - fallow	0-10	5.9	2.50	135	348	0.24	3.96	0.63	0.69	53
		10-20	6.2	1.91	60	170	0.17	4.42	0.63	0.11	45
				After rice harvest							
Normal	Rice - barley	0-10	+	+	+	+		+	+	+	+
		10-20	+	+	++	+		+	±	++	++
	Potato - rice	0-10	±	+	+	+		+	+	+	-
		10-20	±	+	+	+		+	+	++	+

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TABLE 5 CONTINUED

Fertilization	Cropping pattern	Soil depth (cm)	pH of H_2O (1:5)	Organic matter (%)	Available p_2O_5 (ppm)	Available SiO_2 (ppm)	Exchangeable cations (med/100 g) K	Ca	Mg	Solution Zn (ppm)	Pore (%) in soils
	Rice - rye	0-10	+	++	+	+		+	+	+	+
		10-20	+	+	++	±		±	±	±	++
	Rice - fallow	0-10	6.0	1.55	106	81		2.70	0.46	0.60	51
		10-20	6.0	1.15	32	110		3.70	0.75	0.40	43
Heavy	Rice - barley	0-10	+	+	+	±		++	±	–	±
		10-20	+	±	++	±		+	±	–	++
	Potato - rice	0-10	±	±	+	+		+	±	±	±
		10-20	–	–	+	±		+	+	±	+
	Rice - rye	0-10	+	+	+	–		+	±	–	++
		10-20	+	+	++	±		+	±	–	++
	Rice - fallow	0-10	6.1	1.80	132	398		490	0.69	1.55	51
		10-20	6.3	1.60	32	178		460	0.81	0.80	42

[a]* = no difference, +, ++, +++ = increased, – = decreased compared with rice - fallow.

Table 6. Yield of crops in 5 cropping patterns in northern region. Gyeonggi Provincial Office of Rural Development, Bucheaon. 1977-78.

Cropping pattern	Crop (variety)	Transplanting or sowing date	Fertilizer (kg/ha) $N-P_2O_5-K_2O$	Yield[a] (kg/ha)
Rice - barley	Rice (Milyang 21)	15 Jun	120-60-80	4.53
	Barley (Olbori)	10 Oct	120-90-170	4.13
Rice - garlic	Rice (Milyang 21)	15 Jun	120-60-80	4.50
	Garlic (local var.)	10 Oct	150-150-150	4.73
Rice - rye (fodder)	Rice (Milyang 21)	15 Jun	120-60-80	4.85
	Rye (local var.)	10 Oct	120-90-90	26.83
Irish potato - rice	Irish potato (Irish cobbler)	1 Apr	100-90-110	8.91
	Rice (Milyang 21)	15 Jun	120-60-80	4.56
Rice - fallow	Rice (Milyang 23)	25 May	150-60-80	5.60

[a]Rice: brown rice.

Table 7. Yield of crops in 7 cropping patterns in the central region. Chungbug Provincial Office of Rural Development, Cheongju, 1977-78.

Cropping pattern	Crop (variety)	Transplanting or sowing date	Fertilizer (kg/ha) $N-P_2O_5-K_2O$	Yield[a] (t/ha)
Rice - barley	Rice (Milyang 21)	16 Jun	150-100-120	5.30
	Barley (Bunong)	15 Oct	120-80-70	2.10
Rice - wheat	Rice (Milyang 21)	18 Jun	150-100-120	4.87
	Wheat (Jogwang)	15 Oct	120-80-70	4.60
Rice - rye	Rice (Milyang 21)	27 May	150-100-120	5.95
	Rye: forage (local var.)	15 Oct	120-80-70	27.50
Irish potato - rice	Irish potato (Irish cobbler	5 Apr	100-100-120	10.98
	Rice (Milyang 21)	16 Jun	150-100-120	5.07
Pea - rice	Peas (Sparkle)	10 Mar	40-100-100	4.40
	Rice (Milyang 21)	16 Jun	150-100-120	5.61
Rice - garlic	Rice (Milyang 21)	22 Jun	150-100-120	4.94
	Garlic (Danyangjaerae)	20 Oct	300-200-150	3.75
Rice - fallow	Rice (Suweon 258)	27 May	180-100-120	5.13

[a]Rice : brown rice.

Crop Experiment Station in Iri. Consecutive frost-free period in Iri is 183 days, which is 12 days longer than in Suweon. When an early rice variety, Josaengtongil, and an early wheat variety, Jogwang, were used in the rice - wheat pattern, fallow time in a year was 33 days (Table 9). Therefore, high yielding longer season rice varieties can be used in rice - wheat pattern if a shorter season wheat variety such as Olmil is in the pattern. Traditionally, naked barley is grown in paddies; but wheat is grown in uplands because of its longer growing season.

Table 8. Yield of crops in 6 cropping patterns in the central region, Chungnam Provincial Office of Rural Development, Yuseong, 1977-78.

Cropping pattern	Crop (variety)	Transplanting or sowing date	Fertilizer (kg/ha) $N-P_2O_5-K_2O$	Yield[a] (t/ha)
Rice - barley	Rice (Milyang 21)	15 Jun	150-80-90	5.18
	Barley (Gangbori)	20 Oct	150-80-70	6.46
Rice - garlic	Rice (Milyang 21)	15 Jun	150-80-90	4.88
	Garlic (local var.)	25 Oct	250-250-250	8.48
Irish potato - rice	Irish potato (Irish cobbler)	10 Mar	100-80-100	6.30
	Rice (Milyang 21)	15 Jun	150-80-90	5.16
Chinese cabbage - rice	Chinese cabbage (hybrid)	1 Mar	220-150-260	34.84
	Rice (Milyang 21)	15 Jun	150-80-90	5.06
Rice - fallow	Rice (Milyang 23)	30 May	180-90-90	5.86
Rice - fallow	Rice (Milyang 21)	15 Jun	150-80-90	5.30

[a] Rice : brown rice.

Table 9. Yield of crops in rice-wheat patterns in the southwestern region. Honam Crop Experiment Station, Iri, 1976-77.[a]

Cropping pattern	Crop (variety)	Date: Trans-planting or sowing	Date: Harvesting	Growth duration (days)	Fallow (days)	Yield (t/ha)
Rice - wheat	Rice (Josaengtongil)	24 Jun	26 Sep	94	24	5.56
	Wheat (Jogwang)	20 Oct	15 Jun	238	9	4.64
				(332)	(33)	
Rice - wheat	Rice (Milyang 21)	24 Jun	30 Sep	98	20	6.22
	Wheat (Jogwang)	20 Oct	15 Jun	238	9	4.64
				(336)	(29)	
Rice - wheat	Rice (Iri 300)	24 Jun	17 Oct	115	13	5.99
	Wheat (Jogwang)	3 Nov	18 Jun	231	6	4.73
				(346)	(19)	
Rice - fallow	Rice (Tongil)	10 Jun	5 Oct	117	248	6.23

[a] Numbers in parentheses represent the total for each cropping pattern.

Southeastern region

Consecutive frost-free period in the southeastern region is 204 days in a year and low-temperature stress on cropping patterns in the experimental sites is minimum. Rice - barley and rice - wheat patterns are adapted to the region; however, farm returns from barley and wheat are negative because of high production cost and relatively low yields. Fallow time in the traditional rice - barley pattern is 54 days; thus triple-cropping with short-season vegetable crops is possible. Experiments indicate that the Irish potato - rice - spinach pattern is economical. Rice-

barley/ squash may not be practical because of the short fallow time of 5 days with an overlapping period of 51 days. However, Irish potato - rice - spinach could be practical with a net income of US$2,868/ha and a reasonable fallow time of 16 days in a year (Table 10). In spite of its high profitability, this pattern will be practiced in a limited area because it requires certain soil conditions and intensive labor.

South coast region

In the south coast, consecutive frost-free period is more than 200 days in a year. Research at Gyeongnam PORD shows that some vegetable and industrial crops such as onion, rapeseed, and malting barley can be grown in the paddy and the cropping system is diverse (Table 11). The rice yield depends on the variety's yield potential rather than on transplanting time. A long-season variety, Milyang 23, yielded more than the early varieties Milyang 21 and Honamjosaeng, and longer season varieties of the rice - fallow pattern in the northern region can be grown in a double-cropping system without yield reduction. Research is concentrated on the introduction of new crops such as malting barley, onion, rapeseed, and Chinese cabbage in rice-based cropping patterns that are traditional in the uplands. Net income per hectare is US$3,855 for rice - onion, $3,197 for Irish potato - rice, and $3,070 for rice - malting barley. These are higher than income from the rice - fallow pattern by 48, 18, and 19%.

Another experiment examined the possibility of double-cropping using an early rice variety, Milyang 21 (Fig. 1). Delayed transplanting reduced the growth duration of rice. The maximum rice yield was obtained from the 15 June planting; yield decreased as the transplanting date was advanced or delayed under normal fertilizer conditions. Yield reduction at early planting can be solved with improved cultural practices, but yield reduction at late transplanting is due to short growth duration and lower temperature during the ripening stage of the rice plants. Therefore, Milyang 21 should be transplanted by the end of May and harvested in early September to allow timely transplanting of Chinese cabbage seedlings.

PROBLEMS IN INCREASING CROPPING INTENSITY

Korea is in the temperate region, thus there are problems in intensified planting of crops from tropical countries. First, low temperature is the most limiting factor for double- or multiple-cropping systems; therefore, development of high yielding short-season varieties is necessary. The second problem is wet soil. Although climatic conditions are favorable for double-cropping, some crops grow in upland soils that are poorly drained after rice harvest. The third limitation is technology. Farmers who grow food crops usually do not have technology for growing high-value vegetables. Labor shortage and high wages are a fourth problem. The rural population is decreasing, and wages in 1979 increased by 380% compared to that in 1975. Net income from food crops except rice is negative because of less mechanized labor-intensive cultivation, low yields, high wages, and low price of farm products. However, profitability of cropping patterns should be understood in terms of family-based labor use during the off-season. Lastly, there is no intention to produce more cereal food, especially barley. Since self-sufficiency in rice has been achieved,

Table 10. Average growth duration, yield, and net returns of crops in 5 cropping patterns in the southeastern region. Yeongnam Crop Experiment Station, Milvane, 1976-78.

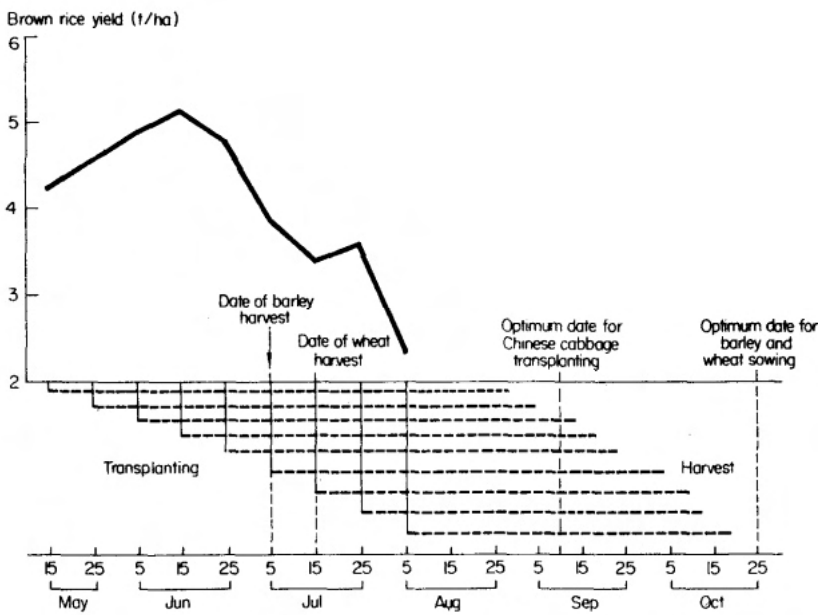
Cropping pattern	Crop	Transplanting or sowing date	Growth duration (days)	Fallow (days)	Yield (t/ha)	Gross return (US$/ha)	Cost (US$/ha)	Net return (US$/ha)
Rice - barley	Rice	16 Jun	112		6.80	2781	1885	896
	Barley	16 Nov	199		2.92	695	1275	–580
	Total		311	54		3476	3160	360
Rice - wheat	Rice	17 Jun	112		7.10	3394	1885	1509
	Wheat	16 Nov	204		2.88	786	1275	–489
	Total		316	49		4180	3160	1020
Oats - rice	Oats	2 Mar	103		2.02 [a]	354	1275	–921
	Rice	17 Jun	112		7.04	3367	1885	1482
	Total		215	150		3721	3160	561
Rice - barley/squash	Rice	10 Jul	89		4.73	2261	1885	376
	Barley	16 Nov	199		1.86	1169	1275	–106
	Squash	3 Mar	123 (–51) [b]		12.55 [c]	443	1275	–832
	Total		360	5		3873	4435	–562
Potato - rice - spinach	Potato	11 Apr	62		18.19 [c]	2496	1350	1146
	Rice	17 Jun	100		6.31	2578	1885	693
	Spinach	5 Oct	187		9.80 [c]	1441	1240	201
	Total		349	16		6515	4475	2040

[a] Dry weight as hay. [b] Overlapped for 51 days with barley. [c] Fresh weight.

Table 11. Yield of crops in 8 cropping patterns in the south coast area. Gyeongnam Provincial Office of Rural Development, Jinju, 1977-78.

Cropping pattern	Crop (variety)	Transplanting or sowing date	Fertilizer (kg/ha) $N-P_2O_5-K_2O$	Yield[a] (t/ha)
Rice - barley	Rice (Milyang 23)	15 Jun	150-60-80	6.83
	Barley (Olbori)	5 Nov	90-80-80	4.39
Rice - malting barley	Rice (Milyang 23)	15 Jun	150-60-80	6.55
	Malting barley (Hyangmag)	5 Nov	90-80-80	4.64
Rice - wheat	Rice (Milyang 23)	20 Jun	150-60-80	6.71
	Wheat (Olmil)	5 Nov	90-80-80	4.69
Rice - rapeseed	Rice (Milyang 21)	25 Jun	150-60-80	5.17
	Rapeseed (Yudal)	30 Oct	100-80-80	2.66
Rice - onion	Rice (Milyang 21)	25 Jun	150-60-80	5.58
	Onion (Cheonjuhwang)	30 Oct	280-180-230	33.50
Rice - Chinese cabbage	Rice (Honamjosaeng)	30 May	150-60-80	4.50
	Chinese cabbage (Daehyeong-garag)	11 Sep	250-200-250	145.45
Irish potato - rice	Irish potato (Irish cobbler)	25 Mar	150-120-150	6.46
	Rice (Milyang 23)	20 Jun	150-60-80	6.58
Rice - fallow	Rice (Milyang 23)	5 Jun	150-60-80	6.84

[a] Rice : brown rice. Barley, malting barley, rapeseed : grain. Onion : fresh bulb. Chinese cabbage : fresh wt. Irish potato : fresh tuber.



1. Changes in brown rice yield and growth duration of an early variety, Milyang 21, in the south coast region, Gyeongnam Provincial Office of Rural Development, Jinju, China, 1977-79.

both the farmers and the government have paid more attention to rice than to other crops.

SUMMARY

Results of the wetland rice cropping pattern tests conducted at three crop experiment stations and at four provincial Offices of Rural Development in Korea are summarized:

1. Income from rice in any cropping pattern was relatively stable, but returns from barley and wheat lagged behind input cost. In the northern region, however, Irish potato - rice, rice - forage rye, and rice - garlic were identified for stable income.
2. The available phosphate, silica, and exchangeable calcium in paddy soils increased after 2 years of double-cropping patterns compared to the rice - fallow pattern.
3. Yields of rice in double-cropping patterns were not significantly less than those of rice - fallow pattern. Therefore, double-cropping with high-value vegetables such as Irish potato, garlic, pea, and Chinese cabbage in the central region is feasible.
4. In the southwestern region, high yielding and long-season rice varieties can be used in the rice - wheat pattern if a short-season wheat variety — Jogwang or Olmil — is introduced in the pattern without considering income.
5. The traditional patterns in the southern area, rice - barley and rice - wheat patterns, were adapted although farm returns from barley and wheat were negative because of high input cost and low yield. A triple-cropping pattern of Irish potato - rice - spinach with net income of US$2,868/ha and reasonable fallow time of 16 days in a year at Milyang could be practical.
6. In the south coast area, the warmest region among the testing sites, the net incomes of US$3,855, $3,197, and $3,070/ha from rice - onion, Irish potato - rice, and rice - malting barley are higher than income from the rice - fallow pattern by 48, 18, and 19%.
7. Problems in increasing cropping intensity in Korea are a) low temperature, b) wet soil damage to upland crops in paddy after rice, c) lack of farmers' technology for growing high-value vegetable crops, d) farm labor shortage and high wages, and e) lack of intention to produce cereal food crops, especially barley, because of self-sufficiency in rice.

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DISCUSSION

Pookpakdi: Do you have a cereal crop as a winter crop and legumes like soybean as a summer crop in dryland cropping patterns in Korea?

Yun: The traditional cropping patterns in dryland areas are mainly soybean - barley or soybean - wheat patterns.

Hanwan: The rice yields obtained from experimental plots seem to be lower than the national average yields (expressed in polished rice), especially after 1976. Could you please comment on this.

Yun: The early-maturing rices usually yielded lower than late-maturing rices. We have to use the early-maturing rices in double-cropping patterns. Also, yields obtained by Korean farmers are generally higher than those from experimental plots because the experimental plots receive less intensive cultural management such as the fertilizer rate, and some other components. Most Korean farmers are seriously working to maximize rice yield especially in the rice - fallow pattern, which uses intermediate or late-maturing rices.

Hoque: You used a fertilizer rate of 150-60-80 kg N, P_2O_5 per ha in rice. What kind of efficiency do you usually get with this fertilizer rate? Also, can you please give us some idea about the farmers' fertilizer rates for rice crops?

Yun: Our recommended fertilizer rates are 150-100-120 kg N-P_2O_5-K_2O/ha. Because we have newly developed rice varieties with relatively high nitrogen response, the optimum nitrogen rate for maximum yield is usually more than 210 kg N/ha in soils of my country. I don't have any idea about farmers' fertilizer rates in tropical countries.

The rice-based cropping system and its development in China

Guo Yi-Xian

China's vast cropping area extends from the south end of Hai-nan Island (18° 9'N) to the northern part of Hei-long-jiang Province (50° 13'N), and from tide-flooded lowland fields along the eastern shores to the Yun-Guei plateaus of about 2,600 m above sea level in the southwest. As a result, varied cropping systems have developed throughout the country.

ENVIRONMENTAL FACTORS

The major environmental factors that affect the rice cropping systems of China are temperature, rainfall, day length, and soil.

Temperature

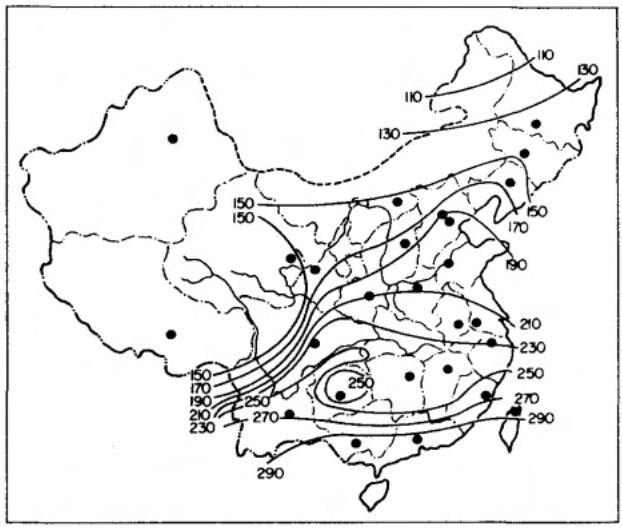
Because China traverses the tropics, the subtropics, the temperate zone, and the subrigid zone, temperature is the main environmental factor that affects rice cropping systems. The mean January temperature at the south of Hai-nan lsland averages 34° C, that at northern Hei-long-jiang is about -30° C. Because of the influence of the sea and the mainland, the mean July temperatures in the north and the south differ less. The highest average July temperature in the Si-chuan Basin is 30°C, and the lowest in the northeastern part in Hei-long-jiang is about 20° C.

The length of the growing period for rice varies considerably in the different regions. The period is shortest (less than 110 days) in the northern part of Hei-long-jiang and longest (290 days or more) in southern Guangdong Province. The growing period increases from north to south and from east to west (Fig. 1). In some areas along the east coast affected by the ocean climate, temperature in the spring rises rather slowly; hence, the growing period of rice is shorter than that in the inland region on the same latitude.

Precipitation

The annual precipitation in China is irregularly distributed. Generally, it diminishes from the southeast to the northwest, and from areas along the coast to inland regions

Agricultural Academy of Sciences, Bei-jing, China.



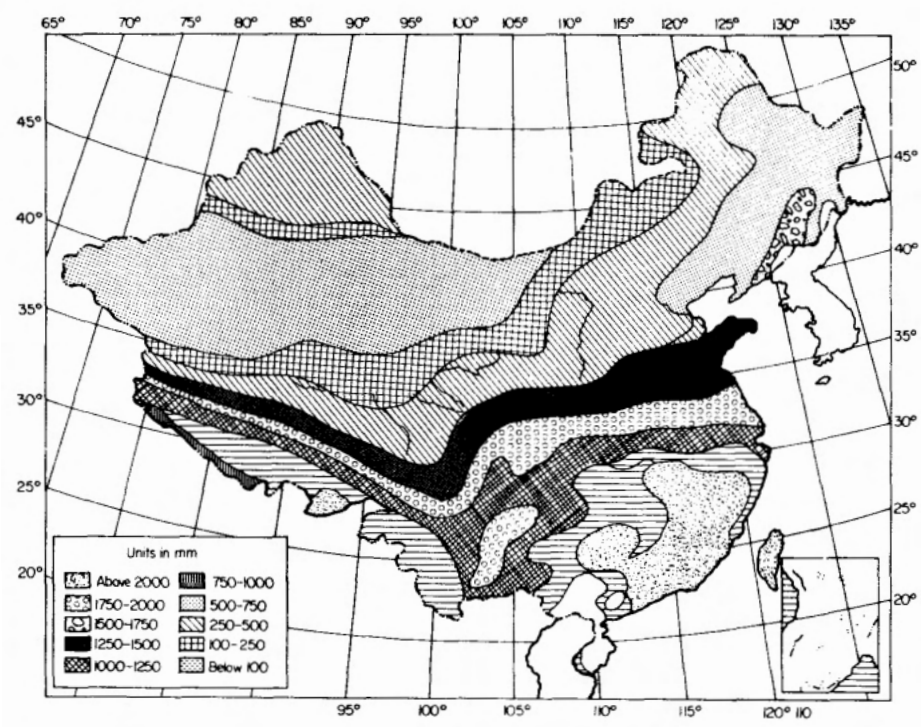
1. Growing periods of rice in different areas of China.

(Fig. 2). Along the west slope of the Da-xing-an-ling Mountains and running southward, the isohyet of 500 mm annual precipitation passes through the upper reaches of the Liao-ho River and the fringes of the Yan-shan and Tai-hang-shau Mountains to the north slope of the Chin-ling Mountains. Areas west of this line have an annual precipitation of less than 500 mm. The isohyet drawn from the Huai-he River to Chin-ling represents an annual precipitation of 750 mm, and that along the Yangtze River, 1,000 mm. The annual precipitation in areas south of the Yangtze River is more than 1,000 mm.

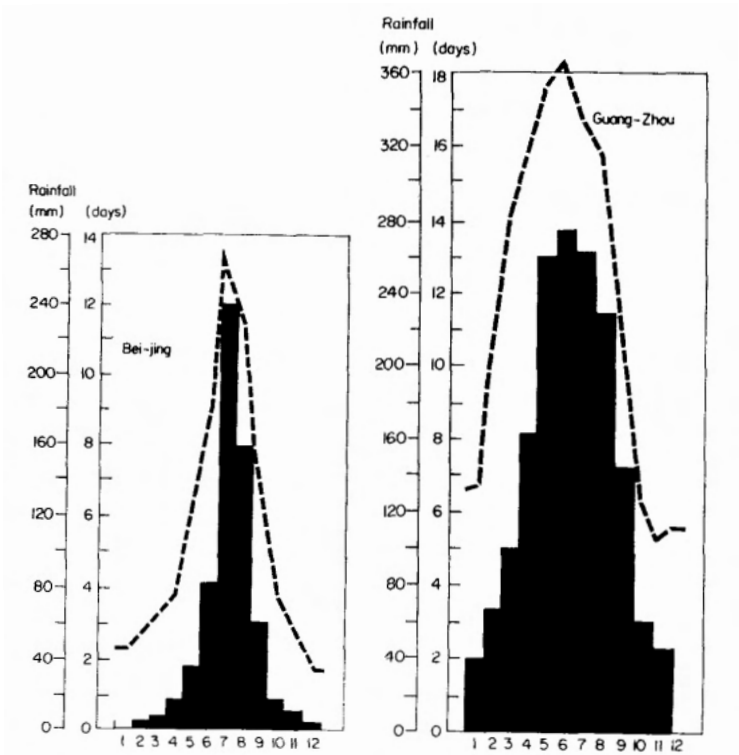
Under the influence of the monsoons, the annual precipitation is highest in summer and lowest in winter in all localities. The rainfall concentration in summer is more apparent in higher latitudes and in areas north of the Huai-he River. In Bei-jing for example, the summer rainfall is 75.1% of the annual precipitation, while the winter rainfall is only 1.7%. In Guang-zhou, South China, the summer rainfall is 46.5% of the annual precipitation, and that in winter is 9.0% (Fig. 3).

Day length

Differences in latitudes and growing seasons among localities cause differences in the conditions under which rice is grown. In areas near the Hei-he County (50° 13' N), in Bei-jing (39° 48'N), and in Shao-Xing County (30°'N) of Zhe-jiang Province (where mid-June to early July is the rice-growing period), the day length during the whole rice-growing period (May-Sep) is more than 14 hours; in the Haikou County (20°02'N), Hai-nan Island, it is less than 13.5 hours. Moreover, the trends in day length variation during the rice-growing period in the different localities also differ. Differences in day length and trend in day length variations resulted in different varietal responses to day length in the different cropping systems.



2. Distribution of annual precipitation in different areas of China.



3. Distribution of seasonal rainfall in Bei-jing and Guang-zhou, China.

Soil

Because of the wide variation in climate, soil-forming parent rock, and cropping systems, paddy soils in China range from clay to sand, with pH values from lower than 6 to higher than 9. Soils in the plains of Central and South China are alluvial, formed from sedimentary materials of rivers and lakes, deeply layered, rich in mineral and organic matters, and comparatively fertile.

The paddy soil in the hilly regions developed from red loams, yellow earths, and yellowish-brown earth. It is generally acidic, contains comparatively little organic matter, and lacks mineral nutrients such as calcium, magnesium, phosphorus, and potassium. But the purple mud soil developed from the purplish-brown loam has moisture- and fertility-preserving capacities, and is rich in mineral nutrients. It is the high-producing soil in the hilly regions of Sichuan and Guei-zhou Provinces.

There are a few low-producing soils such as the *rust-water field soil,* the *cold-soaked field soil,* the *mashed-mudfield soil,* and the *duck-dropping mud.* Their common defects are poor drainage, heaviness and poor texture, and strong reduction. The *rust-water field soil* contains toxic levels of ferrous salts.

Paddy soils of the north developed mostly from chestnut, meadow, marshy, and saline-alkali soils. Their pH value is usually higher than 8. Except for the meadow soil, they are rich in mineral nutrients and have rather low organic matter (0.5-1.0%).

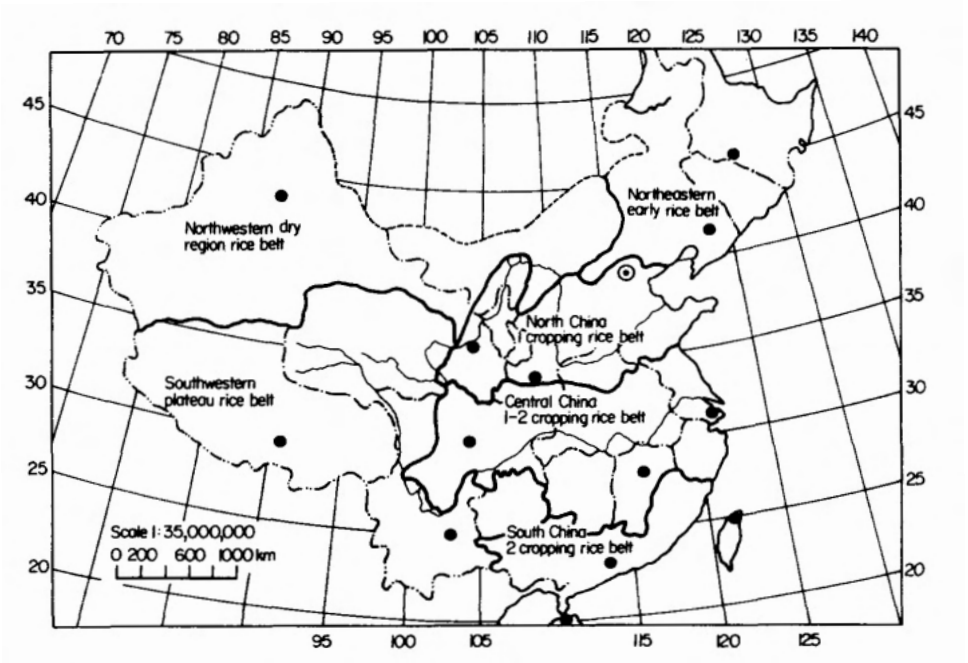
SOCIAL FACTORS

Only about 100 million ha of China's 960 million ha is cultivated. On the basis of 800 million rural population, each farm would average less than 0.13 ha. Moreover, because of the concentration of population in provinces along the southeastern coasts, the per-capita arable land averages less than 0.07 ha in some areas of Jiang-su, Zhe-jiang, Fujian, and Guangdong. Population density played an important role in forming and developing rice cropping systems in different places.

DEVELOPMENT OF RICE-BASED CROPPING SYSTEMS

The late Director of the Chinese Academy of Agricultural Sciences, Professor Dying-ying (1957), divided the rice-cropping areas of China into six belts according to environmental conditions and cropping systems: South China double-cropping rice belt (south of Nan-ling Mountains), Central China single- and double-cropping rice belt (north of Nan-ling mountains and south of Huai-he River and Chin-ling Mountains), North China single-cropping rice belt (north of Huai-he River and Chin-ling Mountains, to the south of the Great Wall, and east of Lan-zhou in Can-su Province), northeastern early rice belt (north of the Great Wall, and east of Da-xing-an-ling Mountains), northwestern dry-region rice belt, and southwestern plateau rice belt (Fig. 4).

Most paddies in old China grew rice only once a year. Even in the South China double-cropping rice belt with sufficient heat, rainfall, and labor, the index of land utilization was low. It was 186.2% in Guangdong until 1952, 141.5% in Guang-si Zong autonomous region, and even lower in the Central China single - and double-cropping rice belt, where the temperature was not as favorable. For example, the



4. Sketch of rice-cropping regions in China.

land utilization index in the paddies of Si-chuan was only 110-120%. Relay cropping of rice was carried out in the southern parts of Zhe-jiang and Jiang-si, and in the eastern part of Hu-nan Province (about south of 28° N).

All the paddies in the three other rice belts — North, northeastern, and northwestern China — grew one crop yearly and accounted for only 4.4% of all rice fields in China.

After the establishment of New China, people built water conservation facilities, established irrigation and drainage systems, improved rice cropping environmental conditions, and applied more fertilizers. As early as the 1950s rice-cropping systems changed from single-cropping to double-cropping, from intercropping to relay-cropping, from one crop a year to two crops, and from dryland to wetland fields. In the 1970s, rice cropping systems in the three rice belts in the south further changed from two to three crops. The double-cropping rice region pushed northward from the original 28°N line to about 32°N; the wheat-rice 2-cropping system pushed northward from the original Yangtze River Basin through the Hai-he and Yellow Rivers into the North China plains, where it has been established as that belt's major rice-cropping system.

Improvements in cropping systems have played an important role in food production in different localities. In Zhe-jiang, grain yields increased from 4.08 t/ha in 1965 to 6.55 t/ha in 1966; with the change from the 2-crop system to the 3-crop system, after rice intercropping was changed to rice relay cropping, the average grain yield increased to 9.4 t/ha in 1978. In the Su-zhou district of Jiang-su Province, adoption of the two-crop system in the 1960s gave an average yearly total grain production

450,000 t more than that in the 1950s. Production in the 1970s was further increased by 1 million t (of which rice yield was 825,000 t). That enabled the district where the per-capita arable land was less than 0.07 ha to attain self-sufficiency in rice.

The development during the past 30 years and the present status of the major rice-based cropping systems of China are briefly described, with the South China double cropping rice belt, the Central China single-, double-cropping rice belt, and the North China single-cropping rice belt as representative crop areas.

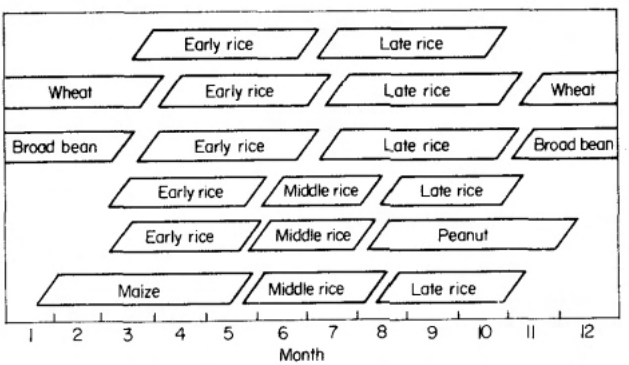
South China double-cropping rice belt

The South China double-cropping rice belt includes provinces south of Nan-ling, Taiwan, Fu-jian, Guangdong, and Guang-si. The total cropping area is 27% of the rice area of China (Taiwan excluded). The district has the highest annual accumulated temperature and the longest plant-growing period in the country.

The mean January temperature, except in the mountainous area in the north, is above 10°C, which allows thermophilic plants to overwinter safely. The annual accumulated active temperature (diurnal average temperature higher than 10° C) amounts to 6,000-9,000° C. Yearly precipitation is 1,500-2,000 mm which is suitable for double-cropping of rice. The cropping system is chiefly double-cropping of rice and in localities where water sources are scarce, upland crops such as sweet potato, peanut, and soybean are grown in combination with rice to make up a two-crop system. In districts of Hai-nan Island and Zhan-jiang, Guangdong, there is a limited area with three rice crops.

The original land utilization index in this belt, however, was not high. Of 1.6 million ha of rice fields in Guang-si, only 0.6 million ha grew 2 rice crops a year. But during the past 20 years, the area in rice increased to 1.5 million ha, or 92% of all rice fields in the province. The 3-crop systems of wheat - rice - rice, maize - rice - rice, and broad bean - rice - rice were tried in the original rice double-cropping region south of the city of Nan-ling (Fig. 5).

In Guangdong in 1952,576,000 ha grew a single crop of rice, and 266,666 ha of intercropped rice made up more than one-third of the rice area of the province. The land utilization index was 186.2% but increased to 204.7% in 1957 with double-cropping and relay cropping of rice. The area of green manure - rice - rice increased from 57,333 ha in 1957 to 722,600 ha in 1965. At the beginning of the 1970s, cropping



5. Major rice-based cropping patterns of the South China rice belt.

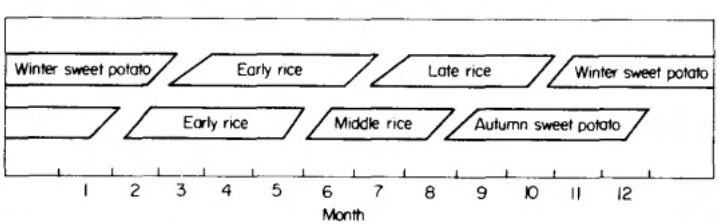
system reforms centered on changing the 2-crop system to a 3-crop system. In 1977 the land utilization index reached 230%; the wheat - rice - rice pattern was grown on 454,666 ha, and the sweet potato (rape or broad bean) - rice - rice pattern on 466,666 ha. Successes in the high-yield experiment with middle rice in a 3-crop rice system also added new features to the rice cropping system of South China.

Because of its low yield (only 1.5-2.2 t/ha), little middle rice had been grown in Guang-dong. But when the Wu-hua County demonstration farm obtained for 5 successive years (1972-76) an average middle rice yield of more than 6 t ha, the originally small 3-crop area was expanded to 46.666 ha and new cropping systems included middle rice: early rice - middle rice - peanut, early rice - middle rice - autumn sweet potato, maize - middle rice - late rice, and broad bean - middle rice - late rice. On Hai-nan Island, the original pattern of early rice - late rice - winter sweet potato was changed to early rice - middle rice - autumn sweet potato (Fig. 6). With the advanced transplanting date of early rice, the early-maturing middle rice avoided the September typhoons, and the early maturity of autumn sweet potato resulted in apparent increase in production (total annual food yield of 15 t/ha). On Hai-nan, the area planted to the new pattern increased to 16,666 ha in 1977.

Central China single- and double-cropping rice belt

The Central China single- and double-cropping belt includes provinces along the Yangtze River, and the Han-zhong Basin of Shan-xi, and Xin-yang district of Ho-nan. The rice-cropping area of this belt, China's most important, accounts for more than 63% of the total rice area of the country. The mean temperature in January is 2-8° C, that in July is 26-30° C, and the annual accumulated active temperature is 4,500-6,000° C and higher. March-October is the rice-growing season. Yearly precipitation is more than 1,000 mm. The trend of rainfall concentration in summer is not as apparent as in North China. There is more rainfall on the upper reaches of the Yangtze River in autumn, and more on the lower reaches in spring. The intermittent drizzles of *plum rains* during late spring and early summer, characteristic of the rainfall in this belt, favor rice production. Areas to the south of Nan-jing, Jiang-su; He-fei, An-hui; Xin-yang, Hu-nan; Gucheng, Hu-bei; and Nan-zheng, Shan-xi provinces (about 32-33° N) are suitable for double-cropping of rice.

In the past, however, most of the rice fields in this belt grew one crop a year, or



6. Comparison of the original pattern early rice - late rice - winter sweet potato and the new pattern early rice - middle rice - autumn sweet potato.

were double-cropped with wheat, rape, and green manure (such as Astragalus and common vetch); double-cropping of rice was practiced only in the southern parts of Zhe-jiang and Jiang-xi, and the eastern part of Hu-nan (about 28° N) which was less than 10% of all the rice fields in this belt. In 1972, only 3,300 of 400,000 ha of double-cropped rice in Zhe-jiang had relay cropping of rice; the rest had intercropping. In 1960 the relay-cropped area increased to 800,000 ha, and by 1966 it was 61 % of the total rice area. Fields of double-cropped rice lying idle in spring and winter were grown to winter crops such as green manure, barley, wheat, rape. The result was a double-cropped rice-based, 3-crop system (double-rice 3-crop system for short) that further raised the land utilization index (av 232% in 1978) in the province. The average annual yield was 9.42 t/ha.

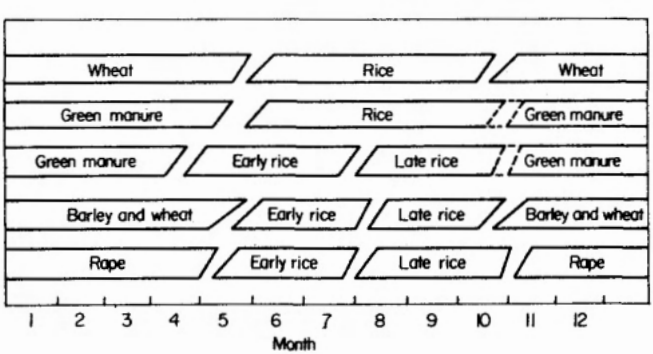
In the late 1950s double rice cropping was pushed northward into Shanghai municipality and areas of Su-zhou District in Jiang-su; after 20 years the double-rice 3-crop system had become the local cropping system superseding the double-cropping system of wheat - rice, rape - rice, and green manure - rice (Fig. 7). In 1976 the Shanghai double-rice 3-crop area accounted for 95% of the total area in the municipality, with grain yields averaging 11.24 t/ ha. In 1978 in Su-zhou district, the double-rice 3-crop area was 74% of the total for rice.

In Si-chuan on the upper reaches of the Yangtze River, rainfall is concentrated in the summer and autumn and a severe drought occurs in spring resulting in a rice cropping system of *winter water fields* (the fields storing water in winter). In the early 1950s 2.6 million ha of 3.3 million ha of rice fields had stored water in winter, and the land utilization index amounted to only 110-120%.

With the construction of water conservation facilities and improvement in other agricultural conditions, winter water fields changed gradually into rice-based double-cropping areas with wheat - rice, rape - rice, and rice - rice. In 1978 winter water fields were reduced to about 1.8 million ha, the land utilization index of paddies was above 170%, and production increased.

The most difficult problem in the expansion of the double-rice 3-crop system in the Central China rice belt is the short growing period in a year. The problem is solved by:

1. Raising and transplanting seedlings of rape and rice and using the age of seedlings to make up for the deficit in the growing period in the fields - rape seedlings of 40-45 days, early rice seedlings of about 35 days, and late-rice



7. Major rice-based cropping patterns of Su-zhou District, Jiang-su Province, China.

seedlings of 25-50 days or older according to variety requirements.

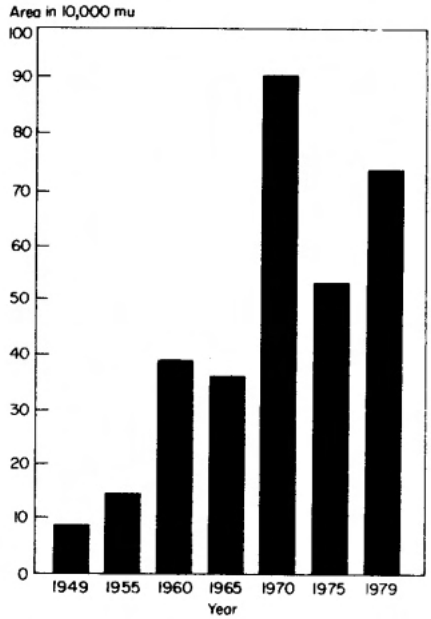
2. Selecting and using early- and medium-maturing varieties. There is a deficit in the growing periods for late-maturing varieties of all three crops. Therefore, the pattern in Zhe-jiang is one early and two late (using early-maturing varieties for the first crop, and late-maturing varieties for the second and third crops); that in Jiang-su uses medium-maturing varieties for all three crops to ensure the transplanting of early rice seedlings not later than 5 June and of late rice seedlings not later than 15 August, and the seeding of wheat or transplanting of rape seedlings not later than 5 November.
3. Improving techniques in raising seedlings. Plastic film is used to preserve heat in seedbeds for early rice seedlings. For late rice, the requirements of seedling age of the different varieties (dense seeding for young seedlings, and thin seeding for older seedlings) are considered. For seedlings more than 50 days old, twice-transplanted seedlings are used to ensure that suitably aged and strong seedlings are produced.
4. Creating sources of manure by returning stalks and straw to the fields, keeping swine, growing green manure, using water surfaces of ponds, rivers, and lakes to grow aquatic green-manure plants (water hyacinth, water cabbage, etc.) and raising azolla in rice fields. These provide more organic fertilizers to be applied in combination with chemical fertilizers to attain year-round high production and increase production year after year.

North China single-cropping rice belt

The North China single-cropping belt includes Bei-jing, and He-bei, Shan-dong, Shan-xi Province, Ning-xia Wei autonomous prefecture, and areas north of Hai-he River in An-hui and He-nan provinces, central and northern parts of Shan-xi, and areas east of Lan-zhou in Gan-su Province. The mean temperature in this belt is -6 to -2° C in January, and 24–28° C in July. The annual accumulated active temperature is 3,000-4,500° C and the yearly sunshine period is usually 2,000-2,800 hours or more.

During the rice-growing season (April to October) the comparatively large difference between day and night temperatures (11.3-14.5° C) is most favorable for rice growth; hence, the per-unit yield is comparatively high. The annual precipitation, however, is low: about 600–700 mm on the east, and less than 400 mm on the northwest. Rainfall is concentrated in summer, drought in spring is rather severe, and the insufficiency of water sources seriously limit the rice-cropping area of this belt. In the 1950s the rice cropping area of the belt accounted for 1.5% of that of the whole country. After 20 years, efforts in changing upland fields to paddies succeeded, and rice areas expanded. Bei-jing had only 5,566 ha of rice in 1949, but 61,333 ha in 1970 (Fig. 8). The area (64,000 ha) in 1971 was 11.7 times that in 1949.

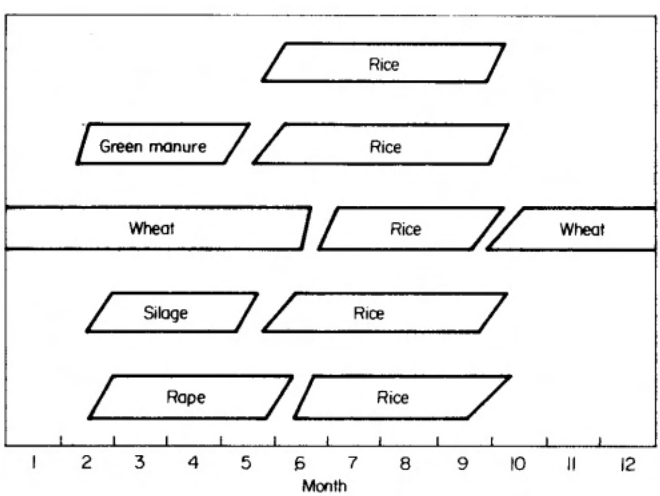
The original cropping system was a single crop of rice each year. After harvest, the field was left idle for more than 7 months and land utilization was low. To increase the yearly grain production of rice fields, experiments on a two-crop system were initiated in the late 1950s and the combination spring green manure (rape) - rice, silage barley - rice, wheat - rice, and rape - rice were tried as a double-cropping system, one after the other, with success. Thus, the rice cropping system of Bei-jing shifted from the original single rice crop to a single crop of rice and a double crop of



8. Rice cropping areas of Bei-jing Municipality, China. 1 ha = 15 mu.

wheat or rape, etc. and rice in rotation (Fig. 9). The wheat - rice double-cropping area has spread to 70% of the total rice area of the whole municipality.

To solve the problem of insufficiency of growing period the wheat - rice system should be adopted. From seeding to harvest wheat needs 250 days, and rice 160-180 days, or a total of 410-430 days. To make up for the deficit of 45-65 days in a year, early- or medium-maturing rice varieties should be planted, and suitably aged



9. Major rice-based cropping pattern in Bei-jing Municipality, China.

seedlings should be raised for transplanting in late June to early July to assure harvest in late September to early October, allowing timely sowing of wheat. More farmyard manure and chemical fertilizer should be applied to satisfy the needs of the two crops.

Success in the experiment on dry-seeded rice led to the seeding of rice in dry fields before the rainy season; the crop grew until the rainy season when a stable water layer was established. The treatment gave a 6-6.75 t/ ha yield and used only one-half to one-third of the irrigation water used when the seedlings were raised and transplanted. Especially adapted to the climatic characteristics of the North China rice belt, the treatment facilitates the expansion of rice production in this belt and adds new features to the cropping system.

DISCUSSION

The reformation of rice-based cropping systems in China has contributed significantly to increase in grain production. The development has not been uniform, however. In some localities the rice-cropping system has not changed much; in others the change failed to bring about a high and steady yield. In most localities special efforts are required to improve rice-based cropping systems.

First of all, on the edges of the double-cropping rice area of China (around 32° N in Central China and mountainous districts 500-600 m above sea level in South China), the drop in temperature during the early part of April, known as *Dao-chun-han* (reversed spring cold) and that during the early part of October known as *Han-lu-feng* (cold dew wind) usually decrease yield by causing rotting of seedlings of early rice and the improper fertilization and filling of grains of late rice. The planting seasons in the double-rice 3-crop system in districts along the middle and lower reaches of the Yangtze River follow one another closely. One crop is harvested and the next is planted within 10-15 days; any delay upsets the whole planting plan for the year. and even makes crop maturity impossible. Proper adjustments must be made for single-cropping rice, double-cropping rice, and double-rice 3-crop systems in these localities to permit adaptation to the local production situations and to eventual agromechanization.

There is great concern over the trend of slow production increase in areas where the double-rice 3-crop system was practiced for a comparatively long time. Results of examinations (Table 1) by the Shanghai Academy of Agricultural Sciences and the Zhe-jiang Academy of Agricultural Sciences on the fertility of soils showed that after the double-rice 3-crop system was practiced, the contents of soil organic matter, total nitrogen, and total phosphorus increased. Results obtained by the Guang-dong Academy of Agricultural Sciences were similar (Table 1). Contents of organic matter, total nitrogen, total phosphorus, and total potassium in soils successively cropped for 3 years under the wheat - rice - rice system were higher than those in soils cropped successively for the same number of years under the system of double-cropping rice and winter fallow. The reasons for this phenomenon were 1) more organic and chemical fertilizers were applied. 2) more stalks, leaves. and residues of plants were returned to the soil, and 3) prolonged waterlogging in fields retarded the decomposition of organic matter and, it was believed, provided more fertilizer in the

Table 1. Comparison of some major soil nutrients before and after change in cropping systems, China.

Item	Organic matter (%)	Total nitrogen (%)	Total phosphorus (%)	Total potassium (%)	Data from
Before change	4.54	0.248	0.119		Agric. Sci. Academy of Shanghai
After change	5.10	0.271	0.156		
Before change	2.80	0.188	0.213		Agric. Sci. Academy of Zhe-jiang
After change	3.57	0.190	0.239	0.24	
Rice - rice 3 years plot	1.32	0.076	0.048	0.59	Agric. Sci. Academy of Guangdong
Wheat - rice - rice 3 years plot	1.53	0.080	0.059	0.65	

3-crop system than in the 2-crop system. The 3-crop system would not cause deterioration of soil fertility.

The major cause of the slow increase in production is the deterioration of the physical properties of soil. Investigations made by the Nan-jing Soil Institute of the Chinese Academy of Sciences have shown that, in rice soils of Su-zhou district, Jiang-su, the double-rice 3-crop system obviously reduced the contents of soil microaggregates and total porosity, and caused poor permeability. Because the waterlogging period is 40 days longer than that under the 2-crop system, the availability of organic matter and total nitrogen is poor, and nutrient release is too slow to meet the nutrient requirements of rice.

Tests in 1975 and 1976 revealed that in the yellow mud soil of Wu-xi County, the release of nitrogen was not apparent until mid-June to late July and did not peak until early August to mid-September; it occurred much later than the peak need of rice, and extra chemical fertilizers had to be applied as a complement.

The deterioration of soil physical properties is also caused by successive plowing and harrowing in wet conditions every year; the tillage layer becomes shallower and shallower, and the plow pan is raised. Large-scale investigations show that the tillage layer in the double-rice 3-crop system is 5-7 cm shallower than that in the 2-crop system. Usually the depth of the layer is only 10-12 cm. To prevent the deterioration of soil physical properties, first of all, the irrigation and drainage systems must be integrated to lower the underground water level. In the Su-zhou District *surrounding ditches* and *cross ditches* are being dug in rice fields to drain out the water; then reasonable cropping systems are put into practice. Several cropping patterns are rotated so that deficits of the systems might be compensated mutually. For example, a 3-crop system is rotated with a 2-crop system to relieve the seasonal stress, and allow the soil in the rice fields to be plowed in winter and the upturned soil to take the sun; or one upland crop — two crops of rice (such as wheat - rice - rice, rape - rice -rice, broad bean - rice - rice, and green manure - rice - rice) is rotated with two upland crops — one rice crop (such as wheat - soybean - rice, wheat - rice - soybean, wheat -maize - rice, and wheat - green manure - rice) to allow the rice field soil to return to the completely dry state.

In a soil-reform experiment in 1975, the Dong-ting Brigade of Wu-xi County tested a two upland crops — one rice crop system (naked barley interplanted with

maize and soybean; after harvesting barley, interplanting sesbania with maize and soybean; plowing the sesbania as a green manure after harvesting maize and soybean, then transplanting the rice seedlings). In April of the following year, the redox potential of the soil rose from 260 mV to 540 mV, and the rate of permeation of water from 1.94 mm minute to 5.535 mm/minute.

The rice-based cropping systems of China will be further improved by incorporating the rotation of upland crop with rice, cereal crop with leguminous crop, and cereal crop with fodder crop to increase the per-unit land area and the *per-labor crop production* to meet the requirements of the "Four Modernizations" in our country.

DISCUSSION

Kasmo: It is said that successive plowing and harrowing raise the plow pan and make it shallower. There is an attempt to overcome this occurrence by lowering the groundwater level. Is there any danger that by so doing, the groundwater level will not go back to its original level. and the remedy will be worse than the malady?

Guo: There is no danger because we take this measure in areas where the groundwater level is so high that soil moisture reaches saturation after rice harvest, retarding the sowing of wheat. In these places. the water level in the rivers and ponds is also high. The problem is how to lower the groundwater level of paddy fields, after the panicle initiation of rice. We don't worry that the groundwater level cannot recover. We worry that it is too high. In areas where the groundwater level is not high we do not dig ditches, for the reasons you indicated.

Zandstra: Your presentation mentioned no grain legumes such as mungbean, soybean, and peanut in the wetland cropping patterns. What have been the experiences in China with these crops in the wetland rice-based cropping patterns?

Guo: Mungbean in China is used only as a catch crop, or intercrop with other food crops. It is grown in paddy fields only when severe drought occurs.

In China, most of the paddy fields are irrigated. Soybean and peanut grow mainly in dryland or hilly areas, where water is insufficient or the soil is sandy and establishment of standing water is very difficult. We cultivated more broad-bean (*Visia faba*) in wetlands because it is more tolerant to wet conditions.

Recently, many institutes in various levels in our country began to investigate how to incorporate the legume grain crop into rice-based cropping systems.

Malla: Do you have any profitable intercropping system on upland rice and do you practice relay seeding of legumes and oilseed crops in wetland rice?

Guo: Yes, we have some intercropping systems on dryland rice such as, wheat - maize - rice. Wheat is sown in late September in plots of about 18 rows 20 cm apart. Maize is sown at mid or end May, 15-25 days before wheat harvest. As maize reaches maturity the space between rows is 3.6 m. Rice is then sown at 18 rows/ plot. Maize is harvested in late September and rice is harvested in early October. Yearly total yields reach about 7.5-9.0 t/ha.

Relay seeding of legumes as a green-manure crop is common in South and Central China, but seeding of grain legumes is not.

Relay seeding of rape as an oilseed crop is done mostly in North China. Relay transplanting of rape seedlings as an oilseed crop is widespread in Central China. Relay seeding of other oilseed crops is rare in China.

Upasena: What are your rice yields? What is the essential difference between the winter sweet potato and autumn sweet potato?

Guo: Rice grain yields in our country average about 4 t/ha.

The winter sweet potato is planted in the beginning of November; temperature is lower, which results in higher yield but late maturity. It is harvested in mid-March. The autumn sweet potato is planted in late August; the temperature is higher; and is very favorable for potato growth. Harvest is in early February.

Cross-site description and analysis: a test of methods

Edwin C. Price and Thelma Paris

Environmental description is an early step in the development of new cropping systems for a site. Aspects of the physical and economic environment are measured. With the information, researchers design new cropping patterns that may prove more productive than the farmers' present patterns and acceptable to them. Rules used for designing new cropping patterns based upon environmental information derive from the experience of researchers and from the scientific evidence of disciplinary research, often from the analyses of crop and systems responses to single factors. Evidence on the suitability of technology from multifactor analyses, particularly of factors representing a range of physical, biological, social, and economic conditions, is rare.

The idea of a minimum data set for design and testing of cropping patterns has been debated within the disciplines and among researchers as a whole. A minimum data set is a small set of variables characterizing soils, climate, pests and diseases. on-farm resources such as land, labor and capital, and off-farm conditions such as input, product markets, and agricultural institutions. The minimum data set, coupled with rules for design, should lead eventually to recommendable cropping patterns.

At the 1978 meetings in Peradeniya (Price 1977), the economics committee of the cropping systems working group set about identifying and testing minimum data sets for cropping systems design. Through methods of cross-site comparisons we tried to identify relationships between hypothesized determinants of cropping systems and attributes of cropping systems adopted by farmers. The determinants are the underlying conditions to which farmers respond in structuring their farm activities. The relationships between determinants and farmers' present systems are regarded as strong indicators of potential systems that might be developed through scientific research.

Comparing cropping systems across network sites requires much time and effort. Some information from network sites isavailable, but is not yet sufficiently comprehensive to support the analysis. To test the methods to be employed in the project.

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cropping systems at 14 Philippine sites were compared and analyzed. In this paper we present the results of the study.

BACKGROUND INFORMATION

Objectives

The study had two main objectives:

- To characterize the physical, biotic, and economic environment and farmers' cropping systems at a large number of diverse sites.
- To identify by techniques of multivariate analysis the relationships between environmental conditions and present cropping systems followed by farmers.

Cropping systems characterization is a complex task. *Systems* implies a multitude of relations that cannot be easily indexed or measured by a few variables. Certain descriptors of cropping systems such as crops grown and their temporal arrangement are taxonomic in nature and cannot easily be treated mathematically. They are diverse with respect to the principles of *fit* they are expected to reflect. For example, yield as a systems descriptor responds to quantities and qualities of measurable inputs on a plot of land, while the area of land on a farm planted to rice reflects allocative decisions at the farm level, involving plot-level, farm-level, and village-level phenomena.

To characterize cropping systems we chose a framework representing farmers' input-input and input-output relationships. These relationships, as descriptors of cropping systems, were grouped as follows:

- land use indices,
- labor use indices,
- capital use indices, and
- output indices.

The determinants were grouped according to the level of aggregation at which they are measured and influence cropping systems. They are:

- plot-level determinants,
- farm-level determinants, and
- village-level determinants.

The following hypotheses were formulated.

1. The cropping systems used by farmers are functionally related to determinants, or economic and physical conditions at a site.
2. Determinants vary in importance according to the explanation they offer for various characters of cropping systems. The results from this study may be used to rank information required for the design of new systems.
3. A specific group of determinants differentially influences each type of cropping systems descriptor such that general relations between a type of determinant and a type of descriptor may be identified.
4. Relationships between determinants and attributes of farmers' present systems may be interpreted as principles for design of new systems.

Previous research

Harwood and Price (1976) state the general proposition that "present and potential multiple cropping patterns are determined by a wide range of physical and socio-

economic conditions against a background of available technology." They suggest that the base crops of systems are associated with water supply. In drier regions, maize, sorghum, millet, and wheat are dominant; in wetter areas rice is dominant. Among the physical factors, rainfall, irrigation, soil and elevation, and temperature were most influential. Relatively permanent economic conditions influencing tropical Asia as a whole are the smallholder structure of agriculture and highly dispersed production. More variable factors are wage rates, human and physical capital in agriculture, and prices of agricultural products and cash inputs.

Seven farming systems found in tropical Asia were identified:

- the subsistence, mixed-cropping homestead,
- large, commercial farms,
- animal-based systems,
- shifting cultivation,
- rolling upland farms,
- fully irrigated systems, and
- rainfed and partially irrigated systems.

Research at IRRI and in the cropping systems network is confined to the last farm type. Even within that, there is much variability in farm resources and systems practiced. The examples and data given by Harwood and Price for this farm type were not sufficiently detailed to allow identification of the major determinants and associated principles of adaptation.

Strong similarities between cropping systems in Indonesia and the Philippines have been observed on dryland, rainfed wetland, and irrigated wetland farms (Price and Barker 1978). Dryland rice-based systems are more diverse and tend toward multiple cropping. Rainfed wetland systems are less diverse and exhibit low levels of cropping intensity. Irrigated systems are least diverse but show high levels of rice multiple cropping.

Farm size and labor use in the Indonesian and Philippine systems also showed similarities. Upland sites had the smallest farms, used about 1,300 labor hours, ha per year, most of which was family labor. Rainfed wetland farms were larger. used about 900 labor hours/ha per year, about half of which was from the family. Irrigated farms were the same size as rainfed wetland farms, but they used about 1,900 labor hours/ha per year, only 20% of which was from the family. The results strongly indicated possible cross-regional similarities of cropping systems on similar land types.

In a study of multiple cropping in Taiwan Chien-pan Cheng (1975) noted that the length of sunshine hours was related to cropping intensity, and that irrigation could contribute to multiple cropping, but was not a prerequisite. In analyzing physical factors that affect cropping systems, Tao-chou Huang (1975) suggested that water availability was associated with total agricultural production but did not increase diversification. Whenever water was abundant, rice tended to dominate and diversification was lower. Dryland crop production was more diverse. Farm survey data in Taiwan gave a more detailed view of the relation of crops to farm characteristics. Calkins (1978) compared a dryland area and a wetland area, and found that in dryland areas water availability was the major factor in farmers' selection of a particular cropping system. Economic as well as agronomic considerations were

evident in lowland areas. They include labor availability and wages, pests and diseases, drainage, prices of products, and transportation.

METHOD OF ANALYSIS

Stratification of study sites

To study a range of environmental factors and cropping systems at the plot, farm, and village levels, we chose an approach not used in previous studies. Following the classification developed by Oldeman and Suardi (1977) and as adopted for the Philippines (IRRI 1975), we chose Philippine sites with 4 rainfall patterns varying from 3-4 to 5-6 wet months and from 2 to 5-7 dry months. Within those we chose areas that were dominantly rainfed lowland, and among these we sought areas that were flat and areas that had sloping topography. Finally, for each combination of rainfall and topography, we located villages with heavy soil and those with light soil. Table 1 shows the combinations of physical conditions in 14 villages and reflects our general success in following the stratification scheme.

Some data were expected to appear in the stratification scheme for physical factors: differing degrees of remoteness from population centers, and variation in prices of products and inputs. To provide variation in farm-level factors we selected from each village 15 farmers representing the range of farm sizes in the village.

Selection of variables

Plot-level determinants are factors that affect the suitability of crops and crop sequences; their values and effects on crop production can be measured on a plot. They are physical or biological in nature, and are not causally related to phenomena on other plots or to more aggregative phenomena at the farm, village, or regional level. Their values do not vary greatly across plots and may remain constant over a relatively large space. The continuous plot-level variables selected were percentage of clay and of organic carbon in the soil, and the number of months of rainfall. Dummy plot-level variables represented topography (0 = flat, 1 = rolling) and irrigation (0= no irrigation, 1 = supplementary irrigation). No farm had year-round irrigation. Plot-level variables were measured on the largest plot of each respondent. Soil characteristics were assessed in the laboratory on samples from the largest plot.

Farm-level determinants of cropping pattern suitability are measured at the farm level and are therefore single valued for a whole farm although they may individually affect given crops and cropping patterns on a plot. They are economic in nature and tend to vary across farms within a village, but their effect in different villages is expected to be similar. Farm-level variables are farm size, number of parcels, family size, livestock income per year, off-farm income per year, loans received per year, value of farm capital, farmers' age, number of years an operator has engaged in farming, and number of years of school an operator has completed.

Village-level determinants of cropping systems are measured at the village level. They have constant values across farms within a village and tend to differ across villages. They include man-land ratio (measured as average number of family members per ha cultivated land), wage rates per day for farm work, the price of rice

Table 1. Physical characteristics on farms in 14 Philippine villages selected for analysis of determinants of cropping systems, 1979.

Site	Wet[a] months (no.)	Dry[b] months (no.)	Dominant soil surface texture	Dominant soil pH range	Dominant soil organic matter range (%)	Topography
Ilocos Norte						
Rayuray	3-4	5-6	Clay	7.6	1.54	Flat
San Lorenzo	3-4	5-6	Silty	7.6-7.7	1.23-1.40	Flat
Nanguyudan	3-4	5-6	Clay loam	6.2-7.0	1.26-1.84	Gently sloping
Pasil	3-4	5-6	Clay	7.6-7.8	.78-1.44	Gently sloping
Zambales						
Amungan	5-6	5-6	Loam	6.4	1.64	Flat
Inhobol	5-6	5-6	Sandy loam	7.2	.69	Gently sloping
Santa Rita	5-6	5-6	Clay loam	6.8	1.54	Flat
Sitio Bunga	5-6	5-6	Clay loam	6.2	1.52	Gently sloping
Cagayan						
Calamaniugan	5-6	2-4	Silt loam	6.6-7.0	1.44-2.17	Flat
Gattaran	5-6	2-4	Clay	6.1-6.3	1.33-2.30	Flat
Tacloban						
Dacay	3-4	<2	Loam	7.0	1.71	Flat
La Paz	3-4	<2	Clay loam	6.2-6.3	3.01-3.07	Flat
Cabacungan	3-4	<2	Loam	6.0-6.1	1.96	Flat
Mayorga	3-4	<2	Clay loam	6.0-6.1	2.58-2.82	Flat

[a] Months with more than 200 mm rainfall. [b] Months with less than 100 mm rainfall.

and the price of nitrogen, and access to transportation facilities. The latter was measured as a scale vector reflecting distance and difficulty of traveling to the nearest market center.

Descriptors of cropping systems reflect resource allocation by farmers as influenced by *determinants* or environmental conditions. We chose sets of descriptors that reflect land allocation, labor allocation, allocation of technical inputs, and overall input-output indicators.

Land-use descriptors were measured at the farm level. The multiple cropping index (MCI) was measured as the total area of crops planted on a farm divided by the farm size and multiplied by 100. The cropping intensity index (CII) was measured as the percentage of the total hectare-months of land used (the sum of the duration × area planted for each crop on a farm) divided by the total hectare-months of land available (farm size × 12).

The percentages of farm area in rice, vegetables, and grain legumes were measured as the area of these crops planted on a farm as a percentage of the total planted area. Vegetables were mainly eggplant, tomato, cowpea (sold as green pods), and garlic.

Labor-use descriptors were measured at the plot level. Labor hired was computed as the man-hours of hired labor as a percentage of total labor for all crops planted on the farmers' largest land parcel. Labor use per hectare for rice, nonrice crops, and the average of all crops was based on the largest parcel of each respondent. The crop activities conducted on the farmers' largest parcels were assumed to reflect input and output relationships on the farm as a whole.

Descriptors of technical inputs, measured at the plot level, included the values of seed, fertilizer, and insecticides used per hectare of rice and per hectare of nonrice crops. Nitrogen used for rice was also measured in kilograms per hectare. The use of modern varieties was recorded as a dummy variable (0 = traditional variety, 1 = improved variety). These descriptors are also referred to as *cash inputs* and *material inputs.*

Production variables were measured on the largest plot of farmers and included the values per hectare of rice produced, other crops produced, rice sold, and other crops sold. Measurement of sales on a per hectare basis was not ideal; sales from the whole farm would have been preferable. For most measures, taking data from the farmers' largest plot was sufficient and greatly reduced the survey time. It was also felt that intense review of farmers' activities on a single management unit would give more reliable data than an inevitably more superficial review of all management units. But the prospective analytical gains from whole-farm data, particularly for crop sales, was not great enough to suggest the more comprehensive approach.

Determinants and descriptors, summarized by village, were presented earlier by Paris and Price (1979). A selection of the summaries is presented in appendices 1 to 7. The farms were basically semisubsistence with a small degree of commercial orientation; diversity of cropping systems was related not only to physical conditions such as rainfall, but to a host of other factors such as input and product markets, associated livestock activities, and factor endowments of farms. However, a clear separation of determinant-descriptor relations was not possible with village summaries because of low degrees of freedom. For the present farm-based analysis, multiple regression and factor analysis were applied on the same data.

Analysis

To test the hypothesis that cropping systems are related to economic and physical conditions at a site, equations were estimated by least-squares regression of the form:

$$Y_i = b_i + b_{ij}X_j + d_i$$

where Y_i, i = 1, 2 . . . 15, is the measure of the *ith* descriptor;
X_j, j = 1, 2 . . . 20, is the *jth* independent variable representing a hypothesized environmental determinant of cropping systems.
B_{ij} is the regression coefficient relating X_j to Y_i; and
b_i is a constant term in the relation of the ith descriptor to independent variables;
d_i is the disturbance term.

Two sets of regression equations were estimated. The first included 20 independent variables for testing the hypothesis that environmental conditions are related to descriptors of cropping systems. The number of equations in which each independent variable was statistically significant allowed identification of the more important determinants.

A second set of equations including only the most important determinants was estimated. That gave a clearer view of the relative importance of different groups of descriptors, and signs of coefficients were interpreted as the direction of relationships.

Earlier work by Nicolas (1977) and Momen (1979) found unsatisfactory the explanation of individual descriptors by selected determinants. We suspected that because individual descriptors could index only limited aspects of multidimensional cropping systems, factor analysis would be appropriate. With this technique, latent relationships among descriptors and determinants might be estimated and reflected in *factors.* A factor is an underlying relationship to which individual variables may be correlated. In the final step of analysis, *factors* representing groups of descriptors and *factors* representing groups of variables were estimated. The group of particular variables highly correlated with a factor indicates the general nature of a latent relationship. We expected our original groupings of variables to be similar to the grouping of variables correlated with factors, to lend credence to the original variable groupings we had chosen. In the case of determinants we expected the latent relationships, or factors, identified through factor analysis to correspond respectively to plot-level, farm-level, and village-level variable groupings; in the case of descriptors, the factors would correspond to the land, labor, cash, and production groupings of input-input and input-output relations.

RESULTS

Tables 2 and 3 show the means and standard deviations across farms of determinants and descriptors included in the analysis. There was sufficient variation in the measures to support the analysis. Simple correlation coefficients between determinants, shown in Appendix 8, were generally low, indicating little prospective problem with multi-colinearity of independent variables. Farmers' age and experience in

Table 2. Means and standard deviations of hypothesized determinants of cropping systems on 207 farms at 14 Philippine sites. 1979.

Variable[a]	Mean	Standard deviation
Plot level – physical		
Topography (0 = flat, 1 = rolling)	.28	.45
Percentage clay	33	13
Percentage organic carbon	.97	.34
No. of mo with rainfall >100 mm	7.5	2.9
Supplemental irrigation (0 = no, 1 = yes)	.27	.44
Farm level – economic		
Farm size (ha)	1.53	1.22
No. of parcels	6.7	10.8
No. of family members	5.2	2.2
No. of adult farm workers in family	2.5	1.6
Livestock income (₱/yr)	364	1064
Off-farm income (₱/yr)	1261	3516
Loans received (₱/yr)	553	1079
Value of workstock and equipment (₱)	4796	5445
Operators' age	49.6	12.6
Operators' years in farming	27.0	14.0
Operators' years of education	5.7	6.1
Village level – economic		
Man-land ratio	6.0	9.6
Wage rate for transplanting (₱/d)	9.8	8.2
Price of nitrogen (₱/kg)	3.9	.6
Price of rice (₱/kg)	1.01	.09
Transport accessibility (1 = easy, 3 = difficult)	2.50	.83

[a]US$1 = ₱7.35.

Table 3. Means and standard deviations of input and output indices of cropping systems on 207 farms at 14 Philippine sites, 1979.

Variable[a]	Mean	Standard deviation
Land utilization		
Multiple cropping index	148	60
Cropping intensity index	.41	.18
Percentage area in rice	78	27
Percentage area in grain legumes	5	12
Percentage area in vegetables	7	15
Labor utilization		
Percentage labor hired	55	33
Mandays/ha, rice	206	412
Mandays/ha, nonrice	57	99
Technical inputs		
Value of cash inputs for rice (₱/ha)	390	367
Value of cash inputs for nonrice (₱/ha)	140	277
Nitrogen on rice (kg/ha)	18	45
Variety of rice (0 = local, 1 = improved)	.47	.34
Production and sale		
Value of rice produced (₱/ha)	2869	4393
Value of rice sold (₱/ha)	219	637
Value of nonrice produced (₱/ha)	1121	2673
Value of nonrice sold (P/ha)	421	1025
Rice yield (t/ha)	2.4	1.5

[a] US$1 = ₱7.35.

farming were correlated at .73, for obvious reasons, and months of rainfall and percentage organic carbon in the soil were correlated at .70. Rainfall months and farmers' age did not figure importantly as variables to explain cropping systems and were deleted at the second stage of regression analysis.

Topography and organic carbon were correlated at -.51 indicating that as slope increased, the percentage of organic carbon in the soil declined. Topography was eventually deleted from the regression analysis.

Wages and topography were correlated at -.49. As slope increased, cropping systems were more diversified with respect to species and crop schedules. As a result, work was more evenly distributed throughout the year, resulting in less periodic demand, less labor hiring, and lower wage rates. Topography and transportation were positively correlated at .38, indicating that transportation was more difficult in rolling land areas.

Dependent variables, or descriptors of cropping systems, were somewhat more highly correlated, but were of no consequence for regression analysis. The percentage of area in rice was negatively correlated with MCI and CII, indicating the difficulty noted elsewhere of converting wetland paddy soils to conditions suitable for production of upland crops (Harwood and Price 1976). As the sites were predominantly rainfed, multiple rice cropping was very rare. The positive condition (.73) between MCI and CII was expected because both are measures of land use intensity.

Labor and material inputs on both rice and nonrice crops were highly correlated. Substitutability of labor and material inputs was not apparent; rather, the two were complementary — farmers who used more labor were inclined to use more material inputs as well. Neither was it clear that increasing the area of a crop on a farm leads to dilution of management. Rather, as the percentage of area in vegetables increased. so also did labor and material inputs per hectare.

Simple correlation coefficients between descriptors and determinants of cropping systems are shown in Tables 4 and 5. They indicated which determinants were most strongly related to descriptors of cropping systems. Low correlations do not necessarily indicate the variable has no effect because its influence may be masked by the effect of other variables. To obtain a clear indication of the influence of individual determinants, multiple regression analysis was done to "control" for other effects.

Appendices 9 to 13 show the results of multiple regression analysis of 20 independent variables (determinants) on 15 descriptors of cropping systems. The significance of the regressions was sufficiently high to allow the conclusion that the selected hypothesized determinants were indeed related to the characteristics of cropping systems. The results of the regressions are summarized in Table 6.

Hypothesized determinants were ranked according to the number of regressions in which their coefficients were significantly different from zero at the 90% level of probability or greater (Table 6). Supplemental irrigation appeared the most important determinant of cropping systems. Plot-level, farm-level, and village-level variables, both physical and economic, were among the highest ranking hypothesized determinants. Nine of the highest ranking independent variables were again regressed on the 15 descriptors of cropping systems.

Results of the second set of regressions are shown in Tables 7 through 10 and summarized in Table 11. *F*-tests indicated 17 regression equations were significant at

Table 4. Simple correlation coefficients[a] between determinants of cropping systems, and land and labor use on 207 farms at 14 Philippine sites, 1979.

Determinant[b]	Land use					Labor use		
	MCI[c]	CII[d]	Area (%) in rice	Area (%) in vegetables	Area (%) in legumes	Hued (%)	Rice (labor h/ ha)	Other crops (labor h/ ha)
Plot level - physical								
Topography	-.05	–.06	–.05	.14	.04	–.60	–.14	.04
% clay	.26	.27	.31	.45	–.03	–.09	–.14	.33
% organic carbon	–.03	.02	.19	–.26	–.30	.46	.10	–.11
Mo of rainfall	–.06	–.11	.31	–.41	–.26	.46	.27	–.21
Irrigation	.53	+.44	–.26	.45	–.01	–.05	.14	.40
Farm level - economic								
Farm size (ha)	–.04	.06	.12	–.28	–.09	.39	.53	–.11
No. of parcels	23	.29	.35	.51	.01	.24	.09	.40
Family size	–.06	–.08	.04	–.08	–.07	–.11	–.05	–.08
Livestock income (₱)	.07	.06	–.25	.00	.40	–.06	–.04	.18
Credit (₱)	.01	–.01	–.00	–.03	–.06	.21	.14	.04
Farm capital (₱)	.22	.22	–.32	.21	.24	–.05	.01	.27
Farmer's age (yr)	–.10	–.16	–.01	–.02	.03	–.05	–.17	.00
Farming experience (yr)	–.08	–.08	–.08	.08	.02	.02	–.05	.05
Education (yr)	.15	.28	–.03	–.07	.05	.15	.41	–.07
Off-farm income (₱)	.05	.01	–.12	–.10	.05	.18	.11	–.07
Village level - economic								
Man - land ratio	.01	–.02	–.00	.09	–.05	–.23	–.13	–.04
Wage rate (₱/d)	.27	.10	–.12	–.05	.15	.46	.13	.01
Price of rice (₱/kg)	.41	.43	–.56	.67	.05	–20	–.13	.53
Price of nitrogen (P/kg)	.18	.17	–.03	–.08	–.08	–.07	.13	·04
Transportation	–.14	–.13	.22	–.07	–.34	–.20	–.01	–.10

[a]Correlation coefficients greater than I25I are significant at the 99% level of probability; those greater than I19I are significant at the 95% level of probability. [b]US$1 = ₱7.35. [c]Multiple cropping index, [d]Cropping intensity index.

Table 5. Simple correlation coefficients[a] between determinants of cropping systems and technical inputs and crop production and sales on 207 farms at 14 Philippine sites, 1979.[b]

Determinants of cropping systems[b]	Technical inputs				Value (₱/ha) of crops			
	Rice (₱/ha)	Other crops (₱/ha)	Nitrogen (kg/ha)	Rice variety	Rice produced	Other crops produced	Rice sold	Other crops sold
Plot level – physical								
Topography	-.02	-.06	.21	-.19	.01	–.07	.00	-.16
% clay	-.00	.57	.17	-.26	.03	.25	-.12	.58
% organic carbon	-.23	–.23	-.24	.26	-.01	–.03	-.02	-.07
Mo of rainfall	-.l0	-.40	–.31	.61	.04	-.l0	.05	-.21
Irrigation	.14	.47	.36	.11	.22	.19	-.06	.41
Farm level – economic								
Farm size (ha)	.39	-.13	-.20	-.04	–.15	-.l0	.13	-.21
No. of parcels	.24	.40	.51	-.12	.01	.04	.11	.21
Family size	.02	-.01	-.04	–.02	-.01	–.l0	.01	-.01
Livestock income (₱)	.19	.12	.10	-.15	-.04	–.03	-.03	-.01
Credit (₱)	.13	.04	–.06	.09	–.04	.00	.07	.07
Farm capital (₱)	.22	.38	.28	-.03	.02	.04	-.05	.24
Farmer's age (yr)	-.05	-.03	.08	.00	-.13	.10	-.04	-.15
Farming experience (yr)	.04	.05	.02	–.04	-.l0	.13	-.13	-.08
Education (yr)	.26	-.04	-.01	.05	-.04	–.03	.09	.07
Off-farm income (₱)	.03	–.03	–.05	.07	–.04	-.05	.09	–.05
Village level – economic								
Man-land ratio	-.16	-.00	.05	-.05	.46	.00	.09	.06
Wage rate (₱/d)	.24	.11	-.13	.15	.03	.05	-.03	.14
Price of rice (₱/kg)	.03	.60	.39	–.21	.02	.18	-.19	.48
Price of nitrogen (₱/kg)	-.17	–.16	.04	.05	.01	-.06	.02	-.16
Transportation	-.12	-.20	-.01	.15	.08		-.04	–.13

[a] Correlation coefficients greater than I25I are significant at the 99% level of probability; those greater than I19I are significant at the 95% level of probability. [b] US$l = ₱7.35.

Table 6. Importance ranking of determinants of cropping systems based upon the number of relationships out of 15 estimated by regression in which their coefficients are statistically significant.

Determinant	Number of equations in which coefficient is significant	Rank of importance	Relations in which determinant was significant, in order of declining explanatory value[a]
Irrigation	8	1	Production, materials, land, labor
Price of rice	7	2	Production, land, labor, materials
Price of nitrogen	6	3	Labor use, production, materials, land
Farm size	6	3	Materials, labor, production: land
% clay	6	3	Labor, production, materials: land
Organic carbon	5	4	Materials = labor, land: production
Wage rate	5	4	Land use, labor = materials: production
No. of parcels	4	5	Production, labor, materials: land use
Livestock income	4	5	Land use, labor = production: materials
Education	4	5	Labor, production, materials, land
No. of mo rainfall	3	6	Materials, labor: land, production
Experience in farming	3	6	Labor, materials, land: production
Transportation	3	6	Materials, labor: land, production
Topography	2	7	Labor, materials: land, production
Family size	2	7	Labor, production: materials, land
Off-farm income	2	7	Materials, land: labor, production
Farm capital	2	7	Materials: land, labor, production
Man-land ratio	1	8	Production: land, labor, materials
Age of operator	1	8	Materials: land, labor, production
Credit	0	9	

[a]Items preceding a colon are significantly related. Items that are significantly related in the same number of equations are indicated by the equal sign.

Table 7. Relationships between hypothesized determinants of cropping systems and land utilization, estimated by regression analysis of 207 farms at 14 Philippine sites, 1979.[a]

Determinant	CII[b] (coef × 10^3)	MCI[c]	% area, rice	% area, grain legumes	% area, vegetables
% organic carbon	-6.90*	-45.9	20.2**	16.1**	6.69**
% clay	1.70	.395	-.275**	.010	.226**
Irrigation	126**	56.4**	2.589	–.971	3.31*
Farm size	15.1	1.44	.998	1.30**	–1.84**
No. of parcels	.912	-.407	-.215	–.103	.256**
Education	74.4**	1.45**	–.199	.114	–.010
Price of nitrogen	48.9**	26.2**	–6.146**	2.77*	–.709
Price of palay	11.1**	2.89**	–2.957**	.184	1.46**
Wage	27.1	2.70**	–.828**	.386	.054
Constant	-.342	-106	237	–4.40	–59.4
Adjusted R^{-2}	.37	.47	.38	.15	.58
F	14.3	21.0	15.3	5.2	33.2

[a]* indicates the coefficient is significantly different from zero at .99 level of probability; **, at .95 level of probability. [b]Cropping intensity index. [c]Multiple cropping index.

Table 8. Relationships between hypothesized determinants of cropping systems and labor utilization, estimated by regression analysis of 207 farms at 14 Philip-Dine sites, 1979.[a]

Determinant	Percentage labor hired	Man-days/ha, rice	Man-days/ha, nonrice
% organic carbon	38.4**	-151**	-29.1
% clay	-.353**	1.82	1.20**
Irrigation	8.62**	303**	31.1**
Farm size	7.42**	158**	1.39
No. of parcels	-.624**	.001	1.43**
Education	.213	17.0**	-1.45
Price of nitrogen	-10.6**	105**	14.2
Price of rice	.265	-20.5**	7.55**
Wage	1.07**	4.76*	.902
Constant	37.0	494	-382
Adjusted R^{-2}	.46	.43	.33
F	20.9	20.5	12.4

[a]* indicates the coefficient is significantly different from zero at .99 level of probability; **, at .95 level of probability.

Table 9. Relationships between hypothesized determinants of cropping systems and rates of technical inputs employed by farmers, estimated by regression analysis of 207 farms at 14 Philippine sites, 1979.[a]

Determinant	Value of cash inputs, rice (₱/ha)	Value of cash inputs, nonrice (₱/ha)	Variety of rice	Nitrogen (kg/ha)
% organic carbon	-420**	-201**	.845**	-22.7**
% clay	-.004	8.17**	-.029**	.038
Irrigation	164**	122**	.582**	15.2**
Farm size	109**	12.1	.160**	-6.60**
No. of parcels	4.28**	.719	.002	1.70**
Education	9.92**	-8.93	.015*	.145
Price of nitrogen	16.1	-.463	-.217**	5.31
Price of rice	-8.11	23.1**	-.036**	.637
Wage rate	12.9**	4.56**	.012*	.026
Constant	688	-1074	4.47	-15.2
Adjusted R^{-2}	.37	.58	.25	.34
F	16.0	32.9	8.7	12.6

[a]* indicates the coefficient is significantly different from zero at .99 level of probability; **, at .95 level of probability.

the 99% level of probability, but 3 determinants related to crop production measures were nonsignificant.

The number of parcels per farm and farmer education were significant in fewer equations than the other independent variables. Farm-level determinants as a whole appeared less influential than other groups of variables. Input relationships reflecting land use, labor use, and cash use were about equally well explained, with about 65% of coefficients appearing significant in the regressions. Production relationships were poorly explained — only the amount of nonrice crops sold appeared to be

Table 10. Relationships between hypothesized determinants of cropping systems and production and sales, estimated by regression analysis of 207 farms at 14 Philippine sites, 1979.[a]

Determinant	Rice yield (cavans/ha)	Value of rice sold	Value of nonrice produced	Value of nonrice sold
% organic carbon	-4.09	-170	-9384	-1853
% clay	-.115	–1.18	1207**	309**
Irrigation	12.6**	106	22018	4772**
Farm size	-1.66	61.9*	-540	-862**
No. of parcels	.312	–4.92	–977*	-147**
Education	.167	8.31	198	288**
Price of nitrogen	–.006	45.2	–4967	2344**
Price of rice	-.006	-25.7	2432*	800**
Wage	-.101	-3.4	110	91.7
Constant	54.0	1337	-113995	-33762
Adjusted R^{-2}	.03	.02	.05	.49
F	1.8	1.6	2.3	22.7

[a] * indicates the coefficient is significantly different from zero at .99 level of probability; **, at .95 level of probability.

strongly determined by the independent variables. A ranking based upon the percentage of coefficients that are significant gave the following determinant-descriptor relationships in descending order of importance.

Determinant	*Descriptor*	*% of significant coefficients*
Plot-level (physical)	Materials use	83
Village-level (economic)	Land use	80
Plot-level (physical)	Labor use	78
Plot-level (physical)	Land use	73
Village-level (economic)	Labor use	66
Farm-level (economic)	Cash use	58
Farm-level (economic)	Labor use	55
Village-level (economic)	Cash use	50
Plot-level (physical)	Production	42
Farm-level (economic)	Production	42
Village-level (economic)	Production	33
Farm-level (economic)	Land use	33

Directions of relationships are indicated in Table 11 where the parentheses indicate the negative sign on significant coefficients. The positive relationship of irrigation with input intensities reflects the complementarity of water with other factors of production. The negative relations between the percentage of organic carbon in the soil and material inputs (mostly fertilizer) probably indicates farmers' inclinations to use less fertilizer on fertile soils. On fertile soils, MCI was low because farmers were inclined to allocate more land to rice and less to dryland crops. As percentage of clay increased, land use increased, perhaps because of water retention. Use of modern varieties was less prevalent on clayey soils than lighter soils, which

Table 11. Significance and signs of coefficients[a] estimated by regression of 9 hypothesized determinants of cropping systemson 16 measures of resource allocation and production, 207 farms at 14 Philippine sites, 1979.

	Land use					Labor use			Technical inputs				Production and sales			
	CII[b]	MCI[c]	% rice	% grain legume	% vege-table	% hired	Rice	Non-rice	Rice	Non-rice	Var-iety	Nitro-gen	Rice yield	Rice sold	Non-rice produc-tion	Non-rice sold
Plot level - physical																
% organic carbon	*	(*)	(*)	(*)	(*)	*	(*)		(*)	(*)	*	(*)				
% clay	*		*			(*)		*		*	(*)				*	*
Irrigation	*	*			*	*	*	*	*	*	*	*	*		*	*
Farm level - economic																
Farm size				*	(*)	*	*		*		(*)	(*)		*		(*)
No. of parcels					*	(*)		*	*			*			(*)	(*)
Education	*	*					*		*		*					*
Village level - economic																
Price of nitrogen	*	*	*	*		(*)	*				(*)			(*)		(*)
Price of rice	*	*	(*)		*		(*)	*		*	(*)				*	*
Wages	*	*	*	*		*	*		*	*	*					
Adjusted R^{-2}	.29	.34	.39	.16	.58	.46	.43	.33	.37	.58	.25	32	.03	.02	.05	.49

[a] * indicates the coefficient is significantly different from zero at 90% level of probability. The parentheses indicate the negative sign on significant coefficients. [b]Cropping intensity index. [c]Multiple cropping index.

Table 12. Factor loadings in results of factor analysis of determinants and descriptors of cropping systems. [a]

Factor L1		Factor L2		Factor L3		Factor L4	
Livestock income	.43	% clay	.69	Operators age	.78	Education	.57
Topography	.79	No. of parcels	.64	Yr in farming	.75	Off-farm income	.56
Length of rainfall	.72	Farm capital	.55	Transportation	.40	Credit	.46
% organic carbon	.78	Price of rice	.76	Price of nitrogen	.51	Total farm size	.75
Wage rate	.62	Irrigation	.68	Man-land ratio	.37	Family size	

Factor F1		Factor F2		Factor F3		Factor F4	
Cash/ha, nonrice	.77	MCI [b]	.76	Rice sold	.45	Rice variety	.56
Md/ha, nonrice	.63	CII [c]	.67	Rice yield	.58	Cash/ha, rice	.63
% area, vegetables	.83	% area, rice	.70	Returns to rice labor	.84	Md/ha, rice	.82
N/ha rice	.61	% area, legumes	.72	Rice produced	.86	%hired labor	.41
Nonrice sold	.70						

Regressions of *F* on *L* factors

$$F1 = -.149 - .097L1^{***} + .756L2^{**} - .002L3 - .041L4, \text{ adjusted } r^2 = .67$$
$$F2 = -.026 - .083L1 + .467L2^{**} - .003L3 + .167L4^{*}, \text{ adjusted } r^2 = .21$$
$$F3 = .46 + .007L1 + .115L2 + .006L3 - .070L4, \text{ adjusted } r^2 = .01$$
$$F4 = -.009 + .234L1 + .013L2 + .0001L3 + .521L4^{**}, \text{ adjusted } r^2 = .29$$

[a] * indicates coefficient is significantly different from zero at .99 level of probability; **, at .95 level of probability. [b] Multiple cropping index. [c] Cropping intensity index.

was seemingly in conflict with the tendency toward multiple cropping. Coefficients on village-level independent variables appeared anomalous. At higher rice prices, less area was allocated to rice. The result suggests that the demand relationship dominated rice price behavior; apparently the price of rice was high because relatively lower amounts of rice were being supplied.

The relationships displayed in the analysis may reflect principles of cropping system adaptation to the environment. The present analysis must be further refined and should be repeated elsewhere before strong implications for design are accepted. The correlations presented may not reflect direct relationships between variables, but rather an underlying more general pattern of relationships. Following the method that has been described, factor analysis was employed to determine if this was the case. The results are shown in Table 12. The explanation of the descriptor "factors" by determinant factors was not as satisfactory as the regression analysis. Fewer coefficients and fewer regression equations were significant. The factors did not reflect groupings of variables consistent with the classification employed in the study.

CONCLUSIONS

The results of regression analysis encourage the view that determinants of cropping systems can be identified. It is apparent that physical factors measured at the plot level strongly determined the characteristics of cropping systems, and that aggregative village-level factors such as prices and wages were also strongly related.

Farm-level determinants appeared less important. Their relative weakness in explaining the characteristics of cropping systems may be encouraging. It is difficult to design, test, and introduce technology to suit the needs of individual farmers at a site. It is relatively easier to assess the physical and village-level conditions at a site and design and introduce homogeneous technology.

Input intensities are more clearly related to environmental factors than output intensity is. That suggests that during cropping pattern design, the use of inputs should be closely examined for their fit to the environment. Relationships between specific determinants and system characteristics may indicate principles for design. However, the structure of the analysis has required judgment, which, in turn, may lead to biased results. It is necessary that the relationships indicated in this analysis be verified through research at a large number of diverse sites.

Appendix 1. Composition of farms by land types at 14 Philippine sites, 1979.

Site	Average farm size (ha)	Percent of total farm size				
		Irrigated	Lowland rainfed	Planted to tree crops	Un-cultivated area	Upland
Ilocos Norte						
Rayuray	.79	–	97	–	–	3
San Lorenzo	1.17	–	85	–	–	15
Nanguyudan	1.65	1	92	–	–	7
Pasil	.71	25	72	–	1	2
Zambales						
Amungan	2.04	–	92	–	8	–
Inhobol	5.06	2	32	–	66	–
Santa Rita	1.45	11	89	–	–	–
Sitio Bunga	2.52	3	32	47	16	2
Cagayan						
Calamaniugan	3.28	–	100	–	–	–
Gattaran	1.94	4	89	–	–	7
Tacloban						
Dacay	4.01	6	45	42	6	1
La Paz	2.57	1	37	62	–	–
Cabalungan	3.83	5	36	55	2	2
Mayorga	2.84	–	64	36	–	–

Appendix 2. Cropping intensities at 14 Philippine sites. 1979.

Site	Av[a] farm size (ha)	Av effective area (ha)	MCI[b]	Parcels (no./farm)	cropping intensity index
Ilocos Norte					
Rayuray	.79	1.63	206	5.57	.74
San Lorenzo	1.17	2.42	207	6.00	.71
Nanguyudan	.59	1.13	192	3.43	.58
Pasil	.47	.73	155	5.58	.64
Zambales					
Amungan	1.87	2.47	132	1.40	.41
Inhobol	1.73	2.34	135	2.27	.43
Santa Rita	1.45	1.59	110	1.60	.36
Sitio Bunga	.65	.66	105	1.53	.33
Cagayan					
Calamaniugan	3.28	3.51	107	2.07	.36
Gattaran	1.94	2.07	107	1.93	.42
Tacloban					
Dacay	1.83	2.43	133	2.20	.46
La Paz	.95	1.47	155	1.07	.47
Cabacongan	1.35	1.44	107	1.53	.35
Mayorga	1.82	2.74	151.5	1.13	.50

[a]Includes rainfed-rice based only. [b]Multiple cropping index. $MCI = \frac{\text{Effective crop area}}{\text{Absolute area}} \times 100.$

Appendix 3. Percentage of farmers using different rice varieties at 14 Philippine sites, 1979.

Site	Percentage of farmers		
	Traditional varieties	IR varieties	Other improved varieties
Ilocos Norte			
Rayuray	80	7	13
San Lorenzo	27	–	73
Nanguyudan	75	12	13
Pasil	50	–	50
Zambales			
Amungan	18	47	35
Inhobol	38	18	44
Santa Rita	25	25	50
Sitio Bunga	67	6	27
Cagayan			
Calamaniugan	100		
Gattaran	100		
Tacloban			
Dacay	13	87	–
Lapaz	7	93	–
Cabacungan	13	87	–
Mayorga	–	100	–

Appendix 4. Farm resources at 14 Philippine sites, 1979.

Site	Farm size (ha)	Family size	Man-land ratio	Male adult worker (no./ha)	Female adult worker (no./ha)	Carabaos (no./ha)	Cattle (no./ha)	Water pumps per farm	Farmers (%)	
									Hiring tractors	using rotary weeder
Ilocos Norte										
San Lorenzo	1.17	5	4.3	1.7	.9	.9	–	1	–	–
Rayuray	.80	4	5.0	1.0	1.0	2.0	–	1	–	–
Pasil	.72	5	7.0	4.1	1.0	2.3	2.1	.3	–	–
Nanguyudan	.65	6	9.2	2.6	1.0	1.5	2.1	.4		
Zambales										
Amungan	2.01	6	3.0	.8	.4	.7	.4	–	–	–
lnhobol	1.72	5	2.9	.9	.4	1.4	.3	–	–	–
Santa Rita	1.49	6	4.0	1.6	.6	.9	1.0	–	–	–
Sitio Bunga	.89	5	5.6	2.3	.7	1.4				
Cagayan										
Calamaniugan	3.28	5	1.5	.6	.4	.4	–	–	.67	–
Gattaran	2.01	6	2.9	.9	.3	1.0	–	–	.13	–
Tacloban										
Mayorga	1.82	4	2.2	.7	.6	.6	–	–	–	7
Dacay	1.80	6	3.3	.3	.1	.7	–	–	–	–
Cabacungan	1.34	7	5.2	.4	.3	1.4	–	–	–	–
La Paz	.94	5	5.3	1.3	1.1	1.2	–	–	–	20

Appendix 5. Value of crops at 14 Philippine sites, 1979.

Site	Farm size (ha)	Rice yield (t/ha)	Value[a] of production (₱)			Total value (₱) of crops
			Rice	Second crop (garlic)	Other crops	
Ilocos Norte						
San Lorenzo	1.2	2.7	2691	5448	965	9104
Rayuray	.8	3.2	2724	3697	1370	7791
Pasil	.4	3.0	3282	1468	65	4815
Nanguyudan	.7	1.6	871	1600	790	3261
Zambales						
Amungan	2.0	2.1	4701	–	767	5468
Inhobol	1.7	2.2	3334	–	689	4023
Santa Rita	1.5	2.1	2701	–	87	2788
Sitio Bunga	.9	1.9	1582	–	112	1694
Cagayan						
Calamaniugan	3.3	2.1	7978	–	76	8054
Gattaran	2.1	2.2	3954	–	75	4029
Tacloban						
Mayorga	1.8	.6	2806	–	555	3361
Dacay	1.8	2.4	5206	–	3403	8609
Cabacungan	1.3	1.6	2226	–	4582	6808
La Paz	1.0	2.7	2797	–	2880	5677

[a]US$1 = ₱7.35.

Appendix 6. Material costs per hectare for rice production at 14 Philippine sites, 1979.

Site	Material costs[a] (₱/ha)					
	Seeds	Fertilizer	Herbicide	Insecticides	Others	Total
Ilocos Norte						
Rayuray	137	501	–	53	–	691
San Lorenzo	109	475	–	21	–	605
Nanguyudan	87	240	–	23	–	350
Pasil	166	528	–	32	–	726
Zambales						
Amungan	99	115	4	11	–	229
Inhobol	77	274	–	13	–	364
Santa Rita	88	192	–	36	–	316
Sitio Bunga	32	103	–	39	–	174
Cagayan						
Calamaniugan	46	–	11	–	1	58
Gattaran	101	–	–	25	–	126
Tacloban						
Dacay	100	25	5	51	–	181
Lapaz	97	13	–	30	–	140
Cabacungan	95	3	–	9	–	107
Mayorga	115	16	–	3	–	134

[a]US$1 = ₱7.35.

Appendix 7. Summary of costs and return[a] per farm and per hectare at 14 Philippine sites, 1979.

Site	Material costs per farm (₱)	Labor per farm (man-days)	Total variable costs per farm (₱)	Total value product per farm (₱)	Labor costs per ha (₱)	Material costs per ha (₱)	Total variable costs per ha (₱)	Total value of production per ha (₱)
Ilocos Norte								
Rayuray	1,298	258	1,556	7,791	2,580	1,623	4,203	9,739
San Lorenzo	1,202	218	1,420	9,104	1,491	1,027	2,518	7,781
Nanguyudan	493	174	667	3,261	2,142	758	2,900	5,017
Pasil	882	245	1,127	4,816	4,170	1,877	6,047	10,247
Zambales								
Amungan	502	187	689	5,469	800	268	1,068	2,721
Inhobol	715	750	965	4,023	1,156	413	1,569	2,339
Santa Rita	420	156	576	2,789	861	290	1,151	1,871
Sitio Bunga	215	75	290	1,695	952	341	1,293	1,904
Cagayan								
Calamaniugan	208	228	436	8,075	556	63	619	2,462
Gattaran	260	181	441	4,050	746	134	680	2,088
Tacloban								
Dacay	568	461	1,029	8,609	2,049	316	2,365	4,783
La Paz	181	158	339	5,678	1,331	191	1,522	5,977
Cabacungan	197	220	417	6,808	1.313	147	1,460	5,081
Mayorga	345	501	846	3,362	2,202	190	2,392	1,847

[a]US$1 = ₱7.35.

Appendix 8. Simple correlation coefficients between determinants of cropping systems, 207 farms at 14 Philippine sites, 1979.

	Plot level – physical					Farm level – economic				
	Topo-graphy	% clay	% or-ganic carbon	Mo of rain-fall	Irriga-tion	Farm size	Parcels (no.)	Family size	Live-stock income	Credit
Plot level – physical										
Topography	1.0									
% clay	–.32	1.0								
% organic carbon	–.51	.08	1.0							
Months of rainfall	–.41	–.28	.70	1.0						
lrrigation	–.11	.31	.00	.04	1.0					
Farm level – economic										
Farm size	–.27	–.20	.16	.09	–.17	1.0				
No. of parcels	.11	.25	–.16	–.30	.37	.08	1.0			
Family size	–.02	.02	.00	.01	–.02	.02	–.05	1.0		
Livestock income	.13	–.04	–.26	–.22	.04	.04	.17	.01	1.0	
Credit	–.24	.16	.00	.02	-.04	.29	–.03	.01	–.11	1.0
Value of farm capital	.05	.22	–.17	–.22	.30	.05	.29	–.05	.33	.17
Farmers' age	.04	–.11	–.16	–.09	–.09	–.07	–.05	–.13	–.05	–.06
Years in farming	.04	–.03	–.13	–.08	.07	–.00	.04	–.09	–.06	–.06
Years in school	–.08	–.02	.18	.11	–.05	.35	.17	–.12	.06	.08
Off-farm income	–.09	–.10	.05	.02	–.12	.26	–.02	.002	.08	.20
Village level – economic										
Man-land ratio	.22	.09	–.07	–.10	–.02	–.33	–.02	.20	–.06	–.06
Wage	–.49	.17	.27	.30	.01	.15	.11	–.04	–.07	.16
Price of rice	.09	.34	–.12	–.34	.45	–.14	–.51	–.06	.12	–.08
Price of nitrogen	.15	.15	.40	.18	.09	–.05	.01	–.04	–.09	–.20
Transportation	.38	.13	.18	.18	.005	–.16	–.04	–.02	–.20	–.11

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APPENDIX 8 CONTINUED

	Farm level – economic (cont'd.)					Village level – economic				
	Value of farm capital	Farmers. age	Farming expe-rience	Yr in school	Off-farm income	Man-land ratio	Wage	Price of rice	Price of N	Transpor-tation
Plot level – physical										
Topogaphy										
% clay										
% organic carbon										
Months of rainfall										
Irrigation										
Farm level – economic										
Farm size										
No. of parcel										
Family size										
Livestock income										
Credit										
Value of farm capital	1.0									
Farmers' age	.03	1.0								
Years in farming	.05	.73	1.0							
Years in school	.03	-.30	-.26	1.0						
Off-farm income	.03	-.01	-.01	.25	1.0					
Village level – economic										
Man-land ratio	-.02	-.08	-.12	-.02	–.04	–.04				
Wage	-.03	.04	-.02	.07	–.04	–.04	.11			
Price of rice	.33	-.07	.02	.02	.11	-.11	.51	1.0		
Price of nitrogen	-.12	-.14	-.16	.16	.10	–.10	-.01	.10	1.0	
Transportation	-.09	-.16	-.11	.05	.15	-.15	–.04	-.17	-.04	1.0

Appendix 9. Relationship of land use to 20 hypothesized determinants of cropping systems, regression estimates based upon 207 farms at 14 Philippine sites, 1979.[a]

Determinant	MCI	CII[b]	% area, rice	% area, vegetables	% area, grain legumes
Plot level - physical					
Topography	16.8	14.2	-2.41	4.47	.037
% clay	.609	1.09	.266	.202	-.087
% organic carbon	-37.3*	-12.3	12.4	-1.29	-6.14
Months of rainfall	1.00	-6.95	.228	-.562	-.810
Irrigation	58.2***	141***	1.34	5.97	.920
Farm level - economics					
Farm size	2.45	13.5	2.36	-1.76	.550
No. of parcels	-.452	-1.16	-.156	.245	-.134
Family size	-.272	-1.68	-.197	-.315	.466
Livestock income[b]	.797	-2.37	-3.54**	-1.31**	2.62
Off-farm income[b]	1.70	-.667	-1.51***	2.63	-.057
Credit[b]	.739	-4.14	-.181	.403	-1.20
Farm capital[b]	.109	.934	-.310	-.264	-.382
Farmers' age	.139	-.736	-.044	-.055	-.025
Years in farming	-.062*	.710	-.137	.080	.027
Education	1.18	7.69***	-.120	-.003	.127
Village level - economics					
Man-land ratio	.193	-.061	-.0001	.014	.019
Wage rate	2.88***	3.04**	-.906***	.120	.393
Price of rice	2.93***	9.35***	-2.85***	1.44	-. 184
Price of nitrogen	2.93***	40.1	-5.27	-2.34	1.81
Transportation	-2.82	-6.72	.431	-3.77	-2.81
Constant	-123	-1 74	245	-50.7	20.0
R^{-2}	.45	.34	.43	.60	.30

[a]* means the coefficient is significantly different from zero at 90% level of probability; **, at 95%; ***, at 99%. MCI = multiple cropping index. CII = cropping intensity index. [b]Coefficient has been multiplied by 10^3.

Appendix 10. Relationship of labor use to 20 hypothesized determinants of cropping systems, regression estimates based upon 207 farms at 14 Philippine sites, 1979.[a]

Determinant	% of total labor hired	Rice labor (man-days/ha)	Labor on other crops (man-days/ha)
Plot level - physical			
Topography	-19.9***	-19.1	24.8
% clay	-.584***	4.02	1.74**
% organic carbon	33.2***	-693***	23.6
Months of rainfall	-.186	63.6***	3.50
Irrigation	6.83	170***	29.9
Farm level - economics			
Farm size	4.61**	191***	1.38
No. of parcels	-.505***	.660	1.29
Family size	-1.69**	-6.53	2.32
Livestock income[b]	1.73	-15.2	13.0*
Off-farm income[b]	.615	-7.04	.119
Credit[b]	1.66	-4.69	8.05

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APPENDIX 10 CONTINUED

Determinant	% of total labor hired	Rice labor (man-days/ha)	Labor on Other crops (man-days/ha)
Farm capital[b]		-.704	-.337
Farmers' age	.218	-4.04	.313
Years in farming	.010	4.23*	.093
Education	.222	15.6***	-1.67
Village level – economics			
Man-land ratio	.123	1.54	-.401
Wage rate	.767***	2.15	.861
Price of rice	.196	-10.2	7.78***
Price of nitrogen	-7.73**	191***	14.9*
Transportation	3.33	63.4*	-.242
Constant	58.3	-453	-459
Adjusted R^{-2}	.54	.49	.33

[a] * means the coefficient is significantly different from zero at 90% level of probability; **, at 95%; ***, at 99%. [b] Coefficient has been multiplied by 10^3.

Appendix 11. Relationship of use of technical inputs and 20 hypothesized determinants of cropping systems, regression estimates based upon 207 farms at 14 Philippine sites, 1979. [a]

Determinant	Value of material inputs on rice [b] (₱/ha)	Value of material inputs on other crops (₱/ha)	Rice variety[c]	kg N/ha rice
Plot level – physical				
Topography	160.5	12.3	-388**	2.72
% clay	2.64	7.17***	-11.5**	-.319
% organic carbon	-398.5***	-115	-901***	-1.28
Months of rainfall	16.39	10.6	220***	-2.90
Irrigation	148.5**	137***	61.6	19.0**
Farm level – economics				
Farm size	121.2***	1.02	-141***	-8.22***
No. of parcels	3.16	.310	8.06	1.64***
Family size	9.58	3.10	2.13	.665
Livestock income [c]	20.8	-5.23	-67.2	-2.33
Off-farm income [c]	-7.1	7.63*	20.4	.156
Credit [c]	-4.9	-12.6	75.8	.956
Farm capital[c]	5.7	4.84*	18.4*	.931
Farmers' age	-1.53	-.543	5.22	.635
Years in farming	10.54	.864	-3.22	-.377
Education	2.54***	-.347	7.65	.433
Village level – economics				
Man-land ratio	-1.64	-.937	2.44	-.134
Wage rate	13.89***	5.39***	.794	.213
Price of rice	-9.61	20.3***	-3.83	.219
Price of nitrogen	13.04	-21.9	81.6	3.45
Transporation	-8.59	-5.80	146*	.812
Constant	-877	439	805	10.4
Adjusted R^{-2}	.58	.38	.43	.34

[a] * means the coefficient is significantly different from zero at 90% level of probability; **, at 95%; ***, at 99%. [b] US$1 = ₱7.35. [c] Coefficient has been multiplied by 10^3.

Appendix 12. Relationship of crop production and sales to 20 hypothesized determinants of cropping systems, regression estimates based on 207 farms at 14 Philippines sites, 1979. [a]

Determinant	Value of rice produced (₱/ha)	Value of rice sold (₱/ha)	Value of other crops sold (₱/ha)
Plot level — physical			
Topography	-480	6.52	-255
% clay	-48.1	3.90*	290***
% organic carbon	442	-118	-205 0
Months of rainfall	-70.9	18.8	-38.1
Irrigation	2785***	108*	4618***
Farm level — economics			
Farm size	89.3	194	–1105*
No. of parcels	-10.3	-3.02*	-131**
Family size	–253**	-527	529
Livestock income [b]	-42.2	–6.73*	–785
Off-farm income [b]	12.8	-.785	209
Credit [b]	92.1	-6.97	–188
Farm capital [b]	-10.3	–.872	64.0
Farmers' age	-22.4	.428	-61.0
Years in farming	-1.48	-3.98	-4.22
Education	-35.3	-4.85	245**
Village level — economics			
Man-land ratio	238***	52.0	-17.2
Wage rate	52.6	.009	91.3
Price of rice	-45.3	-19.9**	777***
Price of nitrogen	-495	31.2	-2592***
Transportation	-101	-141	-349
Constant	8840	1507	-26371
Adjusted R^{-2}	.23	.51	.47

[a] * indicates the coefficient is significantly different from zero at 90% level of probability; **, at 95%; ***, at 99%. [b] Coefficient has been multiplied by 10^3.

Appendix 13. Simple correlation coefficients between descriptors of cropping systems, 20 farmers at 14 Philippine sites, 1979.[a]

	MCI	CII	Area (%)			% hired labor	Man-days/ha, rice	Man-days/ha, nonrice
			Rice	Vegetable	Legume			
MCI	1.0	.73	−.63	.37	.48	−.03	.20	.40
CII	.73	1.0	−.56	.37	.24	-.01	.25	.33
% area, rice	-.63	−.56	1.0	-.50	−.44	.10	.51	.24
% area, vegetable	.37	.37	−.50	1.0	.02	−.27	.15	.52
% area, legumes	.48	.24	−.44	.02	1.0	.02	.03	.13
% hired labor	−.03	−.01	.10	−.27	.02	1.0	.22	-. 15
Mandays/ha rice	.20	.25	.12	−.15	.03	.22	1.0	−.13
Mandays/ha nonrice	.40	−.15	−.49	.52	.13	−.15	−.13	1.0
Material inputs/ha, rice	.35	.27	−.13	.11	.35	.05	.51	.24
N/ha	.21	.13	−.22	.37	.10	−.27	−.10	.21
Variety	.08	−.02	.16	−.20	−.13	.20	−.19	−.13
Value of rice produced/ha	.09	.13	.05	.08	−.03	.04	.05	−.05
Value of rice sold/ha	−.07	−.09	.17	−.16	.01	.08	.08	−.11
Value of nonrice sold/ha	.36	.36	−.40	.63	.09	.05	.05	.37

	Material inputs		N/ha	Variety	Value of rice produced/ha	Value of rice sold/ha	Price of nonrice sold/ha
	Rice	Nonrice					
MCI	.35	.47	.21	.08	.09	−.07	.36
CII	.27	.45	.13	−.02	.13	−.09	.36
% area, rice	−.13	−.56	−.22	.16	.05	.17	−.40
% area, vegetable	.11	.73	.37	−.20	.08	−.16	.63
% area, legumes	.35	.19	.10	−.13	−.03	.00	.09
% hired labor	.05	−.13	−.27	.20	.04	.08	.05
Man-days/ha rice	.51	-.10	−.10	.19	−.05	.11	−.10
Man-days/ha nonrice	.24	.68	.21	−.13	−.05	−.11	.37
Material inputs/ha, rice	1.0	.26	.03	.07	−.05	.03	.09
Material inputs/ha, nonrice	.26	1.0	.28	.19	.00	.14	.69
N/ha	.03	.28		−.07	.08	.09	.24
Variety	.07	.−.19	−.07	1.0	.04	.02	.16
Value of rice produced/ha	−.05	. 00	.08	.04	1.0	.31	.04
Value of rice sold/ha	.03	−.14	-.09	−.02	.31	1.0	−.12
Value of nonrice sold/ha	.09	.69	.24	-.16	.04	−.12	1.0

[a] MCI = multiple cropping index CII = Cropping intensity index

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Comparison of farmers' and researchers' cropping patterns

Gordon Banta

The International Rice Research Institute (IRRI) has played a major role in promoting and getting cropping systems research accepted in most countries in Asia, and in developing farm-based research methodology. The Asian Cropping Systems Network (ACSN) has ensured a two-way flow of ideas between country programs and IRRI. In a review of the ACSNs Working Group meetings and in personal communication, evidence of the progress being made in cropping systems research is abundant. However, as with any new research approach, there are some problems.

THE ECONOMIC METHODOLOGY PROBLEM

One major problem is that the economic studies comparing the farmers' and researchers' cropping patterns are not finished in time to contribute to the design of the experiments for the next season. There are several reasons for the delay. First. and most important, there is a major imbalance between the resources committed to data collection and to data analysis. Second, many economic procedures being used or planned are not particularly efficient. The two problems produce a third problem. The economists and other team members are increasingly frustrated as the backlog of data to be analyzed grows and results of economic analysis continue to come out late. In the long run, this is the most serious problem as a team is only strong if its members are satisfied with their work.

The problems in the economic component of cropping systems are due to several basic causes.

First, most economic procedures used in cropping systems research fall in the fields of farm management and production economics. In a major review of farm management and production economics literature from 1946 to 1970, Jensen devotes 22 of 75 pages to the questions what is farm management, what is it doing, and where is it going (Jensen 1978). His review shows a dichotomy between those trying to solve problems and those developing methodology for their peer group. He notes that the new methodology has been of little help to those trying to help solve

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farmers' problems. "Given the need for technical data for farm production analysis and planning, it is something of a puzzle why comprehensive multidisciplinary efforts have not been more widespread and numerous" (Jensen 1978). He observes that production economists turned to model building and linear programming and were willing to accept discrete data from other disciplines. That means that the emphasis in farm management and production economics shifted from solving farm problems to solving modeling problems. The priorities now are making the tool work first and solving real problems second.

Jensen (1978) and Upton (1979) question the major reliance on production functions in production economics. "Given the problems of specification bias, intercorrelations among input categories, and problems growing out of aggregating inputs and outputs, it is questionable whether aggregate production function analysis should play any role beyond that of a diagnostic technique. in the preliminary stages of analysis" (Jensen 1978). Although considerable advancement has been made in sophisticated mathematical and econometric procedures, there appears to be little help in the economic literature for economists trying to help solve farmers' problems.

The second basic cause relates to the first. The economic component of IRRI's cropping systems program realized the need for a simple economic analysis procedure for comparing farmers' and researchers' cropping patterns and established a program to develop a methodology. About the same time, country programs started and, in the absence of a methodology, based their data collection and analysis procedures on IRRI's. Unfortunately, a system to develop methodology is not necessarily of much use in solving farmers' problems. Thus, many economists in the network were caught with a mass of numbers and little idea of what to do with them.

CURRENT SITUATION OF THE ECONOMIC COMPONENT

To gain a complete understanding of what the economists are doing, and who they are, a questionnaire was mailed to Bangladesh, Indonesia, Philippines, Sri Lanka, and Thailand, all of which have had cropping systems programs for more than 3 years. The survey covered 22 sites that had been in operation at least 18 months (Table 1). The results confirm earlier discussion. Generally, only cost and return analyses are completed, but they take so long that they are of little use. Manpower appears to be sufficient. If an efficient methodology were available, the economists could be more productive.

THE OBJECTIVE

This paper suggests a simple economic procedure for comparing farmers' and researchers' cropping patterns. The procedure meets these criteria:

1. It must be based on economic principles;
2. All calculations can be done on a hand calculator;
3. All computational procedures used could be taught in IRRI's 6-month training program;
4. Analysis of a typical site can be completed in 1 month;

Table 1. Summary of economic data collection and analysis activities at 22 Asian cropping systems sites.

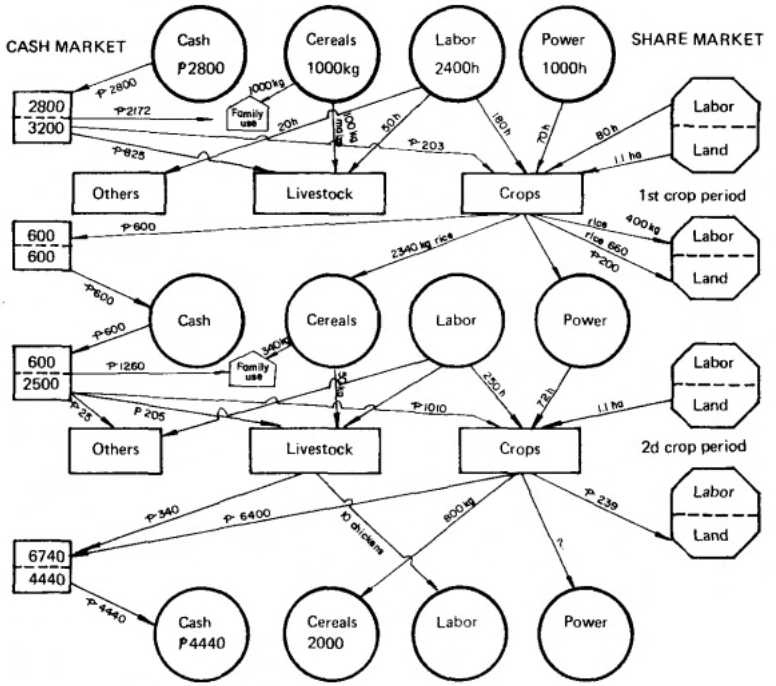
	Head-quarters	Head-quarters site	Site	Not done	Mean months to complete
Baseline					8
Farm records					
Data collection	0	0	16	6	
Weekly or monthly summary	6	3	7	6	
Calculate means of inputs	6	1	8	7	
Calculate S.D. of inputs	6	1	2	12	
Cross tabulation	6	3	7	6	
Cost and return	8	4	4	6	9
Returns to factors of production	8	3	4	7	
Production function	0	3	0	19	
Labor distribution analysis	5	5	2	10	
Cash-flow analysis	4	2	2	14	
Whole-farm budget	0	3	0	19	
Agroeconomic experiments					
Data collection	2	1	17	2	
Cost and returns	5	5	5	7	7
Return to factors of production	6	4	5	7	
Man years					
MS or Ph D	0.2		0		
BS	0		0.7		
High school	0.1		1.4		

5. The results are in a form that noneconomists could understand;
6. The conclusions reached must be the same as one would get with sophisticated procedures, such as linear programming.

One basic assumption in the suggested procedure is that an approximate answer on time is more useful than a precise answer that arrives late. Another assumption is that use of the researchers' informal knowledge gained while collecting data and interacting with the farmers and other researchers in the analytical procedure will lead to more efficient conclusions than those reached by using analytical data alone. The economists working at the site gather much information that is never recorded because it cannot be quantified: an example is impressions about farmers' attitudes. Informal knowledge is one of the main strengths of the on-farm research approach and the importance of the economists' informal understanding and input can-hardly be underestimated.

THE PROPOSED METHODOLOGY

The goal of the proposed methodology is a framework that will help the economists make efficient decisions with a minimum of resources and in a short time. The decision to be considered is, will the new technology replace the current practice? The first step is to clearly define what the new technology is — a new fertilizer rate, a



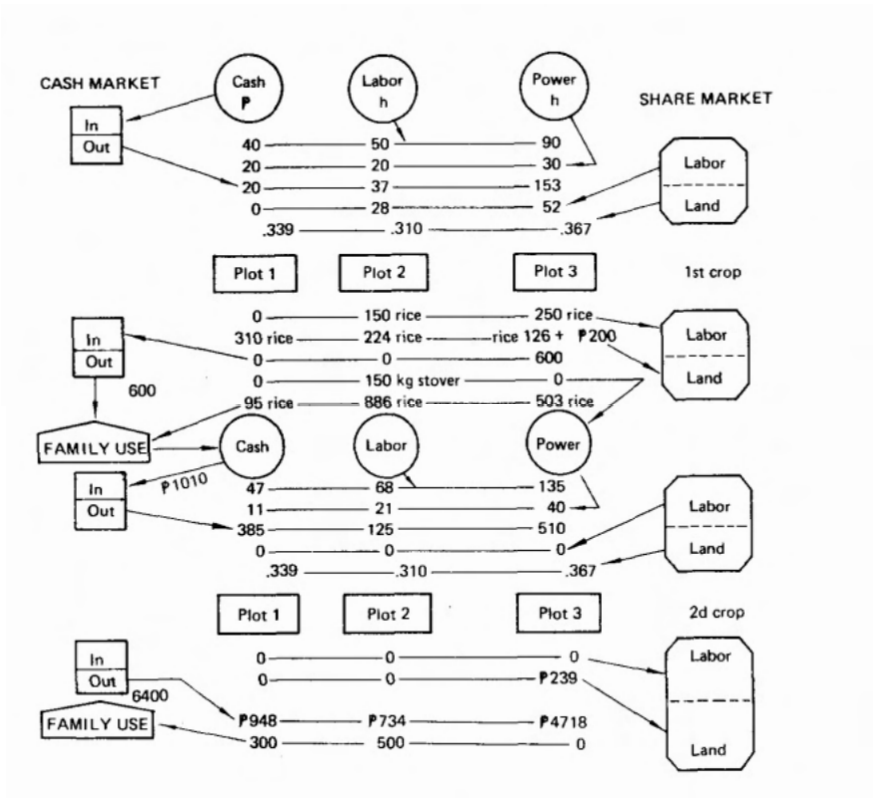
1. Schematic diagram of a farming system.

new cultivar, or a new cropping pattern — and what it is to replace in the current system.

The next step is to understand the current system. It is proposed that a small number of selected farmers be used in case studies to supply this information. The selected farms will represent the majority of farms at the site. The data from those farms will not be aggregated, and each farm will be studied separately. Five farms were selected for this study, but the number should depend primarily on the resources available to do the record-keeping and analysis. A complete analysis of 2 farms is superior to half an analysis of 30 farms that is reported late. To help understand the interaction of resources, enterprises, markets and the family on a farm, a schematic diagram is drawn (Fig. 1).

In the example, the crops received 203 pesos, 180 hours of labor, 70 hours of animal power, 80 hours of share labor, and 1.1 ha of share-rent land. The product of the crops enterprise was divided as follows: 600 pesos worth sold, 2,340 kg rice stored, 400 kg of rice to share labor, and 660 kg of rice plus 200 pesos to share-land rent. A diagram such as this helps team members keep their work on target and in perspective. It also supplies a framework in studying the effect of a possible change in technology on the farm.

The same type of schematic diagram can be used to show the crop enterprise in more detail. In Figure 2, the market cash inputs, family labor, animal power, share



2. Schematic diagram of a cropping system.

labor, and share-land rent inputs are shown above each plot. The distribution of product to these resources are shown below each plot for the first and second crops in 1 year. If a new technology or cropping pattern is proposed, a schematic diagram such as this can be a model to find where the shift in resource flows will occur and how the payment for these resources may be made. The final concern is, did the family benefit by getting more?

Partial budgets

Partial budgets will be used to find if the new technology is more profitable than the technology it is to replace on each farm. Enterprise budgets require more work and are not as efficient as partial budgets as a decision-making tool. Partial budgets are concerned only with those things that change if an alternative is chosen. They can also be used to solve the three basic questions of production economics: 1) what to produce, 2) how to produce it, and 3) how much to produce (Fellows 1960). Starting with the general format of a partial budget, the marginal equivalents are shown in brackets:

Added costs ($\Delta X_2 \cdot PX_2$)	Added returns ($\Delta Y_2 \cdot PY_2$)
Reduced returns ($Y_1 \cdot PY_1$)	Reduced costs ($\Delta X_1 \cdot PX_1$)
Economic disadvantage	Economic advantage

1. What to produce is found by comparing $\Delta Y_1 \cdot PY_1$ to $\Delta Y_2 \cdot PY_2$
2. How to produce it is found by comparing $X_1 \cdot PX_1$ to $\Delta X_2 \cdot PX_2$
3. How much to produce is found by comparing $\Delta X_1 \cdot PX_1$ to $\Delta Y_2 \cdot PY_2$

This quick procedure is not as precise as traditional marginal analysis — the partial budget uses the average of the change, whereas marginal analysis considers only the last unit of change. The researcher must clearly define what will change if an alternative is chosen, and what the basis of the change will be. A minor weakness is that only two alternatives can be compared at one time.

Graphs

Assuming that the new technology is more profitable, the next step is to find if there are any resource limits on its adoption. Graphs supply a quick and understandable method for studying resource flows over time. Cash, labor, and power usually limit adoption. A graph of the current resource flow of all activities on the farm is made first. Then, the net effect of subtracting the current technology resources requirements and adding the new technology resource requirement is added. If the new technology uses the same or less resources, it is acceptable. If it requires more of a resource, a decision must be made. If the farmer has the extra resources, he may use the new technology. If the new technology requires more resources than he has, will he use a combination of the two technologies?

Program planning

Program planning, the final step in the proposed procedure, answers the farmers' question on using a combination of two technologies. Program planning is an approximation method for finding an efficient combination of resource use in an optimization setting. It uses a matrix similar to linear programming, but usually with not more than five rows and five columns. The matrix shows the limits identified in the graph, the resource use levels for each activity at those limit points, and any exogenous constraints considered important.

Program planning is based on price theory and marginal analysis and must meet the same set of assumptions that linear programming does. Several inherent weaknesses in program planning should be understood before it is used. First, there is no strict mathematical procedure to follow, which will ensure that an optimum is reached. Second, in the process of eliminating parameters to get the matrix to a workable size, critical parameters may be discarded. Third, subjective decisions must be made in working the program so different solutions can be obtained from the same initial matrix. The efficiency of the solution depends upon the knowledge and skill of the researcher. Knowledge refers to an understanding of the processes and interrelationships that occur in the farming system. Skill refers to the subjective ability to make an efficient guess as to which parameters will become critical. Skill can be developed through practice. This procedure should be used only by researchers who have spent a considerable amount of time at the site under study.

Space does not permit a detailed explanation of program planning, but discussions with examples are found in several sources (Clarke 1962, Weather 1964, Rickards and McConnell 1967).

A HYPOTHETICAL EXAMPLE

Partial budget example

The following hypothetical example shows the use of the proposed procedures.

A farmer has sufficient lowland to grow the rice his family needs. He has an additional 20 ha in sugarcane. The price of sugarcane has been falling and the farmer is looking for an alternative. Cropping systems experiments conducted on similar upland areas have tested rice, mung, maize, sorghum, and tomato. Should he switch from sugarcane to another crop? If so, to what? The first step is to find, by partial budgets, if the new crops are more profitable than sugarcane.

Table 2 shows the gross returns and variable costs associated with each crop. With the information, a set of partial budgets can find which crops are more profitable than sugarcane (Table 3). In comparing sugarcane and rice, rice will be added and

Table 2. Gross returns and variable costs for some crops.

	Variable cost (US$/ha)	Gross returns (US$/ha)
Sugarcane	260	300
Rice	70	150
Mungbean	10	60
Maize	200	250
Sorghum	70	100
Tomato	400	600

Table 3. Example of partial budgets (US$/ha).

Comparison of sugarcane and rice			
Added costs	70	Added returns	150
Reduced returns	300	Reduced costs	260
Economic disadvantage	370	Economic advantage	410
Comparison of sugarcane and mungbean			
Added costs	10	Added returns	60
Reduced returns	300	Reduced costs	260
Economic disadvantage	310	Economic advantage	320
Comparison of sugarcane and maize			
Added costs	200	Added returns	250
Reduced returns	300	Reduced costs	260
Economic disadvantage	500	Economic advantage	510
Comparison of sugarcane and sorghum			
Added costs	70	Added returns	100
Reduced returns	300	Reduced costs	260
Economic disadvantage	370	Economic advantage	360
Comparison of sugarcane and tomato			
Added costs	400	Added returns	600
Reduced returns	300	Reduced costs	260
Economic disadvantage	700	Economic advantage	860

sugarcane removed. The added costs are the costs that will be incurred in growing rice. The reduced returns are the loss in income due to noncultivation of sugarcane. The economic disadvantage is the sum of the two. The added returns come from rice and the reduced costs are the costs saved by not growing sugarcane. The sum of the two is the economic advantage of switching from sugarcane to rice. A comparison of the economic advantage and disadvantage values allows a decision to be made. In this case, the alternative is more profitable. The same procedure is used for each of the alternative crops. All the crops but sorghum are more profitable than sugarcane. Sorghum is dropped and analysis is started on the next step in the procedure.

Graphing example

The partial budgets indicate that rice, mungbean, maize, and tomato are more profitable than sugarcane. The next step is to find if the farmer can grow them with the resources available to him.

The farmer has $1,500 available to purchase seed, fertilizer, and chemicals at the start of the season. There is no cash income between planting and harvesting, so cash can be considered a stock of resources. There is no need for a graph when a resource is a stock. Dividing the resources required per unit by the total stock of resources will show if there is a limitation and if so, how many units can be produced. The per-hectare cash costs of production are $50 for rice, $10 for mungbean, $100 for maize, and $300 for tomato. The division shows that only maize and tomato cannot be grown on 20 ha. Maize can be grown on 15 ha and tomato on 5. The farmer does not see the 5 ha of tomato as a constraint because he has no intention of planting more than 1 ha of tomato. Thus, there is a 15-ha cash limitation on maize and a 1-ha management limitation on tomato.

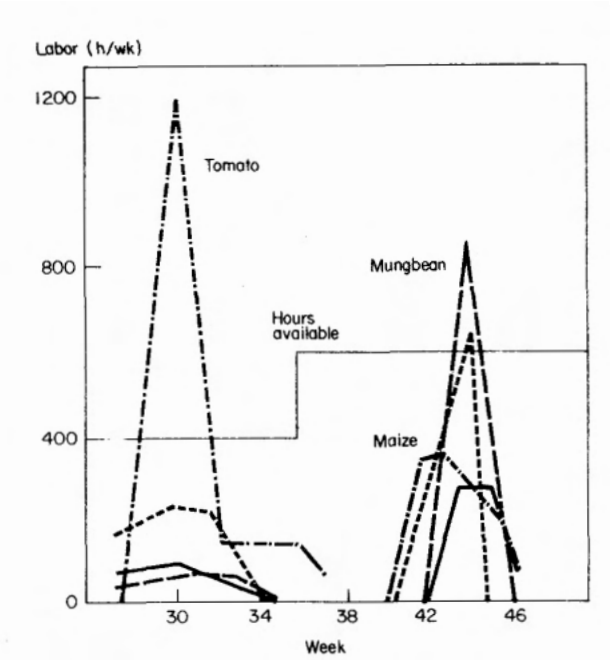
The next resource to consider is labor. Labor gives a flow of services that are either used or lost, and cannot be stored. In Figure 3, the labor use requirements for crops are shown over their production period.

Labor is a limiting factor at 2 time periods — weeks 30 and 44. Tomato can be grown only on a small area because of the labor limitation in week 30. Because of labor limitations in week 44, mungbean and maize cannot be grown on all 20 ha. At this point, a subjective decision must be made: should tomato be rejected completely? The decision is not to, because tomato shows the highest profit and the farmer is willing to grow only 1 ha. The graph shows that rice is the only crop that can be grown on all 20 ha. But because rice gives a low profit, the decision is not to discard any of the alternative crops because of labor limitations. The decision assumes a combination of crops will be grown.

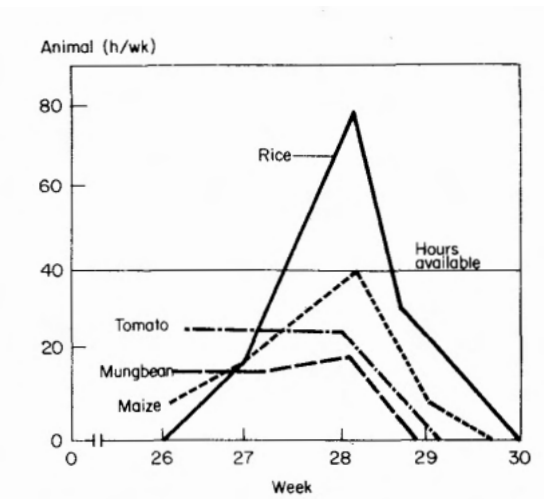
Animal power, another resource which gives off a flow of services, is handled in the same way as labor. Animal power is needed only for land preparation, therefore the time period when it must be analyzed is much shorter (Fig. 4).

Because of a major limitation in week 28 for animal power on rice, only one-half of the 20 ha can be planted to rice. If planted on the 20 ha, maize uses all of the animal power. No crops are discarded at this stage.

Limitations at the next stage have been identified. They are cash for tomato and maize, labor in week 30 for tomato, labor in week 44 for mungbean and maize, and animal power in week 28 for rice. In addition, the farmer has put a limit of 1 ha on tomato.



3. Labor hours for a 20-ha example.



4. Animal hours for a 20-ha example.

Program planning example

Table 4, Part A, shows the initial layout of the hypothetical case. On the available 20 ha, additional rice, maize, mungbean or tomato can be grown. Column 2 shows the gross margin, which is gross return minus variable costs. Column 3 is the land required for each crop. The cash cost of growing 1 ha of each crop plus the total cash available is shown in column 4. Column 5 shows the required labor per hectare to grow each crop in week 30, with a total of 400 hours available. Column 6 is labor data for week 44. Buffalo days per hectare per crop is given in column 7. On the right

Table 4. Program planning example.

Production process (1)	Gross profit ($/ha) (2)	Land (ha) (3)	Cash cost ($/ha) (4)	Labor for wk 30 (h/ha) (5)	Labor for wk 44 (h/ha) (6)	Power for wk 28 (buffalo d/ha) (7)	Limitations
Part A							
Additional rice	100	1	50	5	10	4	10 ha Power
Mungbean	50	1	10	10	50	1	12 ha Labor for wk 44
Maize	150	1	100	10	40	2	15 ha Labor & cash for wk 44
Tomato	300	1	300	60	10	1	1 ha Vegetable
Available resources		20	1500	400	600	40	
Part B							
Tomato	300	1	300	60	10	1	
Maize	1800	12	1200	120	480	24	
Resources	2100	13	1500	180	490	25	
Part C							
Tomato	300	1	300	60	10	1	
Maize	1500	10	1000	100	400	20	
Rice	400	4	200	20	40	16	
Resources	2200	15	1500	180	450	37	
Part D							
Tomato	300	1	300	60	10	1	
Maize	1500	10	1000	100	400	20	
Rice	300	3	150	15	30	12	
Mungbean	150	3	30	30	150	3	
Resources	2250	17	1480	205	590	36	

side is the maximum area that each crop can have. These are established either by setting a limit. such as 1 ha oftomato. or by dividing the total available resource tor the column by each number in the column and taking the smallest number. For additional rice 1,500/50 = 30, 400; 5 = 80, 600 10 = 60, and 40/4 = 10, so power in the 28th week limits additional rice area to 10 ha.

The nest step is to put in part B the crop with the highest gross profit, in this case tomato. Because it is limited to 1 ha, each of the other rates is for 1 ha. Because there are still resources left, the crop with the nest highest net profit, maize, is entered in column 1. To decide how many hectares to plant, check the right-hand column to find which resource is limiting. in this case, labor in week 44 and cash. Since tomato uses little of that labor, it is likely cash will be limiting. Tomato uses $300 cash so there is $1,200 left; maize takes $100/ha so 12 ha can he planted. Now the maize row can be filled in by multiplying each number in part A for maize by 12. Gross margin equals 150 × 12=$1,800, land 1 × 12= 12, cash cost 100 × 12=$1,200, labor in week 30, 10 × 12 = $120, and so on. When all the cash is used up and no process requires zero cash, items in each column are added. The gross margin is $2,100 for the use of these resources: 13 ha, 180 hours of labor in week 30, 490 hours in week 44, and 35 buffalo days/ha. Cash is the limiting resource in this solution.

Now another solution is tried. A hectare of rice takes only half the cash that maize does, $50 vs $100 in column 4. The rice row in part A shows power as the limiting factor. It 3 ha of maize is dropped, leaving 9, an additional 6 ha of rice can be grown, considering the two-to-one ratio in cash. Checking the power requirement, tomato 1 × 1 = i , maize 9 × 2 = 18, and rice 6 × 4 = 24, gives 1 + 18 + 24= 43, but only 40 is available, so 10 ha of maize and 4 ha of rice are tried. The gross margin increases by 100. No more rice can be added because of the power constraint.

Now part C is abandoned and another solution is tried. Mungbean uses little cash or power. Its constraint is labor in week 44. Column 6 shows 150 hours unused (600 less 450). Adding 3 ha of mungbean would increase gross margin $150, which just equals 1 ha of maize. One hectare of rice is removed to get cash to grow the mungbean. part D. The gross margin increases by $50. The constraint is labor in week 44. If more labor were available, other resources are sufficient to grow one more hectare of mungbean. The farmer would have to hire labor for an additional 40 hours to harvest mungbean for an additional gross margin of $50, If labor is worth less than 50/40 = $1.25/ hour, it will pay to hire it. The $1.25/ hour is known as a shadow price.

As is clear from the preceding example, program planning does not follow a strict set of rules. Guesses or estimates have to be made. With a small amount of practice the economist soon develops the ability to run his eye over the rows and pick out opportunities to increase the profit. Program planning can be a very useful tool tor even one with little experience. It uses judgment, plus systematic procedures.

REVIEWING THE BASIC DATA SET

Data from the IRRI site in Cale, Batangas, were used to develop each step of the procedure. The procedure was then compared with the more traditional approach using parametric statistics and production functions. Several interesting relation-

ships, which could have implications for other sites, were found. First, the coefficient of variation of gross crop output for 5 farms over 4 years was 96%, but the individual farms had coefficients of 10, 37, 21, 28, and 55% for the same period. This indicates that using cross-sectional data will overestimate the variability that an individual farmer can expect.

To gain a clear understanding of this situation, a comparison was made of the gross returns from the rice yields and from maize and vegetables, which are traditionally planted after the rice. When the data for 5 farms were aggregated, the correlation coefficient was .38; those for the individual farms were -.36, -.63, .19, -.89, and .54. One more correlation comparing rice yields and cash inputs on the following maize and vegetable crops was run. The correlation coefficients were -.94, –.56, -.57, -.67, and -.34. Aggregate data showed a correlation coefficient of .2. Although most of the correlations were nonsignificant at the 5% level, the consistency of signs plus the fact that farmers agreed that they would be more likely to put more resources into the second crops if they had a poor rice crop, led to the conclusion that the interaction between crops on an individual farm is greater than aggregate data would indicate.

The second anomaly noted related to the frequency distribution of inputs and production. Several of the frequency distributions were found to be bimodal and yet kurtosis and skewness tests would indicate that they were normally distributed. A chi-square test of normality did show that the frequencies were not normally distributed. The few minutes required to plot a frequency distribution on a graph is probably time well invested, particularly if parametric statistical analysis is planned. It was noted that the arithmetic mean overestimated the input levels used by most farmers. Geometric means were a more efficient estimator of what the majority were using.

Two basic assumptions in using production functions are that the factors of production are independent and that they are homogeneous. Several fundamental problems were encountered in developing production functions. The correlation coefficients between the major factors of production on 32 farms for 4 years in Cale were .654 for fertilizer cost and labor use, .503 for fertilizer cost and land value, and .603 for land value and labor use. The major factors of production were not independent and in discussions with farmers, it became clear that productive fields received higher rates of fertilizer and more labor. The farmers tended to consider factors of production as packages. Higher fertilizer levels usually were followed by more crop care, particularly weeding.

The second assumption — homogeneity of inputs — was tested for land, labor, and capital. Land was not homogeneous. Yields and the per-hectare value of the land differed significantly. Labor was divided into three categories by research assistants familiar with the farmers, and coefficients of 1, .8, and .6 were assigned to each category. The coefficients were then multiplied by the number of hours of work. Regressions were run using labor as the independent variable and crop gross returns as the dependent variable. The *r*-value increased 40% when the revised hours were used, indicating labor was not homogeneous. Cash costs of crop production were 90% fertilizer costs. When actual nutrient input was regressed on gross income, the *r*-value increased 60%, over using cash as the independent variable. Farmers had different abilities in purchasing inputs so their cash inputs were not homogeneous.

TESTING THE PROPOSED PROCEDURE

Testing of the proposed procedure was done by using the same data set that Jayasuriya (1979) used for linear programming. The procedure was compared with linear programming because 1) linear programming is widely known and accepted, 2) it is a mathematical technique that will give an economic optimum, and 3) it is based on the same set of assumptions as program planning. The solutions were not expected to be the same. The test is, would the conclusions be the same?

A comparison of the solutions in Table 5 for the five farmers in Iloilo shows some differences, which are, however, not important. The proposed procedure would lead to the same conclusions as would linear programming. The new technology would benefit most of the farmers. New technology would be used on more than one-half of the cropped area. Direct or wet seeding would be used on more than one-half of most farmers' rice area. Both conclude that the new technology is likely to be adopted.

The comparison of the procedures in Pangasinan shows major differences (Table 6). No clear decision about the new technology can be made from the linear programming solutions. The proposed procedure is just as inconclusive. The overall conclusion is the same for both procedures — the new technology is not well adapted to the situation and more research is needed.

CONCLUSION AND RECOMMENDATIONS

The proposed procedures gave the same conclusions as linear programming, with far less work. After gaining some skill with the proposed procedures, I was able to

Table 5. Comparison of informal procedure (IP) and linear programming (LP) solutions for Iloilo, Philippines.

	Area (%) in new technology		Rice area (%) DS or WS[a]		Family income (₱) from crops[b]	
	IP	LP	IP	LP	IP	LP
Farmer 1	50	82	67	21	5,568	6,264
Farmer 2	100	100	100	52	16,989	20,230
Farmer 3	75	71	79	100	15,605	18,706
Farmer 4	67	25	100	50	18,770	18,327
Farmer 5	71	59	12	75	11,783	9,825

[a]DS = direct-seeded, WS = wet-seeded. [b]US$1 = ₱7.35.

Table 6. Comparison of informal procedure (IP) and linear programming (LP) solutions for Pangasinan, Philippines.

	Area (%) in new technology		Rice area (%) DS or *WS*[a]		Family income (₱) from crops[b]	
	IP	LP	IP	LP	IP	LP
Farmer 1	38	5	40	4	15,424	9,034
Farmer 2	63	66	100	18	9,573	4,690
Farmer 3	100	37	75	56	13,908	11,358
Farmer 5	9	32	10	0	15,307	12,509

[a]DS = direct-seeded, WS = wet-seeded. [b]US$1 = ₱7.35.

analyze one farm in one day. The analysis included partial budgets comparing current and new technology, graphs of resource use where required, and program planning. The procedures require no sophisticated mathematics or statistics. A hand calculator with add, subtract, multiply, and divide functions is all that is required. The results and basic principles of partial budgets and graphs can quickly and easily be understood by a noneconomist. The final solution of program planning can be explained but a simple table showing the enterprises and their inputs and outputs will probably be required. If this proposed procedure is used, the economist should have sufficient time for conducting studies on specific problems.

Aggregating farm survey data poses a number of problems and should be used with caution. The analysis of interactions using aggregated farm survey data may lead to conclusions which are the opposite of what the individual farmer faces. Production functions are of limited value for evaluating new technology in the testing phase of cropping systems research.

The researcher should consider these recommendations:

1. Collect data on a small number of selected farmers for case studies.
2. If needed, develop a schematic diagram of the resource stocks and flows, markets and enterprises to help understand the current situation on the farm.
3. Use partial budgets to find if the new technology is more profitable than that currently in use. If it is not more profitable, stop analysis and report it.
4. Use graphs to find the effect of the new technology on the resource requirements over time. If there are no resource limits, stop analysis and report it. If there is a resource limit, go to the next step.
5. Use only the critical parameters in a program-planning matrix. Try several solutions and discuss them with the farmers and other research team members and report the conclusion.

The overall recommendation is that little time should be spent on equilibrium analysis. The system may be in slight disequilibrium. but helping the farmer move a little further up a production function is of little use. Most of the economists' resources should be spent putting the farmer on a new production function. The procedures suggested in this paper should allow the economists to spend more time looking at potential in other areas, such as marketing, credit, and processing in addition to solving special production problems.

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DISCUSSION

Price: You have indicated that the computation of standard deviation is necessary to assess variability in economic performance. How is analysis for variability incorporated into simplified programming?

Banta: I mentioned that more than one-half of the sites are not calculating standard deviation inputs, not to show it is necessary but to show that it is not being done. Analysis of variability is not incorporated in simplified programming. The whole problem of variability is going to be a source of headaches for a long time.

Price: The case of Pangasinan was raised as an indicator that excess farm labor had not been taken account of by partial budgeting techniques. Actually in Pangasinan there is a highly important handicraft industry. Neglect of fields has been noted as a result of the relatively high paying household handicrafts. I think this absorbs the excess labor mentioned and indicates the need for incorporating this industry in the simplified programming.

Analysis of "cases" might present a problem in aggregation because presumably the reason for using "cases" is to reflect specific farm characteristics, with the result that the analysis findings will reflect the special conditions of those farms. Technology is not usually tailored to individual farm requirements but to broader economic and physical phenomena at a site.

Banta: The broad economic and physical phenomena will be found on the case study farms. My first argument is that we should not aggregate. Technology designed for the arithmetic mean farm will have less chance for acceptance than technology designed to fit on five modal farms. I am particularly concerned about the enterprise interactions hidden in aggregate data.

Price: Site-level analysis at IRRI is not computer based, but rather it features manual partial budgeting that has normally been available as soon as the analysis of agronomic results — within a month of the end of each crop season. Each site report has included the economic analysis and it would seem that the partial budgeting analyses have been timely.

At the time of cropping pattern design and re-design, there is often a need to look at the economics of pattern components such as the weeding labor used on experiments vs weeding labor on farmers' patterns or comparable insecticide costs on experimental and farmers' patterns. Would this be a separate analytical activity or would it be incorporated into simplified programming'?

Banta: Analysis of the component technology is part of the total procedure I have suggested. First, it would be evaluated in partial budgets and then graphed to find if there are resource limitations. If no conclusion could be reached. the two alternatives could be put in simplified programming, such as rice production with herbicide and rice production with hand weeding.

Morris: Earlier you were an advocate of large base line surveys, and large numbers of farmer-cooperators from whom farm records were obtained. In particular, I recall a 1972 seminar you gave on Cale, Batangas, when you were the IRRI economist on the cropping systems project. If you had to do Cale, Batangas, over, what approach would you use on the base line survey? How would you select farmers for your case studies? How many farmers do you think would be adequate? How long would you continue these case studies?

Banta: I did a large base line survey and initiated record keeping on 50 farms when cropping systems research started in Cale, Batangas. The objective was to have sufficient information so that an effective methodology could be developed. In this paper I am suggesting a procedure that can be used in the Asian Cropping Systems Network sites. There is a major difference between procedures used to develop a process and the procedures used in the process. Given IRRI's mandate I would use much the same approach on the base line survey but would compare the findings with other procedures such as key informants and group interviews. I have assumed that some form of base line survey has been done. The farmers would then be selected from the major group. The criteria for selection would be farm size, labor and power available, current cropping patterns, land type, and water regime. Five farms should be adequate for a specific set of technology. Three years should be adequate unless there is a major disruption of the factors affecting the farm.

Denning: Your methodology seems to have been developed to meet the requirements for the cropping pattern design and testing stages of cropping systems research and development. Would you comment on the applicability of your methodology to the monitoring of large-scale production programs where there is a need to regularly modify recommendations in the light of a changing socioeconomic environment.

Banta: Since the technical relationships will remain constant, price changes are all that would be considered. Using a small number of farmers over time should supply a stable data base to measure effects of the price changes. However, it is essential that time be spent with these farmers to learn their farm operation before the informal procedure is used. Initially it should be considered an experimental approach and compared to results of a more traditional approach.

Mathema: The study of selected farms is useful so that we can understand the farm in detail. Farms selected in this manner may not represent the majority of the farms in the area where there are dissimilarities in agoclimatic and socioeconomic conditions. It is also not possible to study many farms independently. Thus the recommended technology may not fit in the actual farmers' situations. How would you justify it?

Banta: This procedure assumes that a base line survey has identified the majority group and a few farmers are selected from it. Since the objective of the procedure is to evaluate the new technology, the criterion is "who is the target group?" If two sets of technology are being designed, you may need two sets of case study farms. If the technology will not tit on a set of model farms, I question its likely adoption.

Bantilan: What criteria do you suggest in selecting the model farmer for case study?

Banta: There should be a set of farms in each major land class if different cropping patterns are being designed for the land class. The farms should represent the majority of farms, i.e. modal. The criteria might be farm size, labor, power and current cropping patterns, and water regime.

Samson: Granting that the introduced crops in the cropping patterns being tested perform and yield well, we should also consider the demand for them, which is influenced by eating quality, government support price, and equipment for processing of products. These factors will determine the net returns, hence, acceptability to farmers who test the introduced cropping patterns. Examples of such crops are cowpea used green, soybean, and sorghum which easily germinates and is easily attacked by weevils when not processed or threshed immediately after harvest.

CROPPING SYSTEMS PREPRODUCTION AND PRODUCTION PROGRAM

Environmental and management factors in the design of multilocation testing of cropping patterns

M. Zahidul Hoque

The ultimate objective of site-specific cropping systems research is to develop stable, productive, and profitable alternative cropping patterns for the site. Those patterns should increase total production and income of farmers, and thus improve the overall farm family welfare. Because a tremendous amount of resources is used in developing appropriate technologies at a site, attempts must be made to apply the developed technologies over a large area and get a high total payoff from research. This necessitates multisite testing in as many similar agroclimatic areas as possible to determine the fit and agroeconomic performance of the cropping patterns.

The success of extrapolation of site-specific cropping systems technologies to similar geographic areas largely depends, however, on the accuracy and efficiency with which the designs for multisite testing are made and test sites are selected. The factors that determine the designs may be environmental, managerial, socioeconomic, or traditional. Scientific consideration must be given to these factors in the design to achieve a quick spread of improved cropping patterns over a wide geographic area.

OBJECTIVES OF MULTILOCATION TESTING

The cropping patterns developed through a site-specific research process may be tested at a number of sites with the following objectives:

- to provide data for a large-scale production program over a wider area, based on selected improved cropping patterns;
- to extrapolate research findings on cropping systems technology from one site to other sites, and thus enhance the transfer of modern technology;
- to increase the payoff of site-specific cropping systems research by extending the benefits to a larger number of farmers over a wider area with improved technologies;
- to identify factors significantly affecting the performance of specific cropping patterns at different sites;
- to further improve the cropping patterns being tested in terms of stability,

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productivity, and returns, through identification of possible better component technologies from different sites;
- to identify alternative geographic areas where a particular cropping pattern could be profitably adopted;
- to help develop and undertake cooperative, coordinated, unified national, regional or international agricultural development programs involving the use of improved plant materials and cropping systems technology; and
- to generate data on agrophysics through cropping patterns monitoring, and thus advance cropping systems science.

TYPE OF MULTILOCATION TESTING

Multilocation testing of cropping patterns should be done at the following levels:
- *Provincial or district level.* Provincial- or district-level testing can significantly help in quick integration of research and extension, and thus initiate a production program.
- *National level.* A countrywide testing program can help administrators and policy makers in deciding strategies, priorities, and approaches for national agricultural production.
- *Regional level.* Multilocation testing at the regional level can facilitate scientific collaboration aimed at exchanging improved agricultural technologies, and regional development involving intergovernmental participation.
- *International level.* Multilocation testing at the international level can bring about development of appropriate production technologies as well as gradual advancement of cropping systems science.

DESIGN CRITERIA

A practical design is the prerequisite for a multilocation testing program. Clear understanding must be developed as to the design criteria, keeping the objectives in view. In general, the following design criteria should be considered:
- *Agroclimatic conditions.* Sites selected for a multilocation testing program should be adequately described in terms of existing agroclimatic parameters and should have the most-critical factors in common.
- *Present land use.* The farmers' existing land use patterns at a site reveal not only the agroclimatic potential for that site but also its socioeconomic and traditional aspects. In fact, in areas where surveys and preresearch studies are difficult to make and data on agroclimatic factors are scanty, the existing land use pattern can provide a practical guide in selecting the potential cropping patterns for testing. This is strongly supported by the fact that many sites differ in terms of soil and climate but grow common cropping patterns.
- *Agronomic potential of the test cropping patterns.* Test patterns must exhibit a higher production potential than most of the existing cropping patterns.
- *Economic potential.* Because the adoption and subsequent stability of a particular cropping pattern at a site depend on its economic outturn, the economic potential of any proposed cropping pattern must be considered before a multi-

location test is designed.

- *Availability of component technology.* Sometimes, nonavailability of appropriate component technology might be a constraint to the introduction of a cropping pattern at a site. In other cases, adoption of new component technology associated with a cropping pattern might be difficult and slow. Therefore, it is important to consider the availability, or expected adoption, of new component technologies associated with a particular cropping pattern.
- *Tradition.* The tradition of the people of an area reflects the whole range of thinking at that area and, in many cases, does not allow compromises. Designing a test without considering tradition may lead to failure.

ENVIRONMENTAL FACTORS IN THE DESIGN

Cropping systems scientists in the Asian Cropping Systems Network recognize that agroclimatic classification is a prerequisite for the site-specific cropping systems research and development approach. Agroclimatic or agroecological zonation is needed to broadly group different areas within a region. Detailed description of agroclimatic parameters are needed to determine the potential of a cropping pattern or a crop within a cropping pattern in a particular area. Considering the environmental requirements for growth of different crops, inventories of existing environmental factors should be used as a checklist in assessing whether a cropping pattern or a crop within a pattern will have potential in a proposed geographic area. The following factors provide such a checklist for a given site:

1. Soil factors:
   - texture,
   - structure,
   - chemical properties,
   - moisture status over time,
   - microbes, and
   - elevation.
2. Climatic factors:
   - rainfall — amount and distribution,
   - temperature,
   - relative humidity,
   - evaporation,
   - day length,
   - solar radiation,
   - wind type, direction, velocity over time, and
   - calamities such as hailstorms, typhoons, tidal floods.
3. Hydrology:
   - flooding period, duration, and
   - flooding depth over time.

By comparing the average and extreme conditions of the environmental factors with the optimum and minimum crop requirements for those factors, the potential for a crop or a cropping pattern at a particular site can be estimated. Cross-site comparison involving these factors can help group the sites for the purpose of

multilocation testing. Thus, either monitoring of environmental factors before multilocation testing or availability of already collected data on those factors from reliable sources is a prerequisite for the design of the testing program.

MANAGEMENT FACTORS IN THE DESIGN

Water management can be considered under either the management practices for a cropping pattern or environmental factors. But wherever it is considered, it must be known whether a design is for irrigated, partially irrigated, rainfed wetland, or dryland conditions. Water management can also be included in multilocation testing as a part of component technology associated with a cropping pattern.

A number of other management factors, such as land preparation, cultivar, fertilizer application, weed control, insect and disease control, intercultural operations, are involved in the production of crops. It is difficult to give a decision as to what management practices should be followed in a multilocation cropping pattern test. But, from a practical standpoint, the following alternative levels of crop management are suggested. Any, or all, of these could be used:

- *Farmers' level of management.* The cropping pattern is introduced and grown with farmers' management. Obviously, variation in management among farmers will contribute to production variation as well. This is a practical approach because it provides an opportunity to evaluate the cropping patterns at farmers' resource base, which cannot be changed overnight. Proper monitoring of the individual farmer's input use and management can also help determine the performance of the test patterns at different levels of management on different farms, and thus reveal any production gaps among farms. The main drawback of testing cropping patterns at farmers' management level is that if the farmers use suboptimum management, the production potential of the cropping patterns will remain unknown.
- *Recommended level of management.* Researchers recommend a package of management practices for a cropping pattern. But experience has shown that it is almost impossible to give a recommendation encompassing all the factors that affect the performance of a cropping pattern in a farmer's field. In most cases, there has been success in formulating recommendations with regard to important production factors like variety, water management, fertilizer management, weed control, disease and insect pest management, and planting techniques. But the fact remains that critical component technology may vary with cropping patterns or crops. Moreover, if the component technologies are not properly balanced and tested in the context of an input package concept, the so-called recommended level of management may not be justified. Strong component technology research in the context of the systems approach can, undoubtedly, minimize this problem. The important thing to keep in mind is that the critical factors affecting the performance of each crop in a pattern must be properly taken care of. The recommended level of management may also vary among sites.
- *Intermediate level of management.* If both the farmers' level and recommended level of management are included in the test, an intermediate level between the

two is sometimes also tried. This level will be particularly useful in the economic evaluation of the test patterns.

- *Uniform level of recommended management.* A uniform package of management practices can be followed in all test sites. In fact, the level of management found most suitable for a particular cropping pattern at the research site can be used. Although this level may not be appropriate for all sites, it will provide information not only on the potential performance of the test cropping patterns but also on the contribution of the production practices associated with the patterns. Use of this level of management practices will be more logical if the multilocation test is designed strictly on the basis of similar agroclimatic conditions.

IMPLEMENTATION OF A MULTILOCATION TEST

A well-organized network of test sites is needed to run a multilocation testing program. One or more cropping systems research sites can be used as an operational base for all test sites. To achieve the desired level of success in multilocation testing in a country, or in a region, the following are necessary:

1. *A working group.* The working group includes researchers from the cropping systems research sites, the persons supervising the trials at different sites, and appropriate component technology scientists. The group will design the trials; supervise field implementation, data collection, and analysis; and write the technical report embodying the results of testing.
2. *Testing methodology.* Testing methodologies should be uniform throughout the test sites. Uniformity should be maintained at least in terms of experimental design, size of individual plots, number of replications per pattern, data sheets, and monitoring aspects. If use of standard procedures with regard to certain aspects of the testing methodology is difficult, acceptable ranges should be provided.
3. *Training.* Field staffs responsible for implementing multilocation testing of cropping patterns should be given sufficient training on all aspects of the test program. Training can be on-the-spot job or central and should be supplemented by an operational handbook.
4. *Coordination and supervision.* The whole range of activities under the multilocation testing program should be well-coordinated by a center, and the field problems associated with the testing process should be eliminated to generate reliable data.

DISCUSSION

Zandstra: What institutions are involved in multisite testing in Bangladesh and how do you ensure linkage between research results from the cropping systems sites and multilocation testing sites?

Hoque: The Bangladesh Rice Research institute (BRRI) is trying to utilize the research findings generated at the sites in different national production programs. In most of the crop

production programs in Bangladesh, BRRI usually gets opportunities to contribute in terms of designing, supervising, training staffs, and evaluating the programs. At the moment, BRRI has a multisite monitoring-cum-testing program in coordination with the Land and Water Use Directorate of the Bangladesh Water Development Board. Attempts are also being made to conduct similar multisite tests with the Directorate of Agriculture (Extension and Management), Bangladesh Agricultural Development Corporation, and other agencies working for agricultural development in the country. We utilize BRRI research findings in the design and implementation of the tests, thereby ensuring a linkage between cropping systems research sites and the multilocation testing sites. Moreover, the on-farm testing methodologies developed by BRRI at the research sites are being used, with modifications wherever necessary, in the multisite testing program.

Use of site-related research in multisite testing

Rizalino T. Dilag, Jr., and L. Dale Haws

Over the last 5 years, our efforts and yours have been primarily oriented toward developing relevant new technology for each of our countries. We hope to arrive at a point where that technology will be used by the farmer.

At some cropping systems sites, newly generated information needs to be verified in farmers' fields away from the research site. Other sites are just organizing. Relevant information gained at other network sites may help improve research objectives and methodologies.

DEVELOPMENT AND EVALUATION OF RESULTS

A schematic plan for development is seen in Figure 1. The plan allows one to evaluate research work systematically and, if necessary, to stop the work if it is not economical or stable. The four basic parts are:

- basic research;
- applied research (multisite testing);
- pilot production programs; and
- regional or national programs.

We discuss only the multisite testing phase of the plan.

MULTISITE TESTING

Multisite testing enables us to verify and validate outreach site results in farmers' fields before recommendation. Packaged technology, cultural practices, varieties, or cropping patterns that perform best in outreach sites may be submitted for multisite testing. They will be tested in farmers' fields at various sites covering a wide range of environmental conditions.

Development of project plans

A project plan is written for each trial. It gives the objectives of the experiment, the experimental design, plot layout in the field, instructions on the cultural practices in

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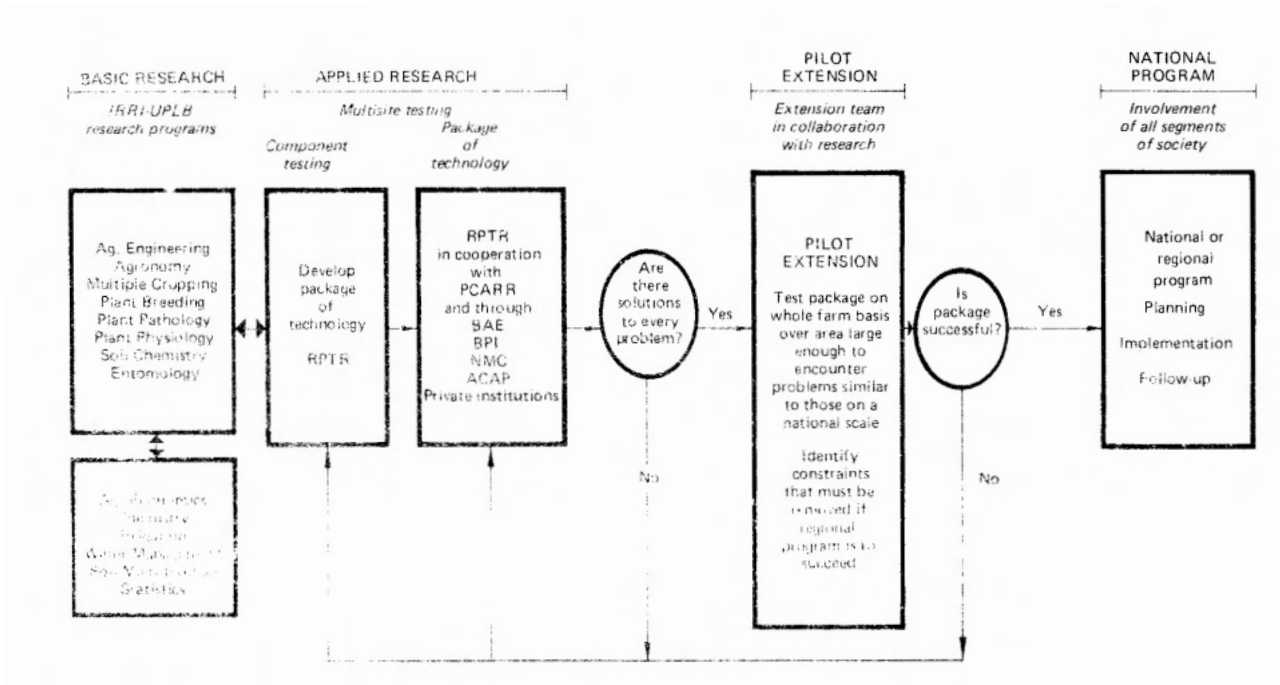


1. Path to agricultural development.

the establishment of the trials, and a list of inputs and the respective amounts needed for each trial. The plan specifies the data to be collected and how to collect them, and includes data sheets and a work schedule.

Our cropping systems trials on rainfed wetland rice areas in 1978 compared rice - rice and rice - ratoon rice. The first crop was a split-plot design replicated three times with seeding rates as main plot and the two varieties as subplots. The second crop was in randomized complete block (RCB) design replicated three times, with ratoon rice and transplanted rice or direct-seeded rice as treatments.

Varietal testing compared the performance of IRRI promising new selections with IRRI varieties as first crops direct-seeded in dry soil shortly before the start of the rainy season. The experiment was in RCB with three replications. Production plots were 1,000 m^2, established in strategic sites on farms easily seen and observed by farmers for demonstration purposes.

The production plots were established by a Bureau of Agricultural Extension (BAEx) technician, in cooperation with the farmer, on sites with an environment similar to that at the cropping-pattern-trial site. The package of technology—cropping patterns with respective cultural practices—that proved best in the applied research trials was used.

Random sampling was used to collect data on yield and other characteristics of the variety used.

All inputs were provided by IRRI-Philippine Council for Agriculture and Resources Research (PCARR). The farmer kept the harvest in exchange for the use of his land, labor, and equipment. The BAEx technician and the farmers were trained to make them proficient in the required cultural practices.

An example of data from these trials is in Table 1.

Packing of materials

All inputs including seeds, fertilizers, chemicals, and other materials needed for establishment of the trials were packed at IRRI. They were weighed, packed in plastic bags, and labeled. A project plan was also enclosed in a kit. The kits were either shipped to the stations, delivered overland, or brought by the technician after training at IRRI.

Training BAEx personnel

Because the work at the site is done by cooperating personnel from BAEx, it is necessary to train them in research and management techniques. All cooperating technicians are trained at IRRI for 7-10 days. During training the trainees establish all the experiments to be evaluated in the field.

Supervision of the plots by IRRI and BAEx personnel is the major work. All data are forwarded to IRRI for analysis and a decision on whether the technology is stable and ready to be tested on a whole-farm basis in a pilot production program.

FACTORS IN SITE SELECTION

Some constraints in site selection are environmental factors.

Rainfall

Rainfall is a main determinant of a cropping pattern in rainfed areas. Soils can be

Table 1. Effect of seeding rates on grain yield[a] of IR36 and IR28 in cropping systems trials as first crop, direct-seeded on dry soil in rainfed wetland areas at 11 sites in Visayas and Mindanao, Philippines, 1978 wet season.

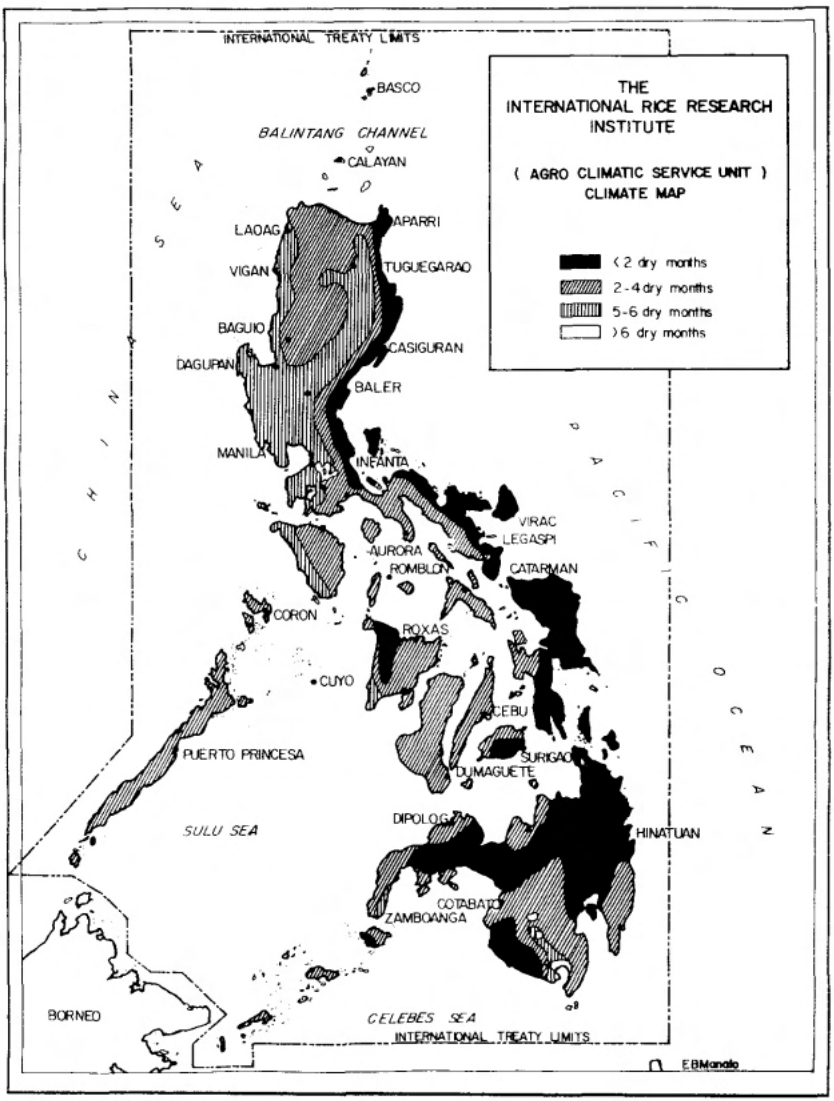
Site	Seeding rate (kg/ha)	Grain yield[b] (t/ha)		
		IR36	IR28	Difference
Parara Norte, Oton, Iloilo	88	4.1 a	3.1 a	1.0**
	110	3.7 a	3.4 a	0.3
Parara Norte, Oton, Iloilo	88	4.0 a	3.0 a	1.0**
	110	3.7 a	3.4 a	1.3
Tacdangan, Cabatuan, Iloilo	88	6.2 a	4.5 a	1.7**
	110	6.0 a	4.6 a	1.4**
Tacdangan, Cabatuan, Iloilo	88	5.3 a	4.1 a	1.2**
	110	5.5 a	3.9 a	1.6**
Caputian, Malalag, Davao del Sur	88	4.5 a	3.8 a	0.7*
	110	4.7 a	4.1 a	0.6*
Taculen, Matalam, North Cotabato	88	6.6 a	4.2 a	2.4**
	110	6.1 a	4.4 a	1.7**
Matalam, North Cotabato	88	8.8 a	4.5 a	4.3**
	110	9.4 b	4.8 a	4.6**
Santo Niño, Norala, South Cotabato	88	5.6 a	4.4 a	1.2**
	110	6.0 a	4.4 a	1.6**
San Isidro, Norala, South Cotabato	88	7.7 a	4.9 a	2.8**
	110	7.0 b	4.1 b	2.9**
Balimbingan, Ladangar, Zamboanga del Sur	88	5.6 a	3.4 a	2.2**
	110	5.6 a	3.2 a	2.4**
Luya, Tuburan, Zamboanga del Sur	88	5.4 a	3.9 a	1.5**
	110	5.1 a	4.1 a	1.0**
Average	88	5.8	4.0	
	110	57	4.0	

[a]Av of 3 replications. [b]Means at each site and for each variety followed by a common letter are not significantly different at the 5% level. *Significant at the 5% level, **significant at the 1% level.

manipulated in many cases to make them more productive. Without water, however, little development can take place.

The first step in developing multisite tests in rainfed areas is determining the time, quantity, and stability of the rainfall in that area. Figures 2 and 3 show the rainfall patterns in the various areas of the Philippines. Note that rain in Central Visayas and Mindanao lasts longer than in Central Luzon.

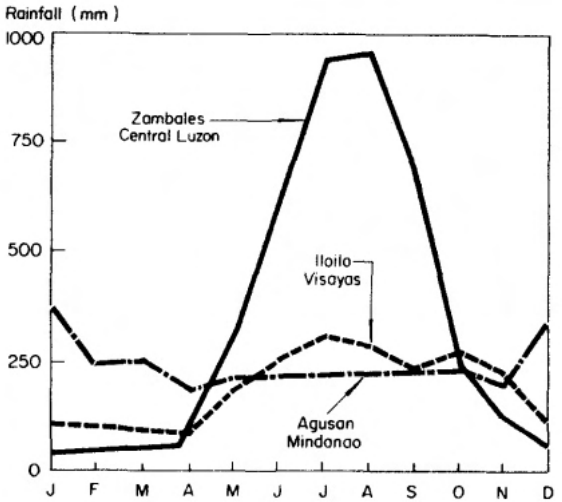
The stability of rain is an important consideration that is given high priority. Table 2 shows rainfall in 4 areas of the country and the probability that an area would receive 150 mm rain in the indicated 3-week period. Iloilo and Cotabato have a probability of receiving significant amounts of rain for a longer time than areas of Dagupan and Cabanatuan. This factor gives more stability to the two-crop rice system and makes possible a third (upland) crop. The intensity of rain is not as important as the probability of receiving sufficient quantities during the growing season. In fact, the high rainfall in July, August, and September in Central Luzon



2. Agroclimatic map of the Philippines based on the number of months during the year when average monthly rainfall is less than 100 mm.

may be more harmful than a lower but more stable rainfall.

Because the work is mainly in rainfed areas, rainfall in each area is the basis for cropping patterns. Rainfall maps are available but generally unreliable. We suggest the use of inexpensive (but good) rain gauges at each site. Their use will give a better insight into the moisture regime in the area than most rainfall data gathered years earlier from distant stations.



3. Typical rainfall patterns for 3 areas of the Philippines — Central Luzon, Visayas, and Mindanao.

Soils

The area to be serviced by the site research should be identified early. Soil maps of such areas are generally available but not always accurate. Soil analyses for P, K, organic matter content, pH, and texture are made as preliminary considerations. Soil series and orders are also important. Soil profiles can help and can be easily obtained. This work should be done in cooperation with the site agronomists.

Only preliminary soil observations are taken in the multisite phase of the program. A more-indepth analysis is made when a site is considered for a pilot area.

Table 2. Rainfall probabilities and actual rainfall[a] in four areas of the Philippines: Dagupan and Cabanatuan in Central Luzon, Iloilo in Visayas, and Cotabato in Mindanao.

Start of rain	Probability (%) of receiving 150 mm of rain during the 3-week period indicated							
	Dagupan		Cabanatuan		Iloilo		Cotabato	
1 Mar	0	(10)	0	(12)	0	(24)	14	(80)
22 Mar	1	(34)	0	(17)	0	(34)	8	(71)
12 Apr	7	(65)	2	(35)	1	(34)	21	(112)
3 May	28	(92)	26	(114)	18	(92)	45	(154)
24 May	66	(227)	45	(157)	36	(140)	42	(148)
14 Jun	68	(228)	41	(153)	69	(214)	59	(178)
5 Jul	82	(375)	72	(236)	74	(254)	45	(157)
26 Jul	84	(411)	81	(263)	69	(249)	39	(149)
16 Aug	82	(343)	71	(246)	71	(245)	48	(174)
6 Sep	75	(257)	69	(206)	56	(191)	44	(154)
27 Sep	52	(181)	41	(157)	61	(206)	59	(225)
18 Oct	12	(68)	7	(64)	38	(145)	54	(216)
8 Nov	11	(63)	15	(57)	34	(145)	29	(125)
29 Nov	0	(22)	2	(37)	23	(106)	24	(110)
20 Dec	0	(9)	0	(16)	7	(62)	19	(92)
10 Jan	0	(4)	0	(5)	1	(31)	12	(74)
31 Jan	0	(7)	0	(5)	0	(27)	6	(66)

[a] In millimeters in the parentheses.

The following illustrates description of soils for a proposed site:

- *Site:* Santa Barbara
- *Rainfed area:* 98,647 ha
- Description of land: The soil series is Santa Rita clay, the most important soil of the province. The series developed from recent alluvial deposits of fine soil materials from the surrounding upland areas. Drainage is generally poor because of topography and the heaviness and compactness of the surface soil and subsoil.
- *Depth:*

  0-20 cm — surface soil, black to dark brown with moderate coarse granular structure; highly plastic and soft when wet, shrinks and cracks and becomes very hard when dry. With the proper amount of moisture, it is slightly crumbly. No stones, gravel, pellets, or cobblestones. The surface soil ranges in depth from 20 to 25 cm. This layer is separated by a diffused and smooth boundary from the subsoil.

  20-70 cm — subsoil, also clayey, hard when dry and soft when wet. Black to dark brown in color. No stones or gravel. Poor in organic matter. Next layer has clear, smooth boundary.

Results of soil analysis:

No. of barrios:	2
No. of samples:	86
Soil type:	Santa Rita series
OM (%):	1.69
P (ppm):	6.42
K (ppm):	288.33
pH:	5.46

Landforms and functions

Definitions for various landforms have been developed over the years but have not been as important a factor in past work as they will be in the future. Initially, identification of field locations, i.e. high and low bund and heavy and light soils was all that was used. One can save a great deal of time if, from the start, location of plots in relation to landforms is scientifically described.

Varieties

Results from testing of rice crops grown in multisite trials will give the site research staff some indication of the suitability of the present technology and varieties within the project area. All things considered, the right variety in the right place may be the most important technology introduced in a new cropping pattern.

Varietal research should be a major activity and varietal testing should be 30-40% of the time in multisite work. This is more time than we have spent in the past.

FIRST YEAR OF APPLIED RESEARCH

We are not starting from zero when it comes to research results concerning cropping systems. A rational way to start multisite work is to meet with the site staff and

determine the best technology available at that time. The established technology can then be evaluated in the first year. By the time the site is organized and operating, results from the first year's work will have been completed and should aid substantially in determining what research is appropriate at the site. Information transfer from site work to multisite personnel and vice versa should be a goal.

If base line surveys are conducted by research site personnel, assignment of project areas may be necessary.

Staffs

An applied research staff should have considerable experience in research as well as in practical agriculture. It is also vital that the person given the responsibility of multisite testing have the full confidence of the site coordinator. The site coordinator is responsible for organizing and operating the site and thus the activities of the multisite testing program.

The number of people necessary to carry out the work will depend on the area and intensity of the work. A large staff is not necessary if the work is organized to include the national extension organization. We have developed a procedure whereby work is done in cooperation with BAEx.

The initial effort with multisite plots throughout the Philippines was in cooperation with local agricultural colleges, which seemed to be better equipped than any other organization to do the necessary research work. However, we could not continue working with these schools for three main reasons:

- First, they were unable to work in farmers' fields because of such constraints as money and transportation.
- Second, teaching loads and other school activities left them with little time for overseeing the trials.
- And finally, after the results of multisite tests were collected and analyzed, there was difficulty in moving the newly developed technology into extension work.

The work completed with extension, however, is immediately available to farmers through BAEx. During the process of organizing and conducting the multisite tests, technicians are trained in managing applied research trials. These technicians can make rational statements as to the effect of the new research in the areas where the work is done and suggest additional research. This information is passed on to the research personnel at the site.

About 25-50 BAEx technicians are assigned to work with us in different regions of the country. To compensate for their efforts, they are provided transportation expenses and about $7.00/trial per month. Thus, a BAEx technician may receive as much as $25.00/month besides his regular salary.

Training

IRRI has found it necessary to train their staff on such things as establishment and management of plots. BAEx people are also trained on methodology for 2 weeks at IRRI. The 6-month course in rice production or cropping systems covers applied research thoroughly. The trainees will later conduct training for all cooperators at the various sites.

DISCUSSION

Dadi Ganda: Considering the delivery of technology to the farmer, especially for secondary crops, acceptance is usually based not only on the technological aspects, but mostly on the socioeconomic aspects (marketing). According to Figure 1 all the problems faced in the extension field should be solved by the researcher. Do you have any practical experiences to solve the marketing problem?

Pantastico: You are right. Fortunately there are several research activities covering marketing aspects in the Philippines.

Multisite testing of cropping patterns in Bangladesh

A. B. M. Fazlul Hoque and M. Zahidul Hoque

Site-specific cropping systems research was initiated in Bangladesh by the Bangladesh Rice Research Institute (BRRI) in 1974. Since then improved rice-based cropping patterns have been developed for rainfed and irrigated areas.

In 1978, BRRI encouraged the Directorate of Land and Water Use, Bangladesh Water Development Board (BWDB), to initiate cropping systems research at one of their irrigation projects in the Dacca-Narayanganj-Demra (DND) area. The findings generated at the BRRI sites at Joydebpur and at the DND site gave a clear indication of what could be the best cropping patterns for rainfed, partially irrigated, and irrigated rice areas in terms of total production.

Initially, a design was made to test a few rice varietal combinations in an aus -transplanted aman (t. aman) pattern, one of the important cropping patterns of the country.

OBJECTIVES OF MULTISITE TESTING

The objectives of the 1979 multisite cropping pattern testing were:

- to determine the relative performance of four types of aus - t. aman cropping patterns at different sites in Bangladesh,
- to identify the most productive aus - t. aman cropping patterns for each of the test sites in 1979,
- to identify the most advantageous aus - t. aman cropping patterns that could be used by BWDB in large-scale production programs, and
- to determine the future course of research activities in terms of developing improved aus - t. aman cropping patterns.

METHODOLOGY

Cropping pattern testing at BRRI research sites has indicated that double- or triple-cropping with modern rice varieties can be productive and profitable. Triple rice cropping patterns, however, require supplemental irrigation.

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Although in most cases, triple rice cropping patterns give higher production than single- and double-cropping patterns, BRRI does not recommend triple-cropping because of gradual development of soil problems due to continuous wet cultivation. However, a triple-cropping pattern of aus rice - t. aman rice - dryland winter crop is highly recommended for irrigated areas. Among the double-cropping patterns, two modern variety (MV) rice crops are recommended for areas with supplemental irrigation and a pattern of at least one modern rice plus one local rice is recommended for the rainfed areas.

Selection of rice varieties depends on the duration of the rainy season, farmers' planting method, and the turnaround time between crops. Four types of rice cropping patterns were proposed for multisite testing in 1979:

1. Long-duration MV aus (BR3, IR8) - MV t. aman (BR4, IR20, Pajam);
2. Short-duration MV aus (Chandina, BR6, Purbachi) - MV t. aman;
3. Long-duration MV aus - local t. aman; and
4. Short-duration MV aus - local t. aman.

In the rainfed aus - t. aman patterns, a MV is recommended more for the aus season rather than for the t. aman season, particularly where the aus crop is transplanted. Thus, the MV aus crop is grown in the monsoon rainy months followed by local t. aman crops, which are usually photoperiod sensitive and have considerable cold tolerance at the reproductive stage.

The test sites were selected on the basis of these criteria:

- they are in major rice-growing areas;
- farmers in the area grow an aus - t. aman pattern;
- the rainfall pattern enables production of two rice crops, or else the sites have facilities for supplemental irrigation;
- there exists a potential for increasing the production of aus - t. aman patterns;
- there exists a scope for undertaking a future production program with improved and productive cropping patterns; and
- the test sites are accessible to the multisite testing group.

Eight sites were selected:

1. *Salna village* in Dacca district is an irrigated area with clay soil where BRRI has a cropping systems research site. Double rice cropping is the most important pattern, followed by triple and single rice cropping patterns.
2. *Bhogra village* in Dacca district is a rainfed area with clay soil. Double rice cropping is the most dominant pattern. BRRI has a research site near the area.
3. *Dacca-Narayanganj-Demra* (DND), a project area of BWDB in Dacca district, is protected from floods and has canal irrigation facilities. The soil is heavy clay and double rice cropping is the most dominant pattern. BWDB has a cropping systems research site in the area.
4. *Jhenaida* in Jessore district falls within the Ganges-Kobadak (G-K) irrigation project of BWDB; however, irrigation is not fully assured because the site is at the tail end of the irrigation canal. The soil is light in texture, and double rice cropping and aus - t. aman - winter crops are the most common patterns.
5. *Swastipur* in Kustia district is also within the G-K Project of BWDB, and irrigation is not well assured. The soil is relatively light and double rice cropping is the most dominant pattern.

6. *Amla* in Kustia district has assured irrigation from the main canal. The soil is loamy clay and the important cropping pattern is double rice although lands are gradually being put under a third winter season crop of pulses or oilseeds.
7. *Durgapur* in Dinajpur district is in the Thakurgaon deep tube well irrigation project of BWDB. The area has a clay loam soil and mostly grows a pattern of two rice crops or a rice crop followed by wheat. The area has a great potential for rice - rice - wheat or other winter crops pattern.
8. *Birganj* in Dinalpur district is also under the BWDB deep tube well irrigation project and has assured irrigation. The soil is light and the common pattern is two crops of rice per year.

The selected cropping patterns were grown with farmers' management. Each test pattern could not, however, be grown at all sites. Both the aus and t. aman crops were grown as a transplanted crop at all sites. Farmers' management levels were monitored at BRRI test sites and determined through farmers' interviews at the BWDB test sites. The management level varied among farms, cropping patterns, and sites. Only fertilizer rates followed by the farmers for different cropping patterns are presented here (Table 1).

The Scientific Officers of the Rice Cropping Systems Division of BRRI and the BWDB extension officers implemented the field trials with assistance from the BRRI casual work assistants and BWDB field overseers. Yields were determined by crop-cuts using methodologies developed at BRRI. In a few farmers' fields at the BWDB sites, farmers' yield figures were used. Data were analyzed by BRRI.

MULTISITE TEST RESULTS

The results of the 1979 multisite testing of cropping patterns are presented in Tables 2-6.

The total grain production per hectare from the four patterns are presented in Table 2. The highest production came from the long-duration MV aus - MV t. aman pattern at Salna and the lowest was from the long-duration MV aus - local t. aman and short-duration MV aus - local t. aman patterns grown at Jhenaida. Thus, there is a production gap of 6.3 t/ha in the aus - t. aman pattern due to varietal combination and test sites. The data reflect the effect of assured irrigation on production. At Salna farmers had assured supplemental irrigation, but at Jhenaida the farmers grew the crops in rainfed fields. Moreover, Bangladesh had a prolonged severe drought in 1979.

The production gap (Table 2) among sites due to cropping pattern ranged from 0.15 to 3.53 t/ha. The data indicate that at sites with high production gaps, the scope for increased production through adoption of better cropping patterns is higher than at sites with small production gaps. Changes in other factors, such as irrigation and better crop management, will be necessary for increasing production at those sites.

The data in Table 2 also show the production gap in a particular cropping pattern due to site, which reflects a whole range of factors. The gaps indicate that a particular cropping pattern could be constrained by environment and management factors.

Table 3 presents the yield per crop and cropping pattern of longduration MV aus - MV t. aman at five sites, along with the total fertilizer used at each site. At Salna

Table 1. Fertilizer rates[a] used on each crop in different cropping patterns by farmers at the test sites, Bangladesh, 1979.

Cropping pattern	Fertilizer (kg N-P_2O_5-K_2O/ha) used by farmers							
	Salna	Bhogra	DND	Jhenaida	Swastipur	Amla	Durgapur	Birganj
Long-duration								
MV aus –	44-36-0	–	32-49-25	47-35-16	51-51-34	66-54-36	–	–
MV t. aman	54-45-0	–	56-48-23	60-49-20	51-51-34	75-75-51	–	–
Short-duration								
MV aus –	58-32-3	–	47-54-0	44-38-13	42-42-28	48-39-25	–	–
MV t. aman	59-57-0	–	67-54-23	61-39-17	28-28-9	66-66-43	–	–
Long-duration								
MV aus –	–	42-27-25	–	54-48-15	–	–	–	–
local t. aman	–	57-43-32	–	40-27-18	–	–	–	–
Short-duration								
MV aus –	93-103-0	38-36-20	–	47-34-17	15-15-10	–	–	–
local t. aman	73-52-0	52-39-27	–	62-39-3	8-8-6	–	–	–

[a]A dash (–) indicates not reported.

Table 2. Grain production from 4 cropping patterns and production gap at 8 test sites in Bangladesh.

Test site	Grain production[a] (t/pattern per ha)				Production gap (t/ha)
	L.D. MV aus – t. aman	S.D. MV aus – t aman	L.D. MV aus – local t. aman	S.D. MV aus – local t. aman	
Salna	8.28	7.04	–	4.75	3.53
Bhogra	–	–	6.5	5.60	0.90
DND	7.43	7.28	–	–	0.15
Jhenaida	2.38	2.11	1.94	1.94	0.55
Swastipur	8.27	7.78	–	5.52	2.75
Amla	6.32	5.35	–	–	0.97
Durgapur	–	6.65	7.04	6.36	0.68
Birganj	–	6.05	–	5.50	0.55

[a] L.D. = long duration (BR3/IR8). S.D. = short duration (Chandina/BR6/Purbachi).

Table 3. Yield per crop and pattern, and fertilizer rate per pattern of long-duration MV aus – MV t. aman at different sites, Bangladesh, 1979.

Test site	Replications (no.)	Av yield (t/ha)			Total N-P_2O_5-K_2O (kg/pattern per ha)
		Aus	T. aman	Total	
Salna	1	4.98	3.30	8.28	98-81-0
Bhogra	–	–	–	–	–
DND	4	3.22	4.21	7.43	88-97-50
Jhenaida	4	1.44	0.94	2.38	107-84-36
Swastipur	2	4.14	4.13	8.27	102-102-68
Amla	2	2.77	3.55	6.32	142-130-87
Durgapur	–	–	–	–	–
Birganj	–	–	–	–	–

Table 4. Yield per crop and pattern, and fertilizer rate per pattern of the short-duration MV aus – MV t. aman cropping pattern at different sites, Bangladesh, 1979.

Test site	Replications (no.)	Av yield (t/ha)			Total N-P_2O_5-K_2O (kg/pattern per ha)
		Aus	T. aman	Total	
Salna	5	3.56	3.48	7.04	117-89-3
Bhogra	–	–	–	–	–
DND	1	3.08	4.20	7.28	115-108-23
Jhenaida	11	1.05	1.06	2.11	104-78-30
Swastipur	7	3.69	4.09	7.78	70-70-37
Amla	24	2.00	3.35	5.35	114-105-69
Durgapur	5	3.73	2.92	6.65	*a*
Birganj	6	2.94	3.11	6.05	*a*

[a] Not reported.

and Jhenaida, aus yields were better than those of t. aman; at DND and Amla the opposite was true. The fertilizer rates used by the farmers were modest. It appears that the fertilizer applied by the farmers at Jhenaida was less efficient than that at other sites, probably because of drought.

Table 5. Yield per crop and pattern, and fertilizer rate per pattern in the long-duration MV aus - local t. aman cropping pattern at different sites, Bangladesh, 1979.

Test site	Replications (no.)	Av yield (t/ha)			Total N-P_2O_5-K_2O (kg/Pattern per ha)
		Aus	T. man	Total	
Salna	–	–	–	–	–
Bhogra	14	4.4	2.1	6.5	99-70-57
DND	–	–	–	–	–
Jhenaida	2	1.39	0.55	1.94	93-75-33
Swastipur	–	–	–	–	–
Amla	–	–	–	–	–
Durgapur	3	3.90	3.14	7.04	*a*
Birganj	–	–	–	–	–

[a]Not reported.

Table 6. Yield per crop and pattern, and fertilizer rate per pattern of the short-duration MV aus - local t. aman at different sites, Bangladesh, 1979.

Test site	Replications (no.)	Av yield (t/ha)			Total N-P_2O_5-K_2O (kg/pattern per ha)
		Aus	T. aman	Total	
Salna	1	2.81	1.94	4.75	166-166-0
Bhoga	27	3.40	2.20	5.60	90-75-47
DND	–	–	–	–	–
Jhenaida	3	1.24	0.70	1.94	109-73-20
Swastipur	3	3.19	2.33	5.52	23-23-16
Amla	–	–	–	–	–
Durgapur	7	3.63	2.73	6.36	*a*
Birganj	12	3.09	2.41	5.50	*a*

[a]Not reported.

The results on the testing of the short-duration MV aus - MV t. aman pattern at seven sites are presented in Table 4. The aus yield range was less than that for t. aman. Fertilizer rates were modest at all sites.

Table 5 presents the results of the long-duration MV aus - local t. aman pattern tested in 19 fields at 3 sites. The yield gap was higher in aus than in t. aman because of test sites. The rates of fertilizer application were modest.

The results of the short-duration MV aus - local t. aman pattern tested at six sites are presented in Table 6. The total production from this pattern was lower than for the three other test patterns at any site.

The multisite testing indicated that, with no severe moisture stress during crop growth and with adequate crop management practices, cropping patterns of either long-duration or short-duration MV aus followed by MV t. aman can be used for large-scale production programs in aus - t. aman areas for satisfactory levels of grain production.

Development and implementation of pilot production programs

L. D. Haws and R. T. Dilag, Jr.

In the 1976 Cropping Systems Symposium at IRRI, we related some of our experiences in using applied research trials and multisite testing to determine the feasibility of starting a production program. As pointed out in an earlier paper at this conference, the results obtained from multisite tests determine if and where a pilot production program should be developed. If such results meet a predetermined goal, a decision is made, in cooperation with extension officials, to expand the multisite area of a few thousand square meters to 100-500 ha.

The pilot program, then, is an organized effort to immediately use the proven technology from applied research trials and multisite tests on a whole-farm basis to identify constraints and problems that should be overcome before expansion on a regional or national scale.

At the end of the multisite testing period, the steps necessary to start a pilot production program are:

1. analysis and evaluation of research data from applied research and multisite tests;
2. presentation of research data and proposal of the pilot production program to the proper government officials;
3. organization of personnel to be involved in the pilot area;
4. training of farm management technologists, information officers, and farmers;
5. implementation of the pilot production program:
6. monitoring and follow-up; and
7. expansion, if indicated.

The steps are discussed on the basis of our Philippine experiences.

ANALYSIS AND EVALUATION OF DATA FROM MULTISITE TESTS

Data from 2-3 years of multisite testing were evaluated to determine areas in which the predetermined production goal was achieved. The plots were established on sites to represent all the rainfall zones of the country. Yield data in Table 1 indicate yield differences in the three major island groups in the Philippines. Rainfall in the

Crop production specialist and senior research assistant, Office of Rice Production Training and Research, IRRI.

Table 1. Grain yield of 3 IRRI varieties or selections used in multisite tests of a 2-rice-crop pattern in rainfed areas of the Philippines

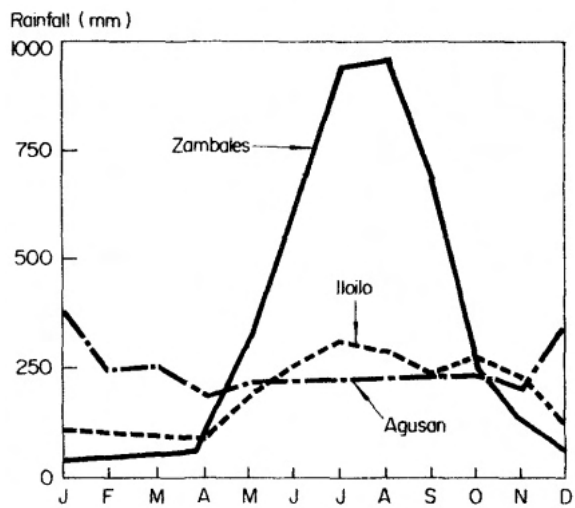
Region	Grain yield (t/ha)		
	1975 (2 crops)		1977
	IR1561-228	IR30	IR36
Luzon	7.4	5.9	6.0
Visayas	7.5	7.4	9.2
Mindanao	9.1	8.8	9.5

southern area (Mindanao) appears more stable and productive than that in the northern area (Luzon) (Fig. 1).

PROPOSAL FOR THE PILOT PRODUCTION PROGRAM

A report of the results of multisite tests and a proposal for a pilot production program were prepared and presented to the regional director of the Bureau of Agricultural Extension (BAEx) for evaluation and approval. An economic analysis was also presented. After the regional director had approved the proposal, a meeting was held with the provincial governor. All other agencies whose support were needed to help the farmer in the proper adaption of the new technology in the pilot production program area were invited. They included the municipal mayor of the target area, the regional directors of the various agricultural agencies, the local pesticide and fertilizer dealers, and bank officials.

After those at the meeting agreed with the proposal, a Memorandum of Agreement (Appendix A) stating what contributions each will make to the overall plan was signed by all parties concerned. This agreement is vital because it binds all parties to the program. It is a living document for *their* program.

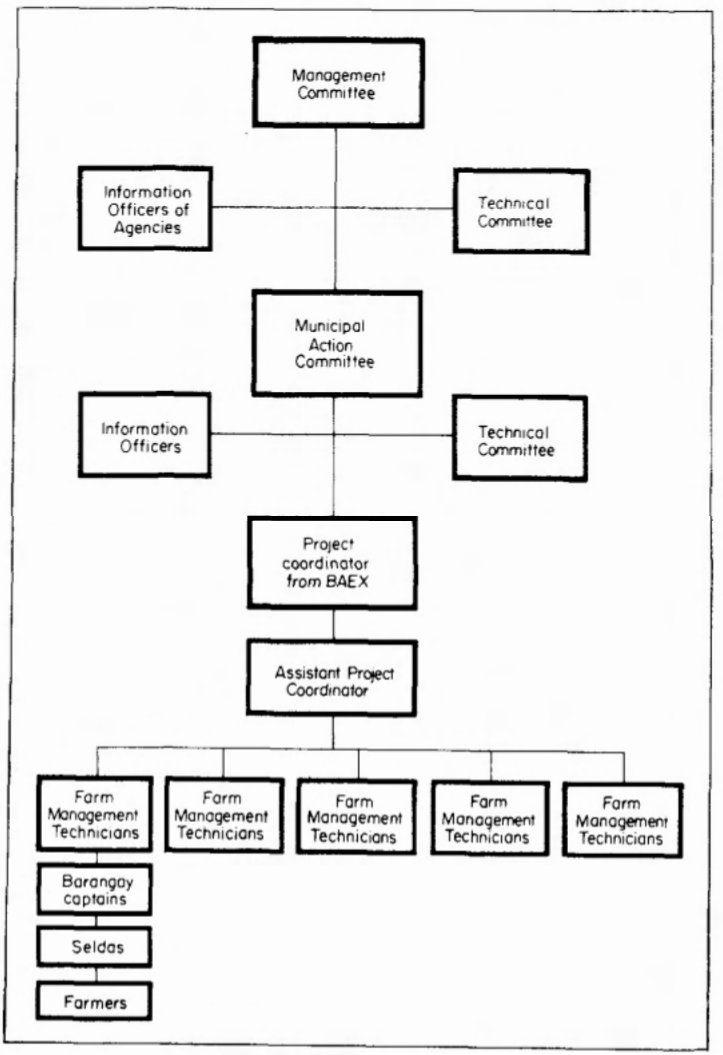


1. Typical rainfall patterns for 3 areas of the Philippines.

A name was given to the proposed program. It gave identity to all members in the pilot area and made the activities of the committee legitimate in the eyes of the farmers. MASAGANA 99 was a magic word for rice production in the Philippines. The names KABSAKA and KASA-TINLU are household words in Iloilo and South Cotabato.

ORGANIZATION OF THE PILOT AREA

The organization in Figure 2 was adopted to serve as a coordinating and implementing body in KABSAKA. Committees at the provincial, municipal, and village levels were formed.



2. Organization chart of KABSAKA.

TRAINING

The success of a program depends greatly on the supervisors' and technicians' dedication, hard work, and skills in demonstrating and supervising the new technology to the farmers. Farm management technicians from the project area were trained at IRRI for 1 week (Appendix B). The training included actual cultural practices and diagnosis of field problems in growing rice. The technicians improved considerably during the training.

For the KABSAKA program, 21 technicians were trained. Each was expected to oversee about 30 ha of land in the project area. Information officers and farmers were also trained.

Knowledge gained at IRRI by information officers made them more precise in communicating and discussing the detailed cultural practices in the media.

Training of farmers became the responsibility of the IRRI-trained technicians. The latter had motorcycles for mobility and lived in the villages where they were assigned. That enabled them to solve problems as they occurred.

IMPLEMENTATION

A detailed program of field activities, which included the following, was developed:

- a sample work plan for a municipality, selection of pilot villages, organizing village seminars, organizing field demonstrations and field days, etc.;
- cultural recommendations for growing rice, based on the national rainfed rice program with modifications, as necessary, for the project area;
- a sample farm plan and budget for 1-ha rice farms; and
- an outline of responsibilities for agencies and personnel at all levels.

All available communications channels were used to create farmer awareness of the new technology and to develop interest in its adoption. Techniques included posters, banners, leaflets, and radio programs.

Each technician was assigned 1-2 villages in the municipality covered by the program.

Seminars and field demonstrations were held in all villages within the program area. Fields were continuously visited by a BAEx technician to guide farmers in the proper application of inputs, maintain their interest, and show them the effects of poor and good management. Field days were held for farmers, rural bank officials, technicians, administrators, and local officials.

Village seminars were organized to train farmers in the skills of applying the new technology. Trained farmers who wished to join the project were listed and the area of their farm included in the program was noted. Their present status with the banks was examined. Banks made production loans available to allow selected farmers to participate in the program. Loans, which averaged ₱1,250 (US$170)/ha, were granted and released in kind (actual inputs), except the amount allocated for land preparation and seeding, which was in cash. Because any deviations from the recommended package of practices was considered a risk, banks were encouraged to provide the full loans.

MONITORING AND FOLLOW-UP

Monitoring and follow-up performed mainly by the technical committee tried to remove problems that prevent smooth operation of the project. Committee members were in constant touch with the project supervisors and farmers to assist them in their problems.

Problems such as timely release of loans, availability of inputs, transportation and marketing of products arose. They were either reported to the municipal action or management committee or brought directly to the attention of the agency concerned for prompt action.

EVALUATION

As mentioned earlier, the main objective of the pilot production program was to identify problems and constraints when a technology was tested on a whole-farm basis. These problems had to be solved prior to expansion to a regional or national program.

Changes in the cultural practices that would be necessary because of socioeconomic or environmental factors were also identified.

EXPANSION

The KABSAKA project has expanded greatly since it started (Table 2). At the end of 1979, there were 470 additional hectares in 4 added municipalities in Iloilo province and 116 ha in 3 municipalities in Negros Occidental province.

When a program is successful, everyone wants to become a member. If it fails, it tends to become an orphan. To change habits that farmers have developed through the years, one must change the attitude of farmers and technicians toward the new technology. The need is for superior technology, support of local government officials, an organization that lets people understand the new technology through training programs, and, finally, markets that are ready to purchase increased harvest.

Table 2. Number of farmers, area, and yield in the KABSAKA Project, Iloilo, Philippines, 1974-78.

Program phase and year	Farmers (no.)	Area planted (ha)	Yield (t/ha)		Total production (t/ha)
			1st crop	2d crop	
Applied Research Phase					
1914	2	0.27	3.0	4.0	7.0
1915	9	25	4.8	5.0	9.8
1916	54	89	5.2	4.0	9.2
Pilot Pogram Phase					
1911	126	140	4.9	1.3	6.2
1978	276	411	4.4	4.6	9.0

Appendix A

MEMORANDUM OF AGREEMENT

KNOW ALL MEN BY THESE PRESENTS:

This Memorandum of Agreement entered into, by, and among the different government agencies and instrumentalities, as represented by their respective regional Directors/ Provincial Heads/ Managers with full authority to do so:

1. IRRI-PCARR — The International Rice Research Institute-Philippine Council for Agriculture and Resources Research (Rainfed Rice Projects)
2. UPLB-NFAC National Multiple Cropping Program
3. National Food and Agriculture Council
4. Bureau of Agricultural Extension
5. Bureau of Plant Industry
6. Department of Agrarian Reform
7. Bureau of Soils
8. National Grains Authority
9. Philippine National Bank
10. Rural Bank of Sta. Barbara
11. Agricultural Credit Administration
12. Area Marketing Cooperative at Iloilo

WITNESSETH: THAT

WHEREAS, a pilot extension project on cropping systems on Rainfed Rice with designation "KABUSUGAN SA KAUMAHAN" — "KABSAKA-SALUD-ULAN" will be established at Sta. Barbara, Iloilo, covering 500 hectares, more or less;

WHEREAS, the said project will necessarily need the support and assistance of all the above-listed agencies in the performance of activities appropriate to their respective functions;

NOW, THEREFORE, for and in consideration of the foregoing premises, the above-listed agencies, through their respective representatives, hereby agree to assume and undertake in the said project their respective functions and responsibilities, to wit:

1. IRRI-PCARR (Rainfed Rice Projects) shall
   a. Provide technology on direct seeding
   b. Help oversee implementation of technology
   c. Help train the management and technical group
   d. Provide four (4) motorcycles (IRRI).
2. UPLB-NFAC (National Multiple Cropping Program) shall
   a. Help oversee implementation of technology
   b. Help train the management and technical group.
3. NFAC shall
   a. Provide funds for training and operational expenses
   b. Act as liaison between the agencies herein above-listed and their Manila central offices
   c. Monitor progress of the project.

4. BAEx shall
   a. Undertake information drive in the project
   b. Assign technical personnel to the project
   c. Supervise the farmers involved in the project regarding technology
   d. Prepare progress and other reports
   e. Provide technical supervision of personnel involved in the project.
5. BPI shall
   a. Provide technology or production technology personnel
   b. Make available to the project recommended certified seeds.
   c. Undertake plant pest control as needed
6. DAR shall
   a. Assist in the organization of Samahang Nayon and Compact Farms
   b. Undertake information drive on land consolidation
   c. Train the farmers in the project on their responsibilities as far as Agrarian Reform is concerned.
7. NGA shall
   a. Undertake the procurement of rice, corn, sorghum, soybeans and yellow corn
   b. Provide up-todate market information.
8. The RB of Sta. Barbara, PNB and ACA shall
   a. Provide production credit to the project which shall include agricultural inputs and chemicals under the supervised credit system.
   b. Undertake collection of loans extended with the assistance of representatives of all the agencies involved.
9. AMC shall
   a. Wage information drive on the organization of agricultural cooperatives
   b. Extend production inputs to farmers in the project
   c. Provide free service/delivery of farm inputs to the project area
   d. Arrange custom plowing for the project farmers
   e. Assist in the gathering of harvest of the project for storage and drying purposes
   f. Assist in the collection of loans extended by RB, PNB, and ACA
   g. Provide containers for the produce of the project.
10. Bureau of Soils shall
   a. Provide soil analysis to the farmers in the project free of charge
   b. Supervise collection of soil samples in the project area
   c. Provide fertilizer and liming recommendations
   d. Update soil fertility recommendations for project area
   e. Provide information and technical assistance related to soils in the project.

This MEMORANDUM OF AGREEMENT shall take effect immediately upon approval by the parties hereto and shall remain in force for the duration that the project is in existence and until the project can undertake or handle by itself what the agencies-parties hereto are bound to undertake for the project unless sooner terminated by the parties hereto to take effect thirty days after due notice.

IN WITNESS WHEREOF, the parties hereto have hereunto signed this Agreement this 23rd day of November, 1976 at Iloilo City.

Appendix B. One-week cropping systems course Iloilo Pilot Extension Project, 29 November-3 December 1976.

Monday

0730	Registration
0830	Welcome Objectives of the training • The Iloilo pilot extension project • Background – Research results – Impact to development
0900	Program orientation • Introduction of staff • Administrative matter • Training methodology
0915	Written test
1030	Practical test
1200	Lunch break
1330	Land preparation and stand establishment on cropping systems for rice • 1st crop • 2d crop
1500	Break
1530	• Continue discussion on land preparation • Slide show

Tuesday

0800	Field work on dryland preparation. • Soaking of seeds in Furadan 3G and airdrying • Plowing and harrowing with carabao • Rototillage with 4-wheel tractor • Passing of *lithao* • Broadcast fertilizer, insecticide and seeds
1200	Lunch break
1330	Fertilizer management for rice on cropping systems • Kinds of fertilizer materials and methods of application – 1st crop – 2d crop • Fertilizer computations
1500	Break
1530	Weeds and weed control • 1st crop • 2d crop • Herbicide calculations

Wednesday

0800	Field work
	• Calibration of sprayers
	— Steps (knapsack & boom)
	— Use of calibration tables
1200	Lunch break
1330	Insect pests of rice and their control
	• Identification of pests and damages
	• Chemical control — specific insecticides and rates of application
1500	Break
1530	Minor insect pests of rice
	• Chemical control
	• Insecticide computations

Thursday

0800	Major diseases of rice
0930	Break
1000	Field diagnosis of insect pests and diseases
1200	Lunch break
1330	Harvesting of first crop
	• Alternatives in establishing 2d crop
1500	Break
1530	Continue — alternatives for 2d crop

Friday

0800	Field work
	• Establishing 2d crop
	— Alternative I — MT-TPL
	— Alternative II — ZT-TPL
	— Alternative III — ZT-DS broadcast
1200	Lunch break
1330	Written test
1500	Break
1530	Practical test
1800	Graduation

DISCUSSION

Sharma: I want to make an observation on development of pilot production progams. Did you consider the type of farmers and size of landholdings in drawing up the programs?

Haws: The decision depends on the farmer when he joins the project. A farmer is usually willing to include only one-third to one-half of his land in the program.

Cropping systems pilot production in Sri Lanka

Reggie A. Wijesooriya

Farming is the way of life — the predominant occupation — of the people of Sri Lanka. Traditionally farmers cultivate their fields without any change of patterns. A cropping systems research program was started in 1976 with the following objectives:

- Identify and understand the existing cropping systems in the rainfed and partially irrigated wetland rice in the intermediate and dry zone, and in the rainfed highland areas in the dry zone.
- Design and evaluate improved cropping systems for such areas.
- Evaluate promising varieties and practices suitable for adoption by farmers in those areas.
- Cooperate with the Extension Service to extend the improved systems to farmers.

Research with minor-tank-based agriculture was initially undertaken at Walagambahuwa in the Anuradhapura district of Sri Lanka (Fig. 1).

After outstanding success in the Walagambahuwa project, similar minor irrigation schemes at neighboring villages copied the technology and carried out a program on their own, with only an extension agent activity. The success of that dissemination program was reported earlier.

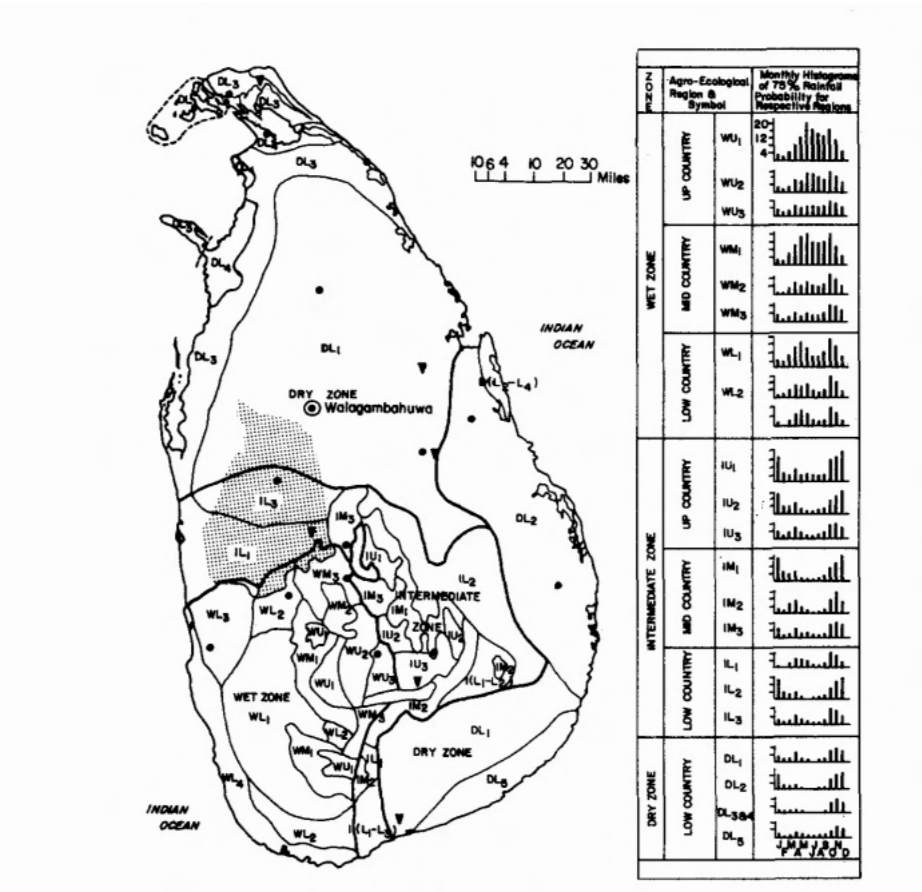
In 1978-79 a pilot production program was started in the Integrated Rural Development Program at Kurunegala district, which had a minor-irrigation-based agriculture with potential for development.

KURUNEGALA DISTRICT

Kurunegala district, the third largest district in Sri Lanka, comes under a special integrated development project sponsored by the International Bank for Reconstruction and Development (World Bank). The project involves US$30 million and has the objective of raising agricultural productivity, employment, income, and living standards.

Kurunegala district has a land area of 294,000 ha, and an estimated population of

Assistant director of agriculture, District Agricultural Office, Kurunegala District, Sri Lanka.



1. Location of Walagambahuwa site and the agroecoiogical regions of Sri Lanka.

1.15 million. The district is predominantly rural. It has a tropical climate with slight variations in temperature, but variable rainfall in a bimodal annual pattern, particularly in the southern part of the district. The northeast monsoon brings rainfall to the whole district during October-December; the southwest monsoon brings rainfall mostly to the southern part during March to June. The average annual precipitation for 1974-75 is 2,075 mm. On the basis of precipitation the district divides into four zones — dry, semidry, semiwet, and wet (Table 1).

High density showers occur during the wet season, resulting in limited soil storage and excessive runoff. Rainfall is adequate for rainfed crop production during the wet season in all parts of the district. During the dry season rice production is feasible in the wet and semiwet zones, but at considerable risk. The total rainfall in the semidry and dry zones is not adequate for rice production.

The topography slopes gently downward from south to north toward the coastal plain. Soils vary from moderately fine (reddish brown earths and low humic gleys) to coarse Regosols and from poorly (low humic gleys) to welldrained (reddish brown earth).

Table 1. Land area and rainfall in the four climatic zones of Kurunegala district, Sri Lanka.

Zone	Land area (%)	Rainfall (mm)
Dry	20	386
Semidry	36	386-482
Semiwet	34	482-579
Wet	10	>519

Thedistrict has nine major irrigation schemes that create a stable environment for the production of high yields of rice. The command area of the schemes is about 10,000 ha. There are about 3,000 minor village irrigation schemes with a potential command area of about 38,000 ha. Poor water management is a major constraint to high rice yields.

A PILOT PRODUCTION PROGRAM FOR MINOR VILLAGE IRRIGATION SCHEMES

Ten minor village irrigation schemes provided a representative sample of 38,000 ha in the dry zone of Kurunegala district. Four were in the dry zone lowland region and six in the intermediate zone low country. Research at Walagambahuwa provided basic data to develop a strategy to overcome problems in the minor irrigation schemes. A cropping systems pilot production program for the minor irrigation schemes started during the 1978-79 crop year.

Land use

A clearly defined threefold system of land use typical of the dry zone is evident in the minor irrigation schemes. The rice lands include about 20 ha below the reservoir in the valley bottom and are irrigated from the reservoir. *Chena* (shifting cultivation) upland crops are grown a short distance from the homestead. In the system, the farmers start cutting and clearing the jungle toward the end of July. The cut jungle is allowed to dry and at the end of August or early September farmers burn the cut jungle. Toward the third week of September the *chena* is ready for seeding of the wet season crop. Cereals are normally planted first, followed by chili, root crops, and pulses. Farmers think of working the rice land in late November or early December, when the reservoirs are full.

The *chena* crop is a hedge against total or partial failure of the rice crop. It brings substantial periodic incomes from the second month onward. For this reason, only when the *chena* crops are secured do farmers turn their attention to paddy lands. Thus, the wet season planting is delayed and early rainfall is not used. The traditional *chena* needs to be developed into a viable system of rainfed farming.

Rice cultivation in the village irrigation schemes starts when the tank is virtually full, usually late in November or early December. At that time rainfall is gradually decreasing and initial land preparation is with stored water. Because of diminishing rainfall, combined with the use of 120- to 130-day traditional and improved varieties, the irrigation scheme sometimes has insufficient water for the crop season. The result

is partial or total crop failure. Dry seeding is seldom practiced. Some farmers use improved varieties but with low levels of management with respect to chemical inputs and weed control.

During the dry season irrigation water is not sufficient for any crop in the paddy area.

For the 1978-79 crop season, rice was planted during the wet season (September-February) and followed by another rice crop or dryland crop such as cowpea, green gram, or a vegetable in the dry season (March-May). This pattern makes use of the early monsoon rains for land preparation. It conserves water in the irrigation tanks and makes a second crop of rice or subsidiary food crops possible during the dry season.

The criteria for selection of the pilot area were:

- no cultivation during the dry season,
- extent of land under each irrigation scheme between 14–20 ha,
- number of farmer families between 10 and 25,
- water management to be done by a person involved in the program,
- positive farmers' reaction to change,
- a representative minor irrigation scheme in the area, and
- accessibility.

The results of the first year's progress are in Table 2.

In the pilot production program, needs identified at the end of the first year were for:

- concentration of minor irrigation scheme structures,
- getting farmers to construct field channels,
- demonstrations to show advantages of improved techniques,
- introduction of farmer education programs,
- introduction of weeders and seeders and generally building up farm discipline, and
- appointment of one village-level leader for each tank to guide farmers, record water issues, do demonstrations, etc.

Program for the 1979-80 wet season

A 1979-80 calendar of operations was drawn up for the 10 villages. It includes:

- a work plan for the 1979-80 crop season;
- training of extension officers and village-level workers;
- fixing of dates for cultivation with regard to preparation of land;
- training on the use of fertilizer, herbicides, water management, harvest, storage, and a crop-cut survey; and
- establishment of demonstration plots.

Demonstrations are an integral part of the agricultural extension program. They enable the extension workers to gain experience in the practice of innovation and give them the necessary confidence to promote it among the farmers. The following demonstrations were planned for each of the 10 minor irrigation schemes:

- *dry sowing* by the normal village method of a 3.5-month variety of new improved seed with the recommended fertilizer practice,

Table 2. Cropping systems production program (10-tank project) in Kurunegala District, Sri Lanka, 1978-79 wet season.[a]

Name of irrigation scheme	Cultivated area (ha)	Total farm families (no.)	Crop establishment completed on	Method of crop establishment	Rice variety	Date of first issue of water	Grain yield (t/ha)		Second season yield (t/ha)	
							Before project	After project	Before project	After project
Ihalagama wewa	8.4	18	20 Nov	Dry sowing	Bg 34-8 62-355 Bg 94-1	5 Oct	1.5	2	0	0
Monnakulama	18.0	45	30 Dec	Sowing Transplanting	Bg 34-8 Bg 33-2	23 Dec	1.4	2.1	0	0
Nugampola wewa	6.8	16	10 Dec	Transplanting	Bg 34-8	27 Dec	2.1	3.6	0	2
Ihalagama game wewa	25.6	36	12 Dec	Sowing	Bg 34-8 62-355	28 Dec	1.4	2.5	0	0
Kumbuk wewa	12.4	26	23 Dec	Sowing	Bg 34-8 62-355	21 Dec	1.5	2.7	0	2
Nithogama Maha wewa	14	36	21 Oct	Sowing	62-355	1 Jan	–	2.8	0	0
Pahala wewalaya Gedera wewa	1.6	35	29 Nov	Sowing	Bg 34-8	3 Dec	1.8	2.6	0	0
Pahala wewa	1.6	31	7 Dec	Sowing	Bg 34-8 62-355 H-10	25 Dec	1.5	2.0	0	0
Maha wewa	11.8	40	14 Dec	Sowing	Bg 34-8	3 Jan	1.25	2.25	0	0
Mamunugama Gederayawa wewa	13.6	52	18 Dec	Sowing Transplanting	Bg 34-8 Bg 34-6	9 Jan	1.8	2.6	0	0

[a]Information supplied by K.H.U. Kumarasinghe, Subject Matter Officer — water management, District Agricultural Office, Kurunegala.

- *dry sowing in rows by hand* with the same package of fertilizer practice, and
- *dry sowing in rows with a push-type seeder* with the same package of fertilizer practices.

A village-level leader was appointed for the 1979-80 crop season to keep records of demonstrations, maintain water issues from the scheme, coordinate input availability, and solve farmers' problems.

SUMMARY AND CONCLUSIONS

The possibility of a successful rice crop by the use of traditional systems of agriculture and existing minor irrigation systems was once in 5 to 6 years. With the new technology, that possibility has been increased to almost one crop every year. In favorable years double-cropping of rice is a possibility. Furthermore, the new rice technology with early-maturing varieties like Bg 34-8 and 62-355 and early planting drastically reduces the risk of crop failure and encourages farmers to invest more in the rice crop.

DISCUSSION

Sharma: What has been the role of scientists in the pilot project? It seems the project is primarily conducted by extension workers and there are chances of dilution of the technology.

Wijesooriya: In a given case the findings are based on on-farm research carried out at a very much similar physical and socioeconomic environment. As such, the normal dilution percentage is not expected in introducing research findings to farmers. We expect a high degee of acceptance, and except for the fact that the extension worker is working in consultation with the research staff, there is not much direct participation of research in the project.

Institutional requirements for regional and national rice-based cropping systems production programs

Virgilio R. Carangal

A high percentage of the arable land (71%) in Asia where 50% of the world population lives is now under cultivation. In most Asian countries, a large proportion of the land suitable for the cultivation of rice is already being used for that purpose. The increase in production of rice in the 1960s and 1970s was due to increased yield per land unit and also to increase in area. Increased food production in Asia will depend mostly on increased yield of crops per hectare and an increase in number of crops produced per year.

RICE-BASED CROPPING SYSTEMS RESEARCH

Initial studies in IRRI and in some national research programs indicate a potential for increasing cropping intensity and production of rice lands, not only with rice but with other crops that can be planted before or after rice. The IRRI cropping systems program expanded in 1974 and a network of cropping systems research sites was established in collaboration with national programs. Work concentrates on rice-based cropping systems for different kinds of rice lands — rainfed wetland, dryland, irrigated, partially irrigated, deepwater, and tidal swamp. But the priority of the national programs is rainfed and irrigated wetland rice where there is very good potential for increased production and cropping intensity.

Studies of rice-based cropping systems at IRRI have led to the formulation of a cropping systems research methodology (IRRI 1975, 1976). This methodology extends to national programs through the Asian Cropping Systems Network. The general approach is to identify a target area and select a research site representing the target area. The site can be one or more villages. An interdisciplinary research team is assigned and research is conducted in farmers' fields.

The first activity is a description of the agricultural characteristics of the site. Next is the design of cropping patterns using any available package of technology for the crops involved and information from the description. The major activities are testing of the designed patterns and component technology experiments in farmers' fields to further refine the technology for that particular environment. After the most profit-

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able patterns are identified in the testing phase, the next step is to test the performance of the patterns at many sites within the environmental complex for which the patterns were designed (multisite testing). After multisite testing, the research team is expected to identify a package of technology specifying the recommended varieties and management practices for each crop in the patterns that can be used in a production program.

The output of the research scheme is a set of cropping systems technology recommendations for different land types, rainfall regimes, irrigation classes, and soil types. Recommendations are specific to a given rice environment and are more complicated than general recommendations for the whole country. The specific recommendations are relevant and assure farmers of increased production and net income.

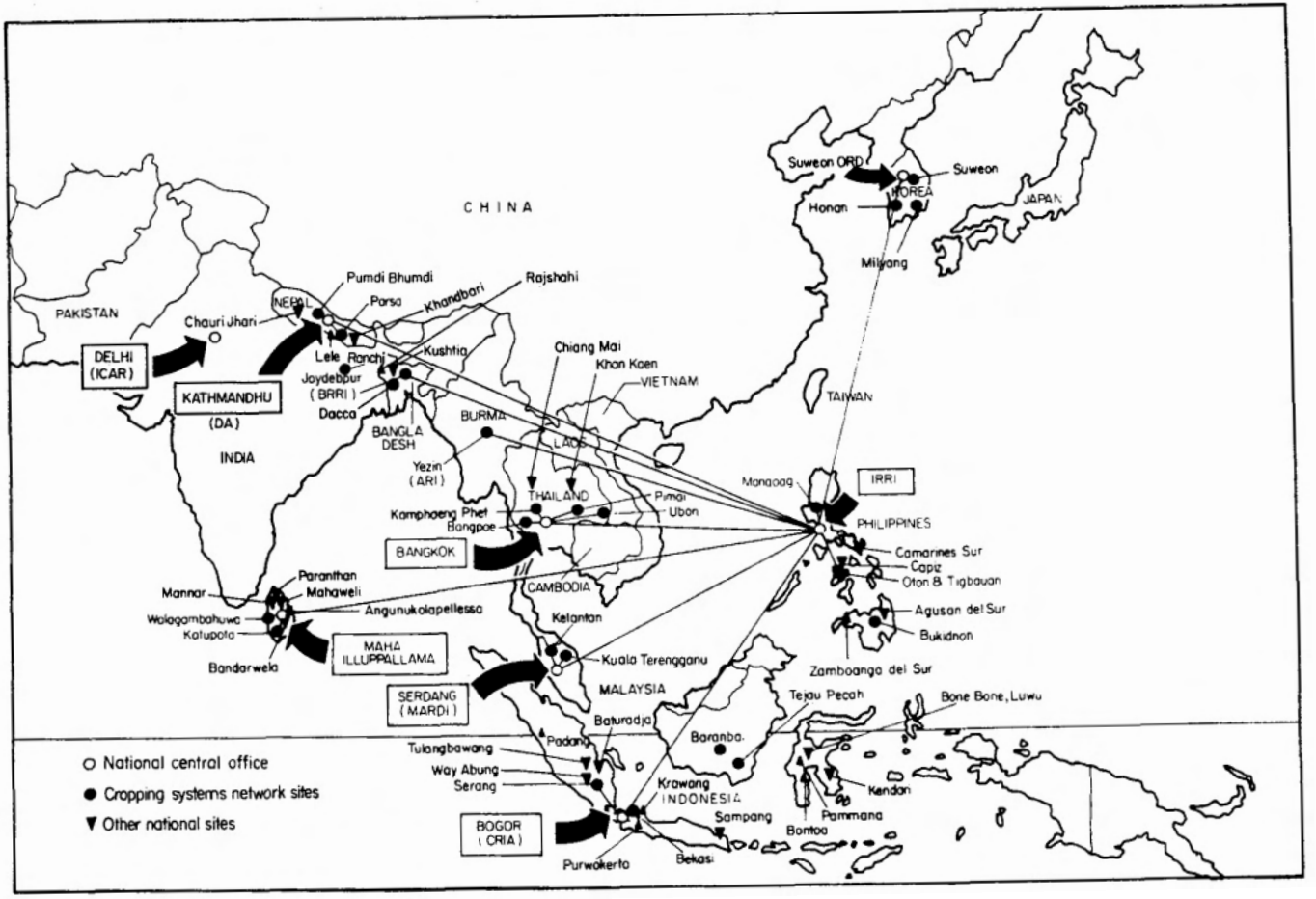
The generation of cropping systems technology is now under way at many research sites in South and Southeast Asia. In 1979, there were 55 cropping systems research sites in the Philippines, Indonesia, Thailand, Sri Lanka, Nepal, Malaysia, South Korea, and Bangladesh (Table 1, Fig. 1). In 1980, there will be 75 cropping systems research sites in 10 countries. Most countries are in the cropping pattern testing phase; some are in the multisite testing phase. These sites are beginning to identify potential cropping patterns better than farmers' patterns (IRRI 1978, 1979). Many national programs will be ready to start production programs in the 1980s. The programs will be mostly with irrigated, partially irrigated, and rainfed wetland rice. In some countries, such as the Philippines and Indonesia, dryland rice cropping systems technology is also expected.

REORIENTATION OF THE RICE PRODUCTION PROGRAMS

Typical farmers usually grow more than one crop on the same land. In rice areas, farmers sometimes grow wetland rice and dryland crops. With the introduction of early-maturing and drought-resistant rice varieties, cropping intensity can be increased and dryland crops can be grown before and after rice. Single-commodity-oriented programs can be reoriented to the cropping systems approach where the main objective is to increase production and farm profit through efficient use of farm resources.

Table 1. Number of operational cropping systems research sites in Asia, 1979.

Country	Number	Sites (no.)				
		Rainfed wetland	Partially irrigated wetland	Dryland	Irrigated	Deep-water
Philippines	I	4	–	4	4	–
Indonesia	15	6	2	7	2	1
Thailand	6	5	–	–	1	–
Sri Lanka	7	3	2	–	3	–
Bangladesh	4	2	1	–	3	1
Nepal	5	4	1	–	3	–
Malaysia	2	2	–	–	2	–
South Korea	9	–	–	–	9	–
Total	55	26	6	11	27	2



1. The Asian Cropping Systems Network sites, 1979.

An example of the commodity approach is the Philippine program called Masagana 99. As a result of its success more commodity programs were initiated — *Masaganang Maisan* for maize and *Gulayan Sa Kalusugan* for vegetables. The programs have their own extension workers and organizational setup. Farmers who plant rice, vegetables, and maize on the same land have three extension workers attending to them. With the cropping systems approach, the focus will be on the rice farmer who grows all three crops. This will maximize the use of the extension workers and can cover more areas. A pilot production program combining the three production programs in three Philippine provinces was initiated in 1976 (Gomez 1977).

COMPONENTS OF A PRODUCTION PROGRAM

Selection of priority areas

A team composed of persons from the national and regional cropping systems research support teams, the organization implementing the commodity programs, the soil classification agency, the weather agency, the irrigation agency, and the extension agency should identify the priority areas. The production program should be concentrated in areas with high potential for increased production and cropping intensity. It should be in areas where there is strong potential for initial success and the national setting is favorable for increased production. These are generally rice areas with irrigation or good, stable rainfall distribution. The priority areas should be in the same areas that are presently involved in an accelerated rice production program. In such places, there are already an organizational setup, facilities for credit and marketing, experienced extension workers, good infrastructure, etc.

Use of package of technology

The research is expected to develop a package of technology for rice-based cropping patterns. The research teams at the site, regional, and national levels will specify the kind of technology for different land types, water, and rainfall regimes in the target areas covered by the production program. The package should include the cropping patterns for the different rice environments and the technology for the crops in the patterns such as the resistant varieties; tillage and planting techniques; timely and correct applications of fertilizer, insecticides, and herbicides; timely harvesting; and good postharvest practices.

With the site-related rice-based cropping research the recommended technology is based on specific environments. The patterns can be the same for an agroclimatic zone, but the component technologies such as fertilizer and insecticide rates, varieties, method of seeding, may vary. Recommendations will be more complicated than those for rice alone, but will be more relevant because the focus is on the rice farm rather than on rice as a commodity.

Availability of inputs

If modern varieties of rice and dryland crops are to be grown successfully, the agricultural inputs such as fertilizer, insecticides, herbicides, and power equipment should be made available at the right time and place. Fertilizer is the most important

input for increased production. Before planting time, stocks in the amounts needed should be made available at the places where they are to be used and at reasonable prices. Extension workers must plan the requirements of the area so that the fertilizer will be there when needed.

Insecticides are another important input. The kind and quantities vary from place to place depending on the predominant insect pest in the target areas. Again, the extension worker must plan so that insecticides needed will be available at the right time. Herbicides should also be available when needed.

The program should include ways to provide farmers or cooperatives with power equipment to intensify production on their rice lands. Small tractors for land preparation and portable threshers are necessary for intensive rice cropping. The threshers must be able to thresh other grain crops.

Rural credit

All improved cropping patterns that are significantly better than farmers' patterns require higher cash and labor costs. Farmers need capital to be able to adopt the new technology generated by most research sites. Therefore, the program should provide credit to farmers. The package of technology should guide lending institutions as to the amount of loan the farmers need for a pattern in a given rice environment.

There are several ways of extending credit to farmers. The scheme varies from one country to another. Most governments have increased production loans markedly, especially for small farmers. Unfortunately the rate of repayment has been disappointing. There should be a detailed study of extending credit to farmers to identify better schemes for small farmers. A desirable credit scheme should have the following characteristics:

- The credit institutions should be able to extend loans to both small and big farmers.
- Loans should be made available on time to meet the expenses of crop production in the patterns.
- Loans should be for the whole crop year and involve different crops in the pattern, not just individual crops.
- Repayment should be adjusted when farmers suffer from crop failure or other unforeseen calamity.
- Time and paper work required in obtaining the loan should be minimum.
- The farmer should receive less cash and more credit in the form of agricultural inputs.
- Extension workers should not be involved in collecting payment.

Seed production and distribution

The recommended technology package for a particular pattern generally includes improved varieties of rice or dryland crops. The program must have a system of seed multiplication and certification so that top quality seed is available to farmers. The certification program requires an effective organization and control but the requirements for certification should be adapted to the local conditions.

Although certification is important, certified seeds need not be planted by every farmer who wishes to grow improved varieties. This is especially true for self-

pollinated crops such as rice and legumes. Farmers can easily manage to produce pure seed that can be classified as good seeds.

Price support

With the intensification of cropping, the production of rice and other crops is expected to increase. Increased production in rural areas is generally associated with low prices of the produce at harvest time. To encourage the farmers to adopt the improved cropping systems they must have assurance of a fair price. Most countries have an agency to support prices at the farm and consumer levels. The price support should extend to all crops in cropping patterns. There should be good coordination between extension workers and the crop procurement agency on volume and time of harvest of crops in different places.

Intensified extension service

There should be enough qualified extension workers to cover the programmed area. In the Philippines, an extension worker covers about 150 farmers in the Masagana 99 (rice production) Program. With rice-based cropping systems the same number of extension workers may be used, but their time will be fully used throughout the year. The extension workers should intensify their campaign for the new cropping systems technology by:

- holding regular farmer classes,
- conducting field demonstrations of the recommended cropping systems technology,
- conducting field days, and
- scheduling farm visits.

The extension workers should not be commodity oriented as in most accelerated food production programs but should assist the farmer in production of rice and the other food crops in the cropping pattern. The extension worker shoud be a generalist with backstopping from crop specialists at provincial or district levels.

Training of extension workers

One of the most important components of any production program is qualified extension workers. They are in close contact with farmers and should learn not only extension methods but also the new technology. Most extension workers now involved in the accelerated rice production programs had training in rice production. For the rice-based cropping systems program, all the extension workers should be trained in the principles of cropping systems, the relation of cropping pattern performance to environment, the improved technology of the different cropping patterns credit and marketing schemes, etc. Training should be at different levels —from farmers to subject matter specialists and even to heads of the program at the provincial and regional levels. Training should be planned at least 6 months before its implementation and training staff trained before the start of the program.

Massive information drive

There should be a massive information drive to explain the program and its

objectives, program goals, how the program should be implemented, roles of participating agencies, etc. The extension workers should hold farmers' classes to explain the program and the new technology. Leaflets in local languages on recommended cropping patterns, improved varieties, fertilizer rates, insect control, etc. should be published. National and local radio programs should be used to disseminate information about the technology.

Mobility of extension workers

Extension workers assigned to cover several villages in remote areas must be mobile. In some countries motorcycles are provided to extension workers. In the Philippines there is a special Vehicle Loan Fund for extension workers to buy motorcycles. The monthly amortization is deducted from their salary. To encourage the extension workers to avail of this privilege an additional incentive in the form of gasoline allowance is given. About 40% of the extension workers got motorcycles through the scheme.

INSTITUTIONAL REQUIREMENTS OF A PRODUCTION PROGRAM

The components of the production program presented here are all important. Interdependence and interaction among the components must be appreciated. For example, if improved varieties are not planted there will be little response to fertilizer. If a workable rural credit system is lacking, farmers cannot raise the money to purchase fertilizers and other inputs needed to increase yields. If there is no price support on a permanent basis, the farmers may be reluctant to invest in the inputs required to express the full yield potential of the improved cropping patterns. If there are no trained production technicians, the right cropping systems technology will not reach the farmers.

Many institutions must work together in a regional and national production program using the cropping systems approach. The number of institutions will vary depending on the organizational setup of ministries involved in agricultural development. For simplification, I will use the Philippines as an example: if the Philippines implements a rice-based cropping systems program, the national Food and Agriculture Council (NFAC), which is presently coordinating the rice program will be the coordinating agency, even if the program is at the regional level only. The present National Multiple Cropping Program, which concentrates on cropping systems site-related research and multisite testing, is coordinated by NFAC.

The cropping systems package of technology will be generated by the interdisciplinary research teams in different agroclimatic zones. In 1980, the Philippines will have teams at 16 research sites in different parts of the country. These teams are backstopped by an interdisciplinary team at the national level. The team at the national level works with members of the site research teams for support in research designs, analyses, and interpretations. In addition, the national team provides contacts with experts from different research centers for consultation on specific problems. There are plans to develop regional capabilities and regional support teams.

The staff members of the national support team are from the University of the

Philippines at Los Baños (UPLB) and NFAC. The site research teams are from the Bureau of Plant Industry (BPI) and direct-hired by the integrated agricultural projects. For the research component the Philippine Council for Agriculture and Resources Research, UPLB, NFAC, BPI, Bureau of Soils, and some colleges of agriculture are involved. The following are the Philippine government agencies that will be involved in the implementation of the other components:

Selection of priority areas	National Multiple Cropping Team Bureau of Soils Bureau of Plant Industry National Irrigation Administration Philippine Atmospheric, Geophysical, and Astronomical Services Administration
Availability of inputs	Fertilizer and Pesticide Authority Private dealers
Rural credit	Central Bank of the Philippines Philippine National Bank Rural Banks Agriculture Credit Administration
Seed production and distribution	Bureau of Plant Industry Private seed growers associations
Price support	National Grains Authority
Intensified extension service	Rural Banks (have also extension workers) Bureau of Agricultural Extension Bureau of Plant Industry
Training of extension workers	Philippine Training Center University of the Philippines at Los Baños Bureau of Agricultural Extension Bureau of Plant Industry
Mobility of extension workers	Special Vehicle Loan Fund National Food and Agriculture Council Philippine National Bank
Massive information drive	National Media Production Center Bureau of Agricultural Extension Bureau of Plant Industry National and local radio stations

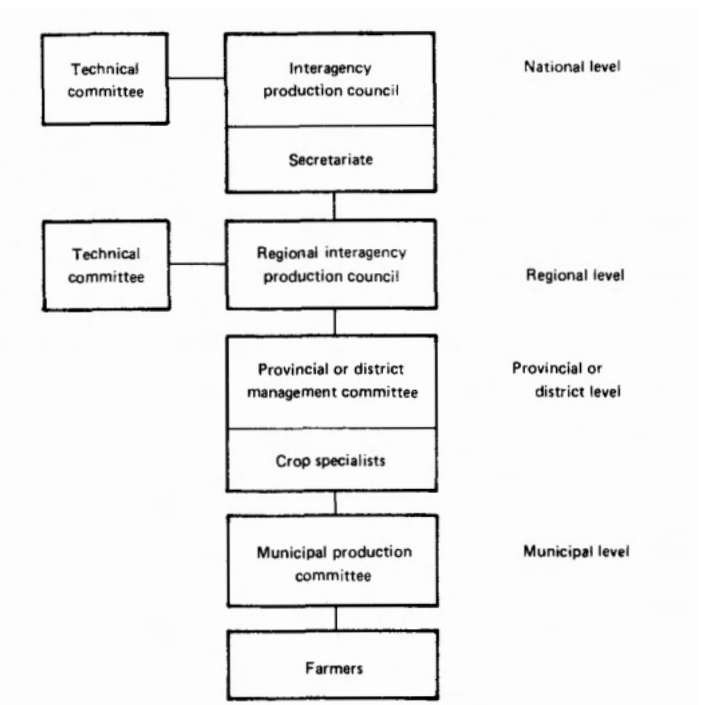
ORGANIZATIONAL SETUP

Many institutions are involved in a production program. Each one has its own activities and line of authority to the provincial and municipal levels. The ideal is to

have all the institutions involved under one ministry. Unfortunately this is not the case. As in any interagency undertaking, the difficult part is the coordination of the activities of the different institutions to effectively implement the various components of the program to attain the objectives.

To ensure better cooperation and coordination, the different institutions should be involved in the preparation of the program. It is desirable to have general plans at the national level and detailed production plans at the regional, provincial or district, municipal, and extension-worker level. The role of each institution should be identified in detail so that everybody knows the activities of each and how the institution fits in the overall program. The production targets should be planned from the extension worker level up to the national level, and not from the national level down to the extension level.

For a national rice-based cropping systems, there should be a supercoordinating body consisting of the heads of various institutions directly or indirectly involved in the production program, with the Minister of Agriculture as the head. For purposes of presentation, I will call this a National Interagency Production Council. The same body should be created at regional, provincial or district and municipal levels (Fig. 2). The members are representatives of the institutions involved at the national level, with the head of the lead agency in rice or food production as the chairman or Executive Officer. A Secretariat should be created at the national level to attend to the day-to-day coordination and operations of programs approved by the Council.



2. Organizational setup for national rice-based cropping systems.

The national technical committee should also be created and headed by the leader of the interdisciplinary cropping systems support team.

If there is a regional interdisciplinary research team, a regional technical committee should also be created. The members of the technical committee should be senior scientists involved in cropping systems and component technology research.

Because the extension workers are farm oriented, there should be crops specialists at the provincial or district level such as rice specialist, maize specialist, grain legume specialist, etc. and a cropping systems specialist to backstop the extension workers in the field.

If the program is only regional, a management committee at the national level can be created with members from the institutions directly involved in the program. A management committee should also be created at the regional, provincial, or district and municipal levels. Technical committees are also created at the national and regional levels.

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Evaluation of insect control recommendations in a cropping systems program

J. A. Litsinger

The objective of cropping systems research is to assess current crop production technology and determine if there are cropping patterns that are economically more attractive than those farmers now grow. Improved cropping patterns tested at cropping systems research sites are evaluated under a set of recommended management practices, including insect control, with farmers' current patterns as a basis for comparison.

Current insect control technology relies heavily on insecticides and economic thresholds. Labor requirements and social acceptability are normally not constraints on insect control for small-scale farmers, but insecticide cost can be a major limiting factor preventing acceptance. It is a challenge to entomologists to develop insect control recommendations that do not strain farmers' financial resources. Farmers usually adopt new technology quickly if it is within their reach in terms of input requirements and demands on management skills, and if it results in a higher profit than they now realize.

As insecticide costs arise, insect control recommendations continually need to be reevaluated for their profitability. Evaluation is a highly dynamic process not only because of rising costs but also because of the ever changing nature of insect pest populations. An available methodology provides an objective and systematic approach to the development of insect control recommendations (Litsinger et al 1980). This paper updates that methodology, particularly in terms of the evaluation process.

Three approaches have historically been used by entomologists to develop insect control recommendations.

The national approach is the most common approach. It presents a list of all known insect pests for a given crop in a country and the most effective insecticides found by screening at experiment stations. These recommendations may or may not include economic thresholds.

There are several reasons why this method falls short in fulfilling the requirements as a recommendation for farmers in cropping systems research:

- Complexity — more pests are listed than occur for a given crop in an area, i.e. too much information for extension workers and farmers to assimilate.

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- Lack of site specificity — the recommendations do not allow for local variations in management practices or influences of environment (Litsinger et a1 1980).
- Lack of cost analyses — the recommendations are not based on profitability in terms of the local requirements of farmers.
- Single-pest approach — often several pests attack the same growth stage and if national recommendations were followed, several insecticides may have to be used at the same time. This is too inflexible.

The second approach is *local testing of alternative recommendations compared to an untreated control.* This would seem to be a logical way of overcoming the problems of the national approach. But the difficulty is that for any given crop in a cropping pattern there is an infinite number of possible recommendations when one considers choice of insecticide, dosage, timing, and frequency of application. One who uses this method never knows if a better recommendation exists, even if the chosen recommendation appears to be significantly more profitable than an untreated check.

The third approach is *local testing of alternative recommendations compared to maximum protection and an untreated check.* This method eliminates the problem of not knowing if a greater yield potential exists. However, many possible alternative recommendations also can achieve high yields. The relationship between yield loss by growth stage and insect control is still unknown. Therefore, a recommendation chosen from this method may be excessive in terms of protecting too many growth stages.

A fourth method is now proposed *—local testing alternative recommendations compared to yield losses at each growth stage.* This method offers the greatest objectivity because each component of a possible recommendation can be evaluated independently in terms of insecticide frequency (Litsinger et al 1980). All methods suffer from the fact that the evaluations are made after the crop is harvested and, thus, there is no assurance that the pest populations and crop yields will be the same in future years. This makes it necessary to test an insect control recommendation for a minimum period of 2-3 years at each site.

If yield losses are consistent year to year for any growth stage, then prophylactic insecticide applications are warranted. But, if the yield losses show high year-to-year variability, then applications should be based on economic thresholds. The yield loss method offers a distinct advantage by allowing a realistic appraisal of economic thresholds. Thresholds also can be modified to fit local conditions.

Experience in applying the partitioned yield loss method to determine insect control recommendations have pointed out several factors worth noting.

- It is important that the maximum-protection treatment keep all insect pests below economic injury levels. Insecticides used have not always been effective in achieving this objective; therefore, the maximum-protection plots should be continually monitored for insect pests in the same manner that is appropriate for the recommended practice. If the maximum protection is suboptimal, it should be revised by choosing better insecticides. higher dosages, or more frequent applications or both. Insecticide cost is not an issue because such treatments are not possible recommendations and profit should not be calculated. However, the yield losses at each growth stage should be converted into

monetary terms to evaluate possible insect control practices.

- Insecticides chosen for the maximum-protection plot should be plant neutral, neither promoting plant growth (phytotonic) nor being phytotoxic. Problems have arisen with the use of carbofuran on rice in this regard because it directly stimulates plant growth. There is a need to evaluate insecticides for phytotonic properties. On the other hand, carbofuran is often used in a recommended insecticide practice for both its ability to control insects and its growth stimulation effects.

CRITERIA IN EVALUATING RECOMMENDATIONS

Insect control recommendations as well as alternative practices are assessed in terms of insect population suppression and also the following factors:

- profit (efficacy and insecticide cost),
- benefit-cost ratio (based on farmers' current acceptable ratio),
- insecticide costs compared to total material and labor costs (compared to farmers' existing system),
- farm-to-farm stability,
- year-to-year stability, and
- management acceptability (from cropping pattern and record keeping data).

Profit

The yield of the insect control practice to be evaluated is compared to that of the untreated control and maximum protection. An ideal practice would be statistically identical to maximum protection, but significantly higher than the untreated check. Otherwise, the practice is suboptimal and needs to be revised according to the yield losses for each growth stage. There is also the possibility that a given practice — although statistically identical to maximum protection — is excessive in terms of number of applications or dosage. This can be assessed again by comparing its yield gain to the yield losses calculated for each growth stage and expressing those losses in monetary terms.

In a recent IRRI experiment on soybean (three growth stages), maximum protection gave a significantly higher yield than the untreated control (Table 1). However, the recommended practice was not significantly different from either the maximum-protection plot or the untreated check. No significant yield loss was detected at any growth stage, although yields at each stage were numerically smaller than those with the maximum protection.

No profit can be determined in this experiment because of a lack of statistical difference. At the soybean price of US$0.40/kg, the yield loss from the combined 3 stages was US$276/ha. The current recommended practice valued at US$32/ha is suboptimal and not highly costly, and could be revised by adding another application at the ripening stage to protect all three growth stages.

A second example — mungbean at Pangasinan — shows the recommended practice to be statistically equal to maximum protection but significantly higher than the untreated check (Table 2). At the mungbean price of US$0.62/kg, the *profit* — 1,320 kg/ha – 320 kg/ha = 1,000 kg/ha × US$0.62 = US$620/ha — US$35/ha (cost

Table 1. Evaluation of the chemical insect control recommendation for soybean. IRRI. Nov 1979-Feb 1980.[a]

Bean fly (% infested plants) 21 DE	Flea beetle (no. of feeding holes/plant) 21 DE	Defoliation (%) 49 DE	Pod borer damaged pods (%)	Yield (t/ha)
Maximum protection[b] at preflowering, reproductive, and ripening growth stages				
0 a	2 a	2 a	l a	1.62 a
Maximum protection without preflowering protection				
18 a	10 c	l a	2 a	1.28 ab
Maximum protection without reproductive protection				
2 a	3 ab	7 b	20 b	1.11 ab
Maximum protection without ripening protection				
0 a	4 ab	1 a	2 a	1.20 ab
Untreated control				
48 b	11 c	19 c	24 b	0.93 b
Recommended practice[c]				
2 a	6 b	4 ab	5 a	1.06 ab

[a]Av of 3 replications. DE = days after crop emergence. In a column, means followed by a common letter are not significantly different ($P \leq 0.05$). [b]Preflowering - 0.5 kg a.i. monocrotophos/ha 2, 9, 16 DE; reproductive – 0.03 kg a.i. decamethrin/ha 25, 35, 45 DE; ripening – 0.03 kg a.i. decamethrin/ha 55, 65, 75 DE. [c]0.25 kg a.i. monocrotophos/ha 2 and 12 DE; 0.75 kg a.i. endosulfan/ha 25 and 35 DE.

Table 2. Evaluation of the chemical insect control recommendation for mung bean planting in December.[a] Manaoag, Pangasinan, Philippines, 1978-79.

Bean fly (% infested plants) 25 DE	Flea beetle (% defoliation) 14 DE	Heliothis (no./25 plants)	Yield (t/ha)
Maximum protection[b] at preflowering and postflowering growth stages			
22 a	7 a	3 a	1.41 a
Maximum protection at postflowering growth stage only			
65 b	16 b	3 a	0.54 b
Recommended practice[c]			
25 a	7 a	3 a	1.32 a
Untreated			
74 b	18 b	24 b	0.32 b

[a]Av of 4 replications (fields). DE = days after crop emergence. In a column, means followed by a common letter are not significantly different ($P \leq 0.05$). [b]Preflowering – 0.5 kg a.i. monocrotophos/ha 2, 9, and 16 DE; postflowering – 0.03 kg a.i. decamethrin/ha 25, 35, and 45 DE. [c]Preflowering – 0.25 kg a.i. monocrotophos/ha 2 and 12 DE; postflowering – 0.75 kg a.i. carbaryl/ha 25 and 35 DE.

of insecticide and labor) — was US$585/ha. The recommended practice included protection in the preflowering and postflowering growth stages; yield losses occurred in both stages. Total yield loss was (1.41 t/ha - 0.32 t/ha) 1.09 t/ha. Preflowering yield loss was calculated as 1.09 t/ha - 0.22 t/ha (0.54 t/ha-0.32 t/ ha) = 0.87 t/ha + 1.09 t/ha = 80% (US$540 ha). Postflowering yield loss was 32% (0.22 t/ha) or US$134/ha. The cost of insecticide was US$18/ha for each stage. Clearly the recommended practice is highly profitable.

Farmers, however, may not accept a recommended practice based only on profit; they may seek to optimize their return on investment.

Benefit-cost ratio

Using the mungbean example one can calculate the benefit-cost ratio (B:C) for the recommended practice. Benefit is 1.32 t/ha - 0.32 t/ha = 1 t/ha = US$620/ha. Insecticide cost is US$35/ha. The B:C therefore = 620/35 = 17.7. The B:C calculated for the farmers' existing system was 1.9 for Pangasinan (IRRI 1979). However, even profitability and return to investment do not guarantee that farmers will readily adopt the recommended practice.

Insect control costs compared to other production costs

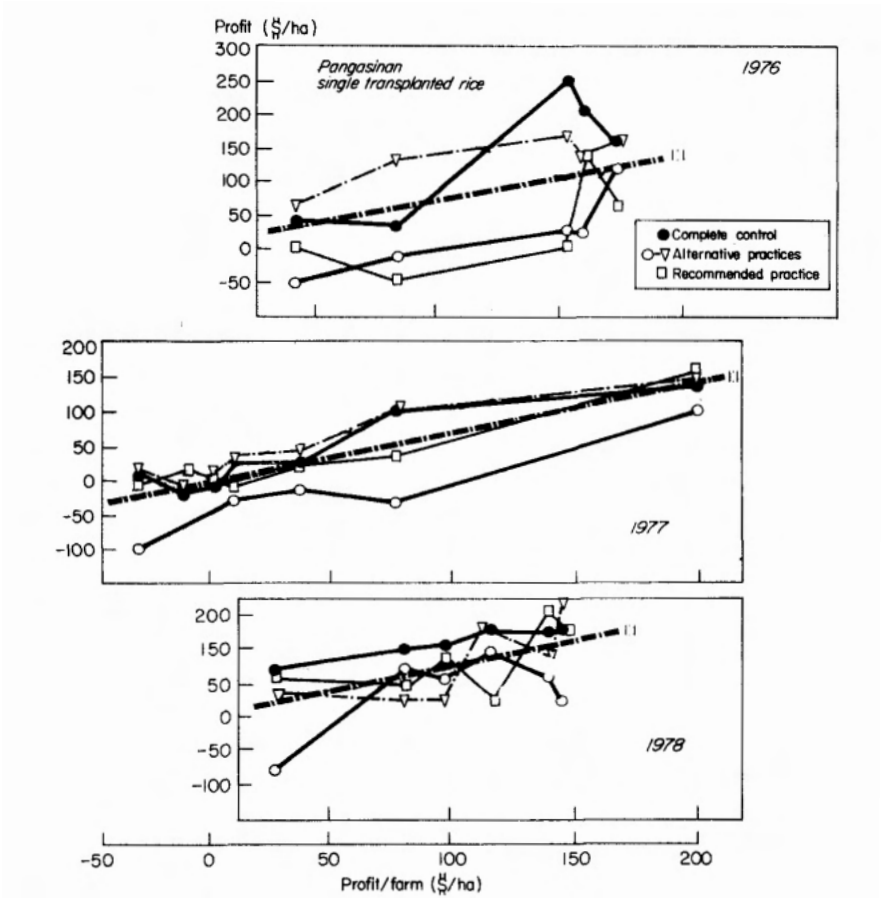
The labor cost for the recommended insecticide practice is US$7/ha, which represents only 6% of the total requirement for mungbean production (US$110/ha). However, the cost of the recommended insecticide (without labor) is US$28/ ha. The total material cost for the recommended cultural practice including insect control is US$77/ha. This amount should be compared with what farmers now spend for material inputs in their existing system of mungbean production. The material cost should be within the range of what farmers now spend and, by the rule of thumb, that amount should not greatly exceed about 75% of what farmers now spend. That was calculated from farm record keeping data as US$36/ ha (range = US$7/ha to US$96/ha). Therefore, the input cost of the recommended practice is higher than what 75% of the farmers now spend.

The foregoing examples were based on the average response of the recommended practice across farms. It is important that a recommended insect control practice be responsive across farms at a site with a wide range of biophysical effects — local variations in insect pest populations, hydrological features, and soil differences.

Farm-to-farm variability

The farm-to-farm variability of insect control practices was analyzed for single crop transplanted rice (TPR) and mungbean in Pangasinan in 1975-78. The recommended practice was compared to the complete control and alternative practices each year. Profits for these recommendations, averaged over all farms, were analyzed and plotted in Figures 1 and 2 to show farm variability for single crop TPR and mungbean. Farms were ranked low to high profits along the x-axis and the profit from each treatment was plotted along the y-axis.

To test farm-to-farm variability, the data were analyzed by the Eberhart and Russell regression analysis. which is a way of measuring the effect of environment (farm) on the treatments. The b coefficients for each treatment across farms were



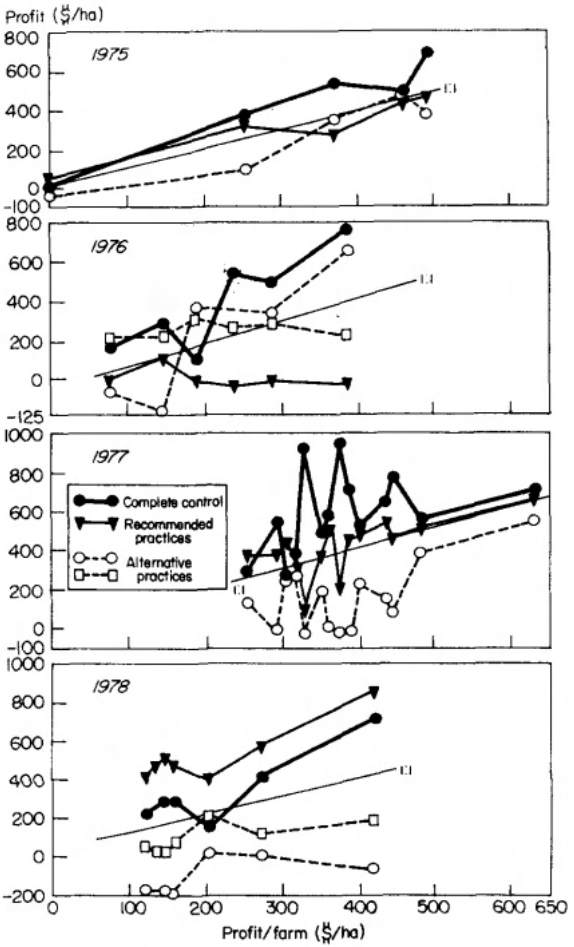
1. Farm-to-farm economic performance of the insect control recommendation for single crop transplanted rice for a 3-year period. Pangasinan, Philippines, 1976–78.

analyzed by analysis of variance. The treatments showed no significant differences ($P \leqslant 0.01$) due to the biophysical environment (farm) in any year for both single TPR and mungbean. The insect control treatments were equally effective in low and high profit farms.

Year-to-year variability

It is well understood that insect pests vary from year to year. If a recommended practice were developed for a cropping pattern, there is no guarantee that it would be suitable in the years that follow. One view would have recommendations based solely on economic thresholds as this would cover all eventualities in the best tradition of integrated pest management (IPM). However, for crops like grain legumes, the attack by insect pests such as the bean fly, thrips, and flea beetle is rapid and control is based on early use of insecticides. For this case, economic thresholds have not been developed, nor do they seem to be a rational approach until insect-resistant varieties are commercially available.

In other cases, prophylactic applications such as seed treatments or early spraying for pod borers on grain legumes are much cheaper than corrective applications



2. Farm-to-farm economic performance of the insect control recommendation for mungbean. Pangasinan, Philippines, 1975-78.

based on thresholds because lower dosages are required. For rice, whorl maggot is best controlled by early application of insecticide before damage symptoms appear. Soil incorporation of carbofuran granules in rice fields before transplanting is less expensive than paddy water broadcast application after transplanting and for certain rice crops produces high profits. Clearly prophylactic insecticide applications have a place in modern insect control technology, but they should be used only for crops on which insect pest pressure is consistent.

Economic thresholds should be considered in cases where year-to-year insect pest pressure is highly variable. However, they should not be recommended without testing, and modifications are perhaps necessary to fit local conditions. The choice of the corrective insecticide should also be evaluated in economic terms under local conditions.

Economic thresholds have been used over a 5-year period in Iloilo and Pangasinan and have been substantially modified from year to year based on local responses (Litsinger et al 1980).

I now illustrate two examples of how insect control recommendations were

developed for single crop TPR and mungbean in Pangasinan from 1975 to 1980.

Single crop transplanted rice. In 1976 the recommended practice for single crop TPR followed the national recommendation and was quite extensive because a wide range of insect pests attacking several growth stages was expected. The cost was high (US$130/ha) mainly because of the high dosage (2 kg a.i. ha) of carbofuran that was needed as a paddy water broadcast application for adequate insect control (Table 3). Despite the high yields obtained, the cost was excessive and the B:C was unfavorable.

Therefore in the recommendations for 1977 the carbofuran dosage was lowered to 1.5 kg a.i./ha by using a newly developed soil incorporation technique and by reducing the number of monocrotophos sprays from 3 to 1. The lower rates did not change its performance, but the B:C was still unfavorable, mainly because of a lower yield due to less-favorable rainfall.

In 1978 the dosage of carbofuran was again reduced based on results elsewhere and the sprays for the reproductive stage were eliminated as the yield loss partitioning showed no response to insecticide at this stage in 1977. Even with the low yield in 1978, the low insecticide cost gave a very favorable B:C. However, the yield of the recommended practice was significantly less than that of the complete control, because of yield loss caused by stem borers during the reproductive stage in 1978.

In 1979 protection from late-season stem borers was added by using endosulfan — the least costly stem borer insecticide currently recommended in the Philippines. But endosulfan failed to control late-season stem borers, even with two sprayings. Therefore the yield from the recommended practice was less than that from complete protection. The B:C was only 1.7.

Analysis of the yield loss component revealed no significant yield loss during the vegetative period. For lack of consistent year-to-year results, to minimize insecticide costs, and to get a more favorable B:C all prophylactic applications were eliminated in 1980 in favor of economic thresholds.

Mungbean. The 1975 recommended practice again was taken from the national recommendation — 1 kg a.i. carbofuran/ha in the seed furrows at planting. This proved to be suboptimal, even though it was relatively inexpensive. It produced a high B:C, but the yield was significantly less than that for complete protection (Table 4). Because of postflowering yield loss, monocrotophos sprays were added to protect this stage in 1976 and carbofuran G was replaced with monocrotophos sprays during the preflowering period (5 and 15 DE).

The results in 1976 were highly favorable — the yield of the recommended practice was statistically identical to that of complete control and the B:C was 6.7. In 1977 an attempt was made to lower the cost further by replacing monocrotophos with a less expensive insecticide (endosulfan). This proved inferior to the 1976 recommended practice because the yields were significantly less than for complete control.

The timing of the postflowering sprays was begun at flowering to make the low dosage (0.75 kg a.i./ha) more effective. Carbaryl (less expensive) was substituted for endosulfan. The insecticide regime for complete protection was changed by spraying monocrotophos three times during preflowering and using decamethrin for postflowering protection.

The changes for 1978 proved to be highly effective. The recommended practice

Table 3. Development of the insect control recommendation for single crop transplanted IR36 rice. Pangasinan, Philippines, 1976-80.

Year	Recommendation[a]				Yield (t/ha)		
	Practice	Insecticide			Complete protection	Recommended practice	Check
		Cost[c] (US$/ha)	Benefit: cost	Net returns (US$/ha)			
1976	2 kg ai. carbofuran G/ha broadcast 5 DT; 0.75 kg a.i. monocrotophos/ha 25, 40, 60 DT	137	1.6	225	4.7 a	5.3 a	3.8 b
1977	1.5 kg a.i. carbofuran G/ha soil incorporated; economic threshold (0.75 kg a.i. endosulfan/ha 45 DT)	62	1.7	105	4.7 a	4.6 a	3.9 b
1978	1 kg a.i. carbofuran G/ha soil incorporated	32	3.3	105	3.7 a	3.1 b	2.4 c
1979	1 kg a.i carbofuran G/ha soil incorporated; 0.75 kg a.i. endosulfan/ha 35 and 45 DT	64	1.7	105	5.6 a	5.0 b	4.3 c
1980	Economic thresholds						

[a] DT = days after transplanting. [b] In a row, means followed by a common letter are not significantly different ($P \leq 0.05$).
[c] Materials and labor.

Table 4. Development of the insect control recommendation for mungbean. Pangasinan, Philippines, 1975-79.

Year	Recommendation[a]				Yield (t/ha)[b]		
	Practice	Insecticide			Complete protection	Recom-mended practice	Check
		Cost[c] (US$/ha)	Benefit: cost	Net returns (US$/ha)			
1975	1 kg a.i. carbofuran G/ha basal	31	8.0	248	0.9 a	0.6 b	0.2 c
1976	0.25 kg a.i. monocrotophos/ha 5, 15, 25, 35 DE	37	6.7	248	0.9 a	0.6 a	0.2 b
1977	0.25 kg a.i. monocrotophos/ha 2 and 12 DE; 0.75 kg a.i. endosulfan/ha 35, 45 DE	48	9.0	434	1.3 a	0.9 b	0.2 c
1978	0.25 kg a.i. monocrotophos/ha 2 and 12 DE; 0.75 kg a.i. carbaryl/ha 25, and 35 DE	35	15.9	558	1.2 3	1.1 a	0.3 b
1979	(as in 1978)						

[a]DE = days after crop emergence. [b]In a row, means followed by a common letter are not significantly different ($P \leqslant 0.05$). [c]Materials and labor.

equaled the complete control in yield and gave a highly favorable B:C. As mentioned earlier, there is concern about the cost (US$935 ha) as being higher than what most farmers now spend, but it is felt that this is not excessive. If the results of the 1979 trial equal those of 1978, there will be high confidence in this recommendation.

The insect pest pressure over the 5-year period has been consistently high in both preflowering and postflowering growth stages. There are no economic thresholds for grain legumes, and the four prophylactic insecticide applications are highly consistent with available technology.

The past 5 years has illustrated how technology generated at the national level can greatly benefit from the adaptive research under farmers' fields conditions in the context of a cropping systems program. From the experience in Pangasinan and Iloilo, it is felt that insect control recommendations can be developed more rapidly at future sites using the methodology of yield loss partitioning, which came out of these research objectives.

INTERFACING WITH INTEGRATED PEST MANAGEMENT

Cropping systems research and integrated pest management (IPM) both embody a holistic approach to crop production. Both involve the team approach to optimize the use of agricultural inputs in a way consistent with the farmers' resource base, Both stress local testing of insect control technology. But the differ in that cropping systems research strives to change the farmers' current cropping system by changing their cropping patterns.

IPM does not involve evaluating introduced cropping patterns, but serves the production program phase.

There is no conflict between the two approaches, rather there is complementarity.

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COMPONENT TECHNOLOGY – INSECT MANAGEMENT

Insect control recommendations for cropping patterns in Northeast Thailand

Weerawooth Katanyukul and Narong Chandaraprapa

Rice-based cropping systems research has been going on in Northeast Thailand since 1977. The typical rice environment of the region, which occupies one-third of Thailand's rice production area, is rainfed wetland. The topographic features, soil types, rainfall patterns, cultivation methods, and socioeconomic aspects of the Northeast were discussed by Somrith and Awakul (1978) and Adulavidhaya (1978). This paper reviews insect control recommendations for the major rice-based cropping patterns in Northeast Thailand, and points out future research needs.

Ubonratchatani (Ubon) and Nakornratchasima (Pimai) were selected as research sites for cropping pattern trials. The two are about 400 km apart and have different agroclimatic environments. Rainfall distribution during the monsoon in Ubon is unimodal; that in Pimai is bimodal. Five cropping patterns are being evaluated at Ubon: rice (direct seeded) - rice (transplanted), yard-long bean - rice, mungbean - rice, peanut -rice, and maize - rice. The last three patterns were also tested at Pimai.

In the initial trials, insect control at the research sites was conducted mainly by the agronomy staff. Until 1978, entomologists served only as consultants.

INSECT CONTROL IN CROPPING PATTERN TRIALS

The insect control technology tested at the sites was developed at experiment stations in Thailand and relies almost exclusively on chemicals. The national recommendations for the test crops in the patterns were evaluated. Carbofuran, monocrotophos, and carbaryl as prophylactic treatments were tested against various insect pests. The rate of application varied, depending on the crop and growth stage.

Dry-seeded wetland rice

A photoperiod-insensitive rice (RD7) was dry seeded. Little information exists about insect pests in this type of rice culture. Carbofuran at 1 kg a.i./ha was recommended for seed furrow application. Target pests during the seedling stage were ants, crickets, and thrips; during vegetative to reproductive stages rice stem borers, gall midge, and planthoppers were the target pests. During the ripening

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stage, the important pest was the rice bug. Insecticide recommendations for these insects in 1978-79 are summarized in Table 1.

The 1979 entomology trial indicated that insecticide application was unnecessary because insect damage to rice was negligible. In the cropping pattern trials, granular carbofuran at 1 kg a.i./ha was applied as a paddy water application as rice emerged if there was enough water in the field.

Mungbean

Mungbean variety U-Thong 1 yields well in Ubon but requires at least three timely sprayings of insecticide against insect pests. The bean fly *Ophiomyia phaseoli* (Tryon) was the most serious insect pest. After plant emergence, 2-3 monocrotophos sprays (0.21 kg a.i./ha) were recommended to reduce bean fly damage (Table 2). Other important insects that attacked mungbean during the preflowering stage were the leaf rollers (*Archips micaceana* Walker, *Lamprosema indicata* Fab. and *L. diemenalis* Guenee), the leaf miner (*Stomopteryx subsecivella* Zeller), and the soybean bean aphid (*Aphisglycines Matsumura*). The most serious at the postflowering stage was the pod borer *Maruca testulalis* (Geyer).

Insects attacking the yard-long bean and insecticide recommendations were similar to those for mungbean.

Peanut

Insect damage on peanut at Ubon generally was negligible, but damage at Pimai was serious. The most destructive insect pests were the leaf miner (*Stomopteryx subsecivella*) and the leaf roller (*Lamprosema* spp). The leafhopper (*Empoasca* sp.) was also observed, but at low density. Insecticide control recommendations for peanut insects are summarized in Table 3.

Observations in research-managed entomology trials indicate that insecticide applications were required within 20 days after plant emergence to reduce damage by defoliating insects. In the cropping pattern trials, all farmers applied monocrotophos three times throughout the growing season.

Maize

The corn earworm *[Heliothis armigera* (Hubner)] and the Asian corn borer [*Ostrinia furnacalis* (Guenee)] were the most common insect pests found on maize, but the populations were too low to cause significant yield reduction.

Second crop transplanted rice

Little insect damage occurred on the second crop of transplanted rice and insecticide control was unnecessary.

Analysis of recommendations

Economic analysis of the insect control recommendations indicated that insecticide control in dry-seeded rice was the most expensive among the first crops grown in Ubon — 22% of total variable cost (TVC) (Table 4). The cost of insect control in mungbean ranked second (14% of TVC). Because insect problems on peanut were few, cost of insect control was only 2% of TVC. In Pimai, the cost of insecticide control in peanut was almost the same as in mungbean.

Table 1. Insect control recommendations in entomology field trials and cropping pattern trials.[a] Ubonratchatani, Thailand, 1978-79.

Growth stage	1978 insect control recommendation			Entomology trials[b]		Cropping[c] pattern trials fields treated	
	Target insect	Insecticide dosage (kg a.i./ha)	cost (US$/ha)	Observed pest incidence	Comments	No.	%
			Prophylactic treatment				
Seedling	Unknown	Carbofuran G (1) basal in seed furrow	39	None		0	0
			Corrective treatment				
Vegetative	Stem borer[d] Gall midge[e]	Carbofuran G (1) apply if 5% silver shoots	39	< 3%	Insecticide unnecessary	4	100
	Planthoppers[f]	MIPC (0.3) spray if 5 insects/hill	5	< 1% insects/hill	Insecticide unnecessary	0	0
Reproductive	Stem borer[d]	Monocrotophos (0.3) spray if 5% deadhearts	6	< 3%	Insecticide unnecessary	0	0
Ripening	Rice bug[g]	Carbaryl (0.6) spray if 4 bugs/m^2	5	None	Insecticide unnecessary	0	0

[a]Cropping pattern: dry-seeded RD7 — RD6. [b]Av of 3 fields tested in 1979. [c]Av of 4 fields. [d]*Chilo polychrysus* and *Tryporyza incertulas*. [e]*Orseolia oryzae*. [f]*Sogatella furcifera*. [g]*Leptocorisa* spp.

Table 2. Insect control recommendations and performance in cropping pattern trials[a] with mungbean (U-Thong 1). Ubonratchatani, Thailand, 1978-79.

Growth stage	1978 insect control recommendation			Cropping pattern trials[b]		
	Target insect	Insecticide dosage (kg a.i./ha)	Cost (US$/ha)	Fields treated for pest		Comments
				No.	%	
Preflowering	Beanfly[c]	Monocrotophos (0.21) after emergence and repeated I week after	7	4	100	1 spray, 2 farmers sprayed carbaryl 0.32 kg a.i./ha
	Leaf minet[d], leaf rollers[e], aphid[f]	Monocrotophos (0.21) 20 and 30 days after crop emergence (two sprays)	7	4	100	1 spray, 1 farmer sprayed carbaryl 0.32 kg a.i./ha
Postflowering	Pod borer[g], aphid	Monocrotophos (0.30) 2 sprays alter flowering	11	3	75	1 spray, 1 farmer sprayed a second application of monocrotophos

[a]Cropping pattern: mungbean - rice (RD7). [b]Av of 4 fields. [c]*Melanagromyza* sp. [d]*Stomopteryx subsecivella.* [e]*Lamprosema indicata,* L. *diemenalis* and *Archips micaceana.* [f]*Aphis glycines.* [g]*Maruca testulalis.*

Table 3. Insect control recommendations in entomology trials and in cropping pattern trials with peanut (Lampang).[a] Pimai, Nakornratchasima, Thailand, 1978-79.

Growth stage	1978 insect control recommendation			Entomology trials[b]		Cropping pattern trials[c]		
	Target insect	Insecticide dosage (kg a.i./ha)	cost (US$/ha)	Observed pest incidence	Comments	Fields treated		Comments
						No.	%	
				Prophylactic treatment				
Preflowering	Leafhopper[d]	Carbaryl (0.32) 2 sprays	5	1 insect: 20 plants 20 DE	Insecticide unnecessary	No spray	–	–
	Leaf roller[e]	Monocrotophos (0.21) 2 sprays	1	41 *Lamprosema* or 26 *Stomopteryx*/ 20 plants			100	All farmers sprayed twice
	Leaf miner[f]			20 DE				
Postflowering	Leaf rollers[e]	Monocrotophos (0.21) 2 sprays	1	16-50% defoliation	–	5	100	All farmers sprayed once
	Leaf miner[f]							
	Cutworm[g]							

[a]Cropping pattern: peanut—rice (RD6). [b]Av of 4 fields, untreated check. DE = days after crop emergence. [c]Av of 5 fields. [d]*Empoasca* spp. [e]*Lamprosema indicata*. L. *diemenalis*, and *Archips micaceana*. [f]*Stomopteryx subsecivella*. [g]*Spodoptera litura* and *Heliothis armigera*.

Table 4. Economic analysis of the insect control recommendations for cropping patterns (first crop before rice) at two sites in Thailand, 1978-79.

Cropping pattern	Insecticide control (US$/ha)			Applications (no.)	All inputs (%/ha)		Insecticide cost:total material cost (%)	Variable cost for insecticide:total (%)
	Insecticide[a]	Labor	Total variable cost		Total material cost	Total variable cost		
Ubon site								
Dry-seeded rice	31	0.93	32	1	99	147	31	22
Yard-long bean	9	3.13	12	34	120	169	8	7
Mungbean	12	8.0	20	2-4	79	140	15	14
Peanut	3	0.93	4	1-2	119	168	3	2
Pimai site								
Mungbean	8	0.63	9	2-3	71	208	11	4
Peanut	13	0.93	14	3	I50	293	9	5

[a]Dry-seeded rice — 1 kg ai carbofuran/ha paddy water application after plant emergence; yard-long bean and mungbean — 0.32 kg ai carbaryl/ ha and 0.21-0.31 kg ai monocrotophos/ha; peanut — 0.21 kg ai monocrotophos/ha.

FUTURE RESEARCH PROGRAMS FOR INSECTICIDE RECOMMENDATIONS

At present, the economic benefit of the insect control recommendations on the cropping patterns has not been fully clarified. Trials on crop loss should be undertaken to determine yield loss due to major insect damage for each growth stage of each crop. In this way the recommended practice can be evaluated against yield losses. Information on the investment cost and benefit for crop protection will provide guidelines on expected farmer adoption.

Mungbean is one of the most insect-susceptible crops. For bean fly control several foliar insecticidal applications are required and the most effective control is a basal application of carbofuran in seed furrow during planting. However, the cost of carbofuran is high and local farmers have not used it. Monocrotophos or dimethoate as foliar applications are alternative methods, but efficacy depends on proper time of application. Other low-cost control methods such as seed treatment with carbofuran (liquid formulation) are suggested for further study.

In peanut, the number of foliar applications could be reduced if insecticide application is based on economic thresholds. A preliminary experiment was designed in 1979 to find the appropriate time of insecticide application for defoliating insects of peanut in Pimai. The experiment was superimposed on a peanut fertilizer trial in a split-plot design. Monocrotophos was sprayed at the rate of 1 kg a.i./ ha depending on the degree of defoliation: 1) weekly (prophylactic), 2)> 25% defoliation, 3) > 50% defoliation, 4) > 80% defoliation.

The number of insecticide sprays ranged from 2 to 9 depending on treatments (Table 5). In the plots with fertilizer, peanut yields were not significantly different among the treatments. In the plot with no fertilizer but insecticide was sprayed every week or at 25% defoliation, yields were greater than in other treatments. The results indicated that fertilized and healthy peanut plants were more tolerant of insect damage — the plants recovered rapidly after the attacking insects were controlled by insecticide. Thus, insecticide sprays could be postponed until the damage on the leaves was up to 50% and only 2 sprays would be required to prevent significant crop loss. On the other hand, more sprays were required for unhealthy plants and insect damage should not be allowed to exceed 25% defoliation. The experiment will be repeated for 2-3 years. Similar research should be done on other crops at cropping systems sites to develop economic thresholds for each crop.

Table 5. Yields of peanut after treatment with insecticide at different levels of defoliation, Pimai, Nakornratchasima, Thailand. 1979-80.[a]

Insecticide spray treatment	Foliar[b] application (no.)	Insecticide control[c] ($/ha)	Yield (kg/ha)	
			Fertilized plot[d]	Nonfertilized plot
Every week	4-9	126	1406	962
At 25% defoliation	2-4	54	1063	763
At 50% defoliation	2-3	50	1094	600
At more than 80% defoliation	2	36	1125	375

[a] Major insects were *Stomopteryx subsecivella*, *Lamprosema* spp., and *Archips micaceana*. Av of 4 fields. [b] 1.0 kg ai/ha monocrotophos for each application. [c] Calculation was made from cost of insecticide, labor costs were not included. [d] 188 kg of 16-20-0 NPK fertilizer/ha applied before planting.

At both sites, insect pests on direct-seeded rice, second-crop transplanted rice, and maize never reached economic injury levels. It is expected that as more farmers adopt these new crops insect populations will increase. Biological factors such as natural enemies of the major insect pests should be identified and other mechanisms suppressing the present pest population in rice and maize should be determined.

NEED FOR BASIC RESEARCH AT EXPERIMENT STATIONS

Adulavidhaya (1978) found that farmers in Northeast Thailand were the poorest in the country. The average yield of rice per unit area was lowest and the price of rice was low compared to that in the Central Plain. Suitable insect control recommendations for farmers in the Northeast must not require much capital. Insect control practices currently recommended are mostly derived from the research results in the Central region where the socioeconomic status of the farmer is much better than that of the farmers in the Northeast.

The use of carbofuran as paddy water application against rice insect pests is common among the farmers in the Central Plain. The variable cost of carbofuran application at the research site was US$39/ha, or 22% of the TVC of rice production. It is impossible for the farmers in the Northeast to adopt such a high-cost control measure.

Monocrotophos applied as foliar spray sometimes show good stem borer control. It is generally known that foliar sprays are much less expensive than paddy water application. New foliar insecticides as well as the time of application should be reinvestigated for control of rice stem borers and the rice gall midge.

Insect-resistant plant varieties are urgently needed for the bean fly on mungbean and the leaf miner on peanut.

More research is needed to identify natural enemies and to find ways of augmenting them. Natural enemy fauna and the role it plays in regulating grain legume insect pests are unknown. The most obvious natural enemies in the cropping systems sites were predators. *Cantheconidea furvellata* Wolff (F. Pentatomidae) was the most abundant and preyed on lepidopterous larvae on yard-long bean, mungbean, and peanut. *Chilomenes sexmaculata* and *Virania discolor* (Coccinellidae) were often observed on those crops. Insecticides recommended against major legume insects should conserve these natural enemies.

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Current insect control recommendations for rice-based cropping patterns in Sri Lanka

M. H. J. P. Fernando

The development of suitable insect control technologies for the cropping patterns of small-scale farmers in the tropics requires an understanding of the total environment of small farms and of the establishment, development, behavior, and population dynamics of the insects involved as modified by the cropping patterns. Insect control innovations that require fundamental changes on the part of the farmers are likely to prove unacceptable. Yet, there are good prospects for improving the efficiency of crop management through gradual introduction of improved insect control technology that is harmonious with the farmers' capabilities.

These are the basic concepts guiding entomological research at the cropping systems site in Walagambahuwa, which represents about 3,000 tank-based settlements with a total of 104,200 ha of wetland in the dry zone of Sri Lanka.

The baseline survey in that village revealed that the system of agriculture was predominantly rice in the paddy tract below the tank with *chena* (slash and burn) in the highlands. The farmers normally wait until the tank is filled by the monsoon from October to December to start cultivation in the paddy tract. They begin work on the *chena* with the onset of rains. The farmers were able to cultivate the total paddy area only once in 6-7 years because of insufficient water. Although the average monthly income of a farm family never exceeded Rs 200 (Rs 16.80 = US$1), which came mainly from the *chena*, there was adequate labor from as many as 5.27 family members.

Laying emphasis on timely cultivation of the paddy tract and considering the resources available, the agronomists of the cropping systems team developed a rice-based cropping pattern that enabled the farmers of Walagambahuwa to plant either two crops of rice or a rice crop followed by other field crops within a year. Thus to develop an insect control strategy for the cropping systems, information such as farmers' knowledge, capabilities, cropping patterns, and economic position was available.

In Walagambahuwa, no substantial entomological work had been carried out because of the shortage of staff. In addition, farmers whose fields are used for entomological trials must be compensated for any crop losses incurred. As no

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provision was made for cash compensation to be offered, other forms of compensation were extended such as preparation of the fields, harvesting, or threshing.

Limitations of staff and budget prevented extensive trials at the site but insect monitoring, advisory work, and information gathering on farmer insect control practices were done. This paper highlights the entomological activities at Walagambahuwa for the past 4 years.

CURRENT INSECT CONTROL PRACTICES OF WALAGAMBAHUWA FARMERS

The insect control practices of Walagambahuwa farmers for five cropping seasons —*maha* 1976-77 to *yala* 1979—are shown in Table 1. Table 2 shows the economic analysis of the practices.

Study of current insect management practices of farmers has identified the following as the main obstacles to adequate control of insects:

- a general lack of awareness of insect problems,
- difficulty of getting farmers to accept change,
- nonavailability of recommended insecticides in the area,
- economic constraints, and
- nonavailability of sprayers.

Interviews indicated that farmers could identify only a few rice pests — the leaf roller, planthoppers, and rice bug. They recognized stem borer damage but not the stem borer moths. The damage by gall midge passed unnoticed and thrips damage was rarely believed to be caused by an insect.

Most of the elderly farmers were generally nonreceptive to instructions and advice. Most still believed in traditional systems of insect control. Even where they applied insecticides, they used sublethal dosages and rarely followed the recommendations. In the remote villages, farmers were unable to buy the recommended insecticides, which were unavailable in the area — an institutional problem.

The main reason for not using the correct insecticide is attributed to the economic constraints of the farmer at the time of need. Most of the farmers are forced to obtain their day-today requirements including agrochemicals on credit from the nearest shop. As shown by the surveys, the farmers have only a meager income, which they receive mostly at the end of the *maha* season. At the beginning of the season in the following year, they are in debt and have sold or mortgaged some of the belongings that they procured at the end of the previous season. This cycle is aggravated if there is crop failure during a season.

In Walagambahuwa, few farmers had sprayers because of the high cost of the equipment and farmers' lack of cash.

A METHODOLOGY FOR DEVELOPMENT OF INSECT CONTROL PRACTICES IN FARMERS' FEILDS

Information on insect complexes associated with cropping patterns is scarce and thorough surveys are needed to have a complete list of insects associated with each pattern. After identifying the insects, it is also important to determine their natural enemies and the latter's efficiency and prevalence in each cropping pattern.

Table 1. Performance of insect control recommendations in farmers' fields, Walagambahuwa, Sri Lanka. 1976-77 maha season to 1979 *yala.*

Growth stage	Insect control recommendation			Entomology trials		Cropping pattern trials[a]				
	Target insect	Insecticide and dosage ha	Cost (US$/ha)	Observed pest Incidence	Comments	Fields treated No.	Fields treated %	Farmers (no.) using recommended insecticide	Farmers (no.) using recommended dosage	Comments
				1976-77 maha season (11 farmers)						
Seedling	Thrips[b]	Dimethoate 40 EC (25 fl oz)	3.3	2% damaged leaves	Insecticide unnecessary	1	9	0	0	Farmers used monocrotophos
Reproductive	Leaf folder[c]	Monocrotophos 60 EC(35-50fl oz)	8.3	50% damaged leaves	Insecticide necessary	10	90	10	4	–
Ripening	Rice bug[d]	y-BHC 10% dust (50-75 lb)	6.2	2 bugs/ 10 hills	Insecticide unnecessary	10	0	–	–	–
				1977-78 maha season (30 farmers)						
Seedling	Thrips[b]	Dimethoate 40 EC (25)	3.3	2% damaged leaves	Insecticide unnecessary	10	0			
Vegetative	Stem borer[e]	Carbofuran 3 G Diazinon 10 G (50 lb)	16.5	10% dead-hearts	Insecticide necessary	4	13	2	2	Some farmers used monocrotophos + endrin
	Leafhoppers[f]	Propoxur 29 EC (35 fl 07)	5	200 insects; hill	Insecticide necessary	6	20	1	1	Some farmers used monocrotophos + aldrin
Ripening	Rice Bug[d]	y-BHC 10% dust (50-75 lb)	6	30 bugs/25 hills	Insecticide necessary	2	7	0	0	2 farmers used monocrotophos and paddy bug was controlled
				1978-79 maha season (20 farmers)						
Seedling	Thrips[b]	Dimethoate 40% EC (25)	3.3	30% damaged leaves	Insecticide necessary	11	55	0	0	Farmers used endosulfan + monocrotophos
Vegetative	Yellow stem borer[e]	Carbofuran 3% G (50 lb.)	18	2.2% dead-hearts	Insecticide unnecessary	10	0	–	–	–

CONTINUED ON NEXT PAGE

TABLE 1 CONTINUED

Growth stage	Insect control recommendation			Entomology trials		Cropping pattern trials [a]				
	Target insect	Insecticide and dosage ha	Cost (US$/ha)	Observed pest incidence	Comments	Fields treated		Farmers (no.) using recommended insecticide	Farmers (no.) using recommended dosage	Comments
						No.	%			
Reproductive	Leaf foldel[c]	Monocrotophos 60 EC (35-50)	8.3	40% damaged leaves	Insecticide necessary	20	100	20	6	Many farmers did not use the correct concentration
Ripening	Paddy bug [d]	g-BHC 10% dust (50-75 lb)	6	3 bugs/25 hills	Insecticide unnecessary	10	0	–	–	–
				1978 yala season (20 farmers)						
Seedling	Thrips [b]	Dimethoate 40 EC (25)	3.3	20% damaged leaves	Insecticide necessary	12	10	0	0	Farmers used monocrotophos
Vegetative	Stem borer[e]	Carhofuran 3 G, Diazinon 10 G (50 lb)	16.6	16% dead leaves	Insecticide necessary	14	70	6	3	Many farmers did not use the recommended insecticide
	Planthoppers [g]	Propoxur 20 EC (35 fl oz)	5	10 insects/hill	Insecticide unnecessary	10	–	–	–	–
Ripening	Rice bug [d]	g-BHC 10% dust (50-75 lb)	6	2 bugs/25 hills	Insecticide unnecessary	I0				–
				1979 yala season (20 farmers)						
Seedling	Thrips [b]	Dimethoate 40 EC (25)	3.3	24% damaged leaves	Insecticide necessary	13	65	0	0	Farmers used monocrotophos
Vegetative	Stem borer [e]	Carbofuran 3 G (15-20 lb)	18	1% deadhearts	Insecticide unnecessary	0	0	–	–	–
Reproductive	Leaf folder [c]	Monocrotophos 60 EC (35-50)	8.3	30% damaged leaves	Insecticide necessary	18	90	14	6	4 farmers used endosulfan
Ripening	Rice bug [d]	g-BHC 10% dust (50-75 lb)	6	I bug: 25 hills	Insecticide unnecessary	0	0	–	–	–

[a]The number of farmers involved in the cropping pattern trials in each season is in the parentheses. [b]*Baliothrips biformis.* [c]*Cnaphalocrocis medinalis.* [d]*Leptocorisa acuta.* [e]*Tryporyza incetulas.* [f]*Nephotettix* spp. [g]*Nilaparvata lugens.*

Table 2. Economic analysis of the insect control recommendations for cropping patterns, Walagambahuwa, Sri Lanka, 1976-79.

Crop year, season	Cropping pattern	Cost (US$/ha) of recommended practice				Cost (US$/ha) of farmers' practices							Yield (t/ha)
		Benefit	Insecticide	Labor	Benefit-cost (1)	Insecticide	Labor	Total material cost	Total material cost	Total variable cost	Insecticide cost total material cost	Variable cost of insecticide total cost	
		(1)	(2)	(3)	(2+3)	(4)	(5)	(4)+(5)	(6)	(7)	(4÷6)	(4+5)÷7 (%)	
1976-77 *maha*	Dry seeded	0	17	2.4	0	5	0.8	5.8	34	144	15	4	2.85
1977-78 *maha*	Wet seeded	0	32	4	0	1.6	0.8	2.4	34	159	5	1.5	3.44
1978-79 *maha*	Dry seeded	0	34	4.8	0	3	1.2	4.2	35	179	8.5	2.5	3.13
1977 *yala*	Wet seeded	0	0	0	0	4.5	0.8	5.3	32	169	14	3	2.85
1978 *yala*	Wet seeded	0	33	4	0	3	1	4	37	191	8	2	3.05
I979 *yala*	Wet seeded	0	34	4.8	0	4	1.2	5.2	35	211	11.5	2.5	3.87

The field testing of various insect control methods must be compatible with farmers' resources. Efforts should also be made to minimize the insecticide requirement for each cropping pattern.

Cultural control

Research to reduce pest populations by cultural methods should receive priority. The main weapons of cultural control are planting time and crop rotation. To minimize insect damage by crop rotation the best results are usually achieved by having botanically unrelated crops following one another. But polyphagous insects, such as those belonging to Noctuidae and Acrididae, have the capacity to build up across crops with time, and attack rotating crops.

Pest-resistant varieties

Promising pest-resistant varieties of rice and grain legumes should be tested at each cropping systems site. In Sri Lanka rice varieties resistant to the brown planthopper and gall midge are available.

Population dynamics studies

Population dynamics study is feasible at cropping systems sites. An assistant could be trained to monitor insect populations by light trapping and crop sampling. Continued collection and analysis of such data will help predict insect peaks. Such information will allow farmers to time sprays or adjust sowing times to avoid peak periods.

Status of insect control recommendations for rice-based cropping patterns in Bangladesh

S. Alam, A. N. M. R. Karim, and C. M. Nurullah

Studies on rice-based cropping systems in Bangladesh were initiated by the Bangladesh Rice Research Institute (BRRI) in 1974. Although BRRI entomologists monitored insect pest incidence and recommended control measures, they were not a part of the cropping systems team. In 1978 an entomologist was assigned to the team.

Recommendations for insecticide use for insect pests of rice, jute, vegetables, pulses, and oil seeds were formulated in 1972. No insect control recommendations have been developed for wheat, a new crop.

In the 1979 *aman* season (October), a superimposed insecticide trial was conducted on three farmers' fields of transplanted rice in a rice - wheat cropping pattern at Salna, Joydebpur. The plots received 1 to 3 sprayings of 2.5 kg a.i. diazinon/ha from tillering to flowering stages. Three applications were about the same as existing extension recommendations.

Insect infestations in the trial were low (Table 1). Plots receiving insecticide produced 0.5 t/ha more rice than the untreated plots, and high economic gain (about 13 times) was achieved.

Presumably, the higher yields in the protected plots did not result from insect control because the insect infestations were low. Some physiological aspects may be involved. The trial should be repeated over several years.

Our present activities indicate that extensive trials at cropping systems sites are needed to formulate insect control recommendations that are profitable and acceptable to farmers.

Divisional head, principal scientific officer, and senior scientific officer, Bangladesh Rice Research Institute, Joydebpur, Dacca.

Table 1. Performance of insect control recommendations for rice in superimposed trials in a rice - wheat cropping pattern during 1979 aman.[a] Joydebpur, Bangladesh.

Growth stage	Observed pest incidence[b]					Yield (t/ha)				Cost of recommended practice			Benefit: cost
	T3	T2	T1	Untreated T0	Comment	T3	T2	T1	T0	Benefit (US$/ha)	Insec-ticide (US$/ha)	Labor (US$/ha)	
Seedbed	Not done	Notdone	Notdone	–	–								
Vegetative	Less than 0.5% DH (stem borers)	Less than 0.5% DH	Less than 0.5% DH	Less than 5% DH	Insecticide unnecessary; recommendation should be revised.								
	No galls (gall midge)	Very few galls	Very few galls	Very few galls	Insecticide unnecessary; recommendation should be revised.	3.56	3.61	3.57	3.06	129	6	4	12.9
	3 in 1-9 scale (grasshopper)	3 in 1-9 scale	3 in 1-9 scale	3 in 1-9 scale	Insecticide unnecessary; recommendation should be revised.								
Reproductive	Less than 0.1% WH (stem borer)	Less than 0.1% WH	Less than 0.1% WH	Less than 0.1% WH	Insecticide unnecessary; recommendation should be revised.								

[a]Av of 3 replications conducted as superimposed trials in farmers' fields during 1979 aman. [b]DH=stemborer dead heart, WH=stem borer whitehead. Diazinon 60 EC 2.5 kg a.i./ha was sprayed at tillering, booting, and flowering stage for 3 applications (T3), at tillering and booting stages for two applications (T2), and at tillering stage for one application (TI).

Developing insect control recommendations for cropping patterns in the Philippines in 1980

J. A. Litsinger

There are many active or proposed cropping systems programs in the Philippines but only two currently have an entomology component with research staff on site:

1. the joint International Rice Research Institute-Philippine Bureau of Plant Industry program initiated in 1975 in Iloilo and Pangasinan provinces, and
2. the World Bank-Philippine Ministry of Agriculture program initiated in 1978 in Agusan del Sur, Bukidnon, and Capiz provinces.

Because of the larger data base from Iloilo and Pangasinan, this paper concentrates on those two sites, which have rainfed wetland environments. The current recommendations for the second program, based on 1 year's results, are summarized. They are of interest because those sites represent mainly dryland environments in high-rainfall areas.

This paper provides an assessment of the performance of current insect control technology at the farm level in Philippine cropping systems programs and notes the need for further research at the farm level and at experiment stations in support of those programs.

DEVELOPMENT AND ASSESSMENT OF CURRENT RECOMMENDATIONS

Rainfed wetland - Pangasinan

The current cropping patterns recommended for Pangasinan are:

- dry-seeded rice (DSR) - mungbean,
- green maize - transplanted rice (TPR) - mungbean, and
- DSR - TPR - mungbean

Dry-seeded rice. Evaluation of DSR began in 1977. As the cultural practice was new, there was no national recommendation for insect control. No serious insect pest problems were anticipated, but the unflooded initial stage could favor some soil pests. Therefore the starting practice was 1.5 kg a.i. carbofuran G/ha placed in seed furrows. Additional insecticide usage was based on economic thresholds.

The leaf folder exceeded the economic threshold of 10% damaged leaves and prompted an application of 0.75 kg a.i. endosulfan/ha. No soil pests were observed

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but the yield was significantly higher than that of the untreated control, giving a US$105 benefit from insecticide (Table 1). This high yield increase was more than what could be explained by leaf folder damage.

The recommended practice was as good as complete protection (6.4 t/ha), indicating no benefit from protecting DSR at the ripening stage. The value of the insecticide applied was high (US$59/ha), which gave an unfavorable benefit-cost (B:C) ratio. A favorable B:C needs to exceed 1.9 based on what Pangasinan farmers accept on their existing system. However, the high yield gave a favorable net return for the crop.

Researcher-managed trials showed that the dosage of carbofuran could be lowered to 0.5 kg a.i./ha. That rate was used in 1978 and in 1979; however, it did not result in a significant yield increase from the untreated control. The 1980 recommendation will be based on economic thresholds with no prophylactic treatments. The carbofuran yield response in 1977 was due not to insect control but to a direct stimulation of rice growth (Litsinger et al 1981). Apparently a 0.5 kg a.i./ha dosage was too low to produce this response.

Further research is needed to define the dosage response function of carbofuran on DSR. However, increasing insecticide cost may be a constraint because DSR still represents a high risk: it may fail because of drought or weeds. Furthermore, a higher dosage of carbofuran as a recommended practice gave a low B:C in 1977. However, data from the farmers' existing system in 1978 were encouraging. Farmers spent more on material costs (US$69/ha) for DSR than for any other rice crop or mungbean (Table 2).

Single-crop transplanted rice. The initial insect control recommendation for TPR in 1976 was based on the national Masagana 99 practice, which called for extensive use of insecticides — 2 kg a.i. carbofuran granules/ha broadcast 3 days after transplanting (DT) and 0.75 kg a.i. monocrotophos sprays/ha 25, 40, and 60 DT. This resulted in a significantly higher yield than in the untreated control and was as good as complete protection (Table 1). Even though the benefit from insecticide was high, the high cost resulted in an unacceptable B:C.

The cost of the recommended practice was much higher than what farmers themselves spend for insecticide on this crop (Table 2). Yield loss partitioning and insect pest monitoring showed that the recommended practice protected the correct growth stages — the vegetative against the whorl maggot, caseworm, stem borer deadhearts, and the reproductive stage against stem borer whiteheads.

Therefore, to lower costs, the dosage of carbofuran in 1977 was reduced to 1.5 kg a.i./ha and the reproductive stage protection was based on the economic threshold — spray 0.75 kg a.i. endosulfan/ha when 3% deadhearts is surpassed. The recommended practice performed well in 1977 compared to the untreated (3.9 t/ha) and the complete protection (4.7 t/ha) fields, and gave a favorable benefit (US$105/ha). However, the lower yield that year gave an unfavorable 1.7 B:C despite the reduced insecticide cost (Table 1).

In 1978 the cost of insecticide was lowered further by reducing the dosage of carbofuran to 1 kg a.i./ha.

Insecticide cost was US$31/ha and the recommended practice produced a high benefit (US$105/ha) and a very favorable 3.3 B:C despite low yields. The yield of the

Table 1. Yields of rice and mungbean, and costs and returns with recommended insect control practices in entomology trials. Pangasinan, Philippines. 1975-79 . [a]

Crop, year	Fields (no.)	Yield (t/ha)[b]			Recommended practice				
		Untreated	Complete control	Recommended practice	Benefit from insecticide (US$/ha)	Insecticide cost (US$/ha)	Labor (h/ha)	Benefit: cost	Net returns (US$/ha)
Dry-seeded rice									
1976	–	–	–	–	–	–	–	–	-
1917	8	5.5 b	6.4 a	6.2 a	105	59	20	1.7	419
1978	6	3.6 a	3.4 a	3.7 a	0	15	4	0	189
1979	6	4.1 a	4.4 a	4.4 a	0	15	4	0	294
Single transplanted rice									
1976	5	3.8 b	4.7 a	5.3 a	225	130	52	1.6	362
1977	7	3.9 b	4.7 a	4.6 a	105	59	20	1.7	333
1978	6	2.4 c	3.1 a	3.1 b	105	31	4	3.3	110
1979	6	4.3 c	5.6 a	5.0 b	105	57	36	1.7	379
Second crop transplanted rice									
1976	5	2.7 b	3.1 a	3.4 a	105	130	52	0.8	85
1977	7	1.9 a	2.2 a	1.9 a	0	45	4	0	0
1978	3	1.4 b	2.2 a	2.2 a	120	30	4	3.9	46
Mungbean									
1975	5	0.2 c	0.9 a	0.6 b	248	30	8	8.0	151
1916	6	0.2 b	0.9 a	0.6 a	248	30	48	6.1	152
1977	15	0.2 c	1.3 a	0.9 b	434	41	48	9.0	318
1978	7	0.3 b	1.2 a	1.3 a	558	28	48	15.9	502

[a]Rice= US$0.15/kg, mungbean=US$0.62/kg, 1 labor h = US$0.14. [b]In rows, means followed by a common letter are not significantly different ($P \leq 0.05$).

Table 2. Yields of rice and mungbean, and costs and returns in farmers existing cropping system. Pangasinan, Philippines, 1975-79.[a]

Crop, year	Fields (no.)	Insect control				Material cost (US$/ha)	Variable cost (US$/ha)	Yield (t/ha)	Net returns (US$/ha)
		Insecticide (US$/ha)	Applications (no./field)	Labor (h/ha)	Total cost (US$/ha)				
Dry-seeded rice									
1976	–	–	–	–	–	–	–	–	–
1917	–	–	–	–	–	–	–	–	–
1978	13	6	1.5	7	4	69	219	2.21	113
1979	–	–	–	–	–	–	–	–	–
Single transplanted rice									
1976	83	2	0.6	5	3	34	150	1.40	60
1977	131	4	0.9	8	5	52	181	2.16	143
1978	32	2	0.5	4	3	59	200	2.60	190
1979	–	–	–	–	–	–	–	–	–
Second crop transplanted rice									
1976	26	4	0.9	8	5	50	178	1.92	110
1977	8	4	1	I	5	33	140	1.95	152
1978	38	8	1.5	11	9	66	178	1.99	121
Mungbean									
1915	–	–	–	–	–	–	–	–	–
1976	63	5	1.3	13	7	31	82	0.22	54
1977	116	5	1.5	12	7	31	55	0.15	38
1978	53	8	2.3	19	11	35	86	0.24	63

[a] Rice = US$0.15/kg, mungbean = US$0.62/kg, 1 labor h = US$0.14.

recommended practice was significantly lower than that of the complete control (3.7 t/ ha) because of late-season stem borer attack.

In 1979, the recommended practice included two prophylactic application of endosulfan for late-season stem borer in addition to the soil-incorporated carbofuran granules (1 kg a.i./ ha) at planting. The 1979 recommendation was also suboptimal; it yielded significantly less than the complete control. Benefit from insecticide was relatively low and B:C was also low (1.7). The endosulfan treatment failed to control late-season stem borer.

The low B:C in 1979 was traced to the high cost of insecticide and the failure of endosulfan to effectively control stem borers. The prophylactic carbofuran treatment was effective but too costly. Therefore in 1980 no prophylactic treatments were recommended and control recommendations were based on economic thresholds. Although more expensive than endosulfan, chlorpyrifos will be recommended for late-season stem borer.

The economic threshold recommendations for TPR were in line with the farmers' present practices. Farmers spent an average of US$24/ha on insecticide and averaged 0.5-0.9 application per field (Table 2). These low figures reflect the fact that most farmers do not use insecticide on this crop. Few farmers know what signs to look for to determine proper insecticide timing, and it is doubtful that those who apply insecticide as sprays are getting any net return from their low-yielding crop. Yields from the existing pattern (1.4–2.6 t/ ha) were low compared to those of the insecticide-untreated plots in the entomology trials (2.1-3.8 t/ha, Table 2) for 1976-78. This was partly due to choice of variety.

Second crop transplanted rice. As with single crop TPR, the 1976 recommended practice for second crop TPR was the national recommendation for irrigated rice. This proved expensive (US$130/ ha) and resulted in a highly unfavorable B:C even though the yield was significantly higher than in the untreated control but equal to the complete control. There appeared to be little room for yield improvement with insecticides (Table 1).

The recommendation for 1977-79 followed the same path of development as the single TPR crop. In 1977 there was no yield gain from the recommended practice but in 1978 the recommendation was highly favorable. The yield gains came from the soil-incorporated carbofuran rather than from the late-season stem borer protection. In 1978 the carbofuran amply paid for itself — cost was US$30/ha and benefit was US$120/ha.

Farmers now spend an average of US$5-9/ha on insecticide for 1.5 applications (Table 2). US$30/ ha is higher than what they now spend but it is not unreasonable. Farmers' material cost is US$66/ha and insecticide represents 8-14% of that amount. US$30/ ha represents 29% of material costs for the improved cropping pattern management package. The 1979 and 1978 results are similar. The recommendation for carbofuran will continue.

Mungbean. The national recommendation for mungbean was tested in 1975 (1 kg a.i. carbofuran granules/ ha in the seed furrow at planting). The resulting yield was attractive and gave a benefit of US$248/ ha and a highly favorable B:C (Table 1). Farmers averaged US$5/ ha for insecticide expenses (Table 2), but their yield in 1976

practice failed to produce a significant yield increase.

The low insect pest incidence in Iloilo is due to the early planting date. The white stem borer prevalent in that rainfed area is a potential pest of an early planted crop because it estivates in the rice stubble during the dry season fallow and comes out within 10 days of the first monsoon rain, usually in April (Litsinger et al 1981). Despite its adaptation to the rice-free fallow period, its numbers are probably reduced because the land preparation for wet-seeded rice no doubt kills larvae that initially infest volunteer rice.

In 1978, when land preparation was significantly delayed (June) because of the slow onset of monsoonal rains, the stem borer became abundant during the reproductive stage.

The large yield increase in 1978 was probably due to growth stimulation by carbofuran. However, as this occurred in only 1 of 3 years, the recommended practice based on economic thresholds is justified. Endosulfan for stem borers did not produce yield gains. As in Pangasinan chlorpyrifos will be used in 1980.

The economic threshold levels were raised in 1980 to reflect the higher cost of insecticide as well as an inability to show a significant yield response from their usage in 1977 and 1978. There is need to reevaluate the threshold levels themselves and also the efficacy of the insecticides that are recommended if the thresholds are exceeded. The use of economic thresholds is in line with the level of insecticide use recorded from the farmers' existing system. Farmers spend from US$2.2 to 2.6/ha for 0.9-1.3 insecticide applications per field (Table 4).

The value of insecticides used in the recommended insect control practice is only US$13-20/ha. The lower cost in the farmers' existing system reflects the fact that either many farmers do not apply insecticide to rice or those that do underdose.

Second crop rice. The insect control recommendation for the second crop TPR in Iloilo has taken the same path of development as that in Pangasinan for the same reasons. The initial recommended practice in 1976 was too costly and produced a low B:C (the acceptable B:C for Iloilo farmers is 2.0), although it gave a significantly higher yield than the untreated control and high benefit and net returns (Table 3). The recommendation was changed by reducing the required dosage of carbofuran from 2 kg a.i./ha in 1976 to 1 kg a.i./ha in 1977 and replacing the prophylactic sprays with economic thresholds.

The 1977 crop was severely affected by drought and the recommended practice resulted in zero benefit and a US$68 negative net return.

The effect of carbofuran on rice growth was particularly apparent in the second crop TPR in Iloilo (Litsinger et al 1981). The 1 kg a.i./ha dosage incorporated into the soil gave a favorable B:C in 1978 despite low yield and returns. The extraordinary yield response in the complete control (4.7 t/ha) was traced to growth stimulation by carbofuran in the seedbed (dry seedbed). It gave a 2.4 t/ha increase over the control on a crop that experienced only stem borer whiteheads and rice bug. Although surpassing economic thresholds, the pests' numbers could not explain all of the yield gain from insecticide usage. There is need to look into the environmental or cultural factors that cause such high carbofuran responses in rice.

The 1980 recommendation calls for carbofuran (1 kg a.i./ha) soil incorporated before transplanting plus economic thresholds. The cost of insecticide (US$30/ha) is

Table 4. Yields of rice and cowpea, and costs and returns of the recommended insect control practices in farmers' existing cropping system in Iloilo, Philippines, 1976-78.[a]

Crop, year	Fields (no.)	Insect control				Material cost (US$/ha)	Variable cost (US$/ha)	Yield (t/ha)	Net returns (US$/ha)
		Insecticide (US$/ha)	Applications (no./field)	Labor (h/ha)	Total cost (US$/ha)				
First crop rice									
1976	163	2.5	0.9	8.8	3.1	33	136	1.99	162
1977	188	2.2	1.2	7.8	3.3	52	163	2.61	229
1978	154	2.6	1.3	6.7	3.5	59	117	2.89	251
Second crop rice									
1976	80	2.3	0.9	9.0	3.5	46	138	1.45	80
1977	118	3.6	1.2	8.9	4.8	56	162	2.22	171
1978	133	3.2	1.2	7.6	4.2	65	166	2.13	244
Cowpea									
1976	26	2.4	0.3	3.9	2.9	35	50	0.04	-35
1977	15	0.3	0.1	3.3	0.8	6	14	0.10	25
1978	18	0.9	0:2	3.5	1.4	10	17	0.14	38

[a]Rice = US$0.l5/kg, cowpea = US$0.38/kg, 1 labor h = US$0.14.

(0.2 t/ha) was no better than that of the untreated control in the entomology trials (Table 1).

However, the 1975 recommendation did not call for postflowering protection. In other words, the complete protection treatment did not give "complete protection."

In 1976 carbofuran granules were replaced with sprays (0.25 kg a.i. monocrotophos/ha 5, 15, 25, and 35 days after crop emergence [DE]), which maintained the cost at US$30/ha. This recommendation proved to be highly favorable, giving a 6.7 B:C. However, trials elsewhere indicated that this could be improved in 1977 by changing postflowering protection. Accordingly a 0.75 kg a.i. endosulfan spray was added at 35 DE and preflowering monocrotophos sprays were at 2 and 12 DE.

In 1977 there was a heavy attack of *Heliothis* at postflowering and the one endosulfan spray was inadequate. Therefore, a second application was applied 45 DE. The recommended practice gave higher yields than the untreated control, a high benefit from insecticide and a high B:C (Table 1). Still there was room for improvement as the complete control yielded significantly higher than the recommended practice.

In 1978 carbaryl replaced endosulfan and spraying began earlier 25 and 35 DE for *Heliothis control.* Insecticide cost was low and gave a high yield, high insecticide benefit and, consequently, a high B:C.

Farmers near the entomology and cropping pattern trials saw the high yields obtained from increased insecticide usage on mungbean and increased their usage of insecticide from 1.3 to 2.3 sprays. But because they did not pay strict attention to proper timing and to using the correct insecticides, their yields did not improve over that of 1976 (0.2 t/ha).

It is felt that the cost of insecticide for mungbean is not excessive but perhaps places demands on the farmer by asking him to spray at specific times whether or not pests are observed. The time for planting mungbean (December) occurs at the time of harvest for the single crop TPR, which may explain why farmers are hesitant to apply insecticides during the preflowering stage. Another likely reason is that they do not recognize the principal preflowering insects and therefore do not see any reason to spray. It would be helpful if a seed treatment for mungbean could be developed. It would reduce labor demands and eliminate the need for proper timing for preflowering insects. Farmers recognize pod borers and direct most insecticide application for control of those pests.

Rainfed wetland - Iloilo

The current cropping pattern at Iloilo is wet-seeded rice (WSR) - TPR - cowpea or mungbean.

First crop wet-seeded rice. The national recommendation for irrigated rice was followed in 1976, and included an application of carbofuran (2 kg a.i./ha) and 3 monocrotophos sprays (0.75 kg a.i./ha). No insect pests were observed and this costly insecticide recommendation was unnecessary. Identical yields were obtained in complete control, recommended practice, and untreated plots (Table 3).

As prophylactic insecticide applications failed to increase yields, the 1977 recommendation was economic thresholds. That year 1 spraying of 0.75 kg a.i. endosulfan/ ha was directed at reducing stem borer deadhearts. However, the recommended

Table 3. Yields of rice and cowpea, and costs and returns of the recommended insect control practices in entomology trials in Iloilo, Philippines, 1976-78.[a]

Crop, year	Fields (no.)	Yield[b] (t/ha)			Recommended practice				
		Untreated	Complete control	Recom-mended practice	Benefit from insecticide (US$/ha)	Insecticide cost (US$/ha)	Labor (h/ha)	Benefit: cost	Net returns (US$/ha)
First crop rice									
1976	6	5.1 a	5.1 a	5.1 a	0	130	52	0	389
1977	6	4.8 a	5.5 a	5.3 a	0	13	16	0	561
1978	5	3.6 b	5.0 a	4.2 b	0	20	32	0	363
Second crop rice									
1976	6	3.9 b	5.0 a	5.2 3	195	130	52	1.4	453
1977	4	1.4 b	1.8 a	1.4 ab	0	44	20	0	-68
1978	5	2.3 c	4.7 a	2.9 b	90	30	4	2.6	174
Cowpea									
1976	5	0 c	0.13 a	0.02 b	8	68	48	0.1	-135
1977	12	0.29 b	0.54 a	0.38 ab	0	4	16	0	- 25
1978	4	0.07 b	0.42 a	0.30 a	87	22	48	3.0	- 16

[a]Rice = US$0.15/kg, cowpea = US$0.38/kg, 1 labor h = US$0.14. [b]In a row, means followed by a common letter are not significantly different ($P \leq 0.05$).

much higher than farmers now spend for TPR (US$2.3—3.6/ha) (Table 4). This low cost again reflects the fact that many farmers do not apply any insecticide and those that do, underdose. However, in terms of total material cost, the recommended practice (US$115/ha) is not out of line with what farmers now spend (US$65/ha).

Cowpea. It has been difficult to improve cowpea with the use of insecticides even though yield losses of 100% have been recorded (Table 3). Crop establishment methods are essential to a good stand under conditions of a sudden cessation of rains typical in Iloilo.

The development of the recommended practice for cowpea followed the same path of development as mungbean in Pangasinan. At first the role of pod borers was underestimated and thrips were not recognized as a pest. In 1976, the complete control treatment did not prevent insect damage.

Researchers are faced with a dilemma. In 1978 a highly significant yield (0.3 t/ha) was produced using the recommended practice (0.25 kg a.i. monocrotophos/ha 2 and 12 DE, and 0.75 kg a.i. carbaryl/ha 35 DE). The cost of the three sprays was US$22/ha, which produced a benefit of US$87/ha but a negative net return of US$-16/ha (Table 3).

Yield will be sacrificed if the number of sprays is reduced further. The 1979 entomology trial had one treatment that evaluated two sprays using the least possible cost that current technology allowed (0.25 kg a.i. dimethoate/ha 5 DE, and 0.75 kg a.i. carbaryl/ha 30 DE).

Farmers now spend only US$10/ha materials for cowpea and receive positive but low net returns of US$38/ha (Table 4). Most farmers do not apply any insecticide. Fertilizer recommended now costs US$36/ha.

There is a need to develop better agronomic practices and increase cowpea's yield potential as well as to develop low-cost insecticide recommendations. Seed treatment with insecticide should reduce costs.

FARMER-MANAGED CROPPING PATTERN TRIALS

Before each crop year, the research team prepares insect control recommendations. Farmer-cooperators who will grow the patterns meet before each crop is planted and the recommendations are explained by the research staff. Insecticides are provided free and given to each farmer by the barrio assistants who live in the village. Farmers are allowed to apply the insecticides to the cropping pattern in any manner they choose.

Allowing the farmers to manage their own insect control with free inputs provides a measure of how the recommendations will be executed in production programs in terms of labor constraints and management capability. Information on a farmer's execution of the insect control recommendation is available from the daily records gathered by economists at the sites.

The farmers' insect control performance for the 1978-79 crop year in Pangasinan and Iloilo are summarized in Tables 5-6. The tables allow comparison with researcher-managed trials, where insecticides were applied by entomologists and with the farmers' existing system in fields outside the cropping pattern trials. Detailed profiles of farmers' practices are summarized in Tables 7-13.

Table 5. Yields of rice and mungbcan, and costs and returns in cropping pattern trials. Pangasinan, Philippines, 1975-79. [a]

Crop, year	Fields (no.)	Insect control			Material cost			Yield (t/ha)	Net returns (US$/ha)
		Insecticide (US$/ha)	Labor (h/ha)	Total cost (US$/ha)	Fertilizer (US$/ha)	Total (US$/ha)	Variable cost (US$/ha)		
Dry-seeded rice									
1976	6	25	5	26	128	189	456	5.1	309
1977	47	21	24	24	71	145	444	4.1	216
1978	48	24	16	26	50	129	376	3.6	164
Single transplanted rice									
1976	39	26	28	30	68	121	330	3.2	175
1977	20	54	21	57	81	156	343	3.6	200
1978	10	30	4	31	35	101	340	3.9	238
Second crop transplanted rice									
1976	26	54	18	57	64	147	359	3.7	196
1977	41	68	23	71	90	166	312	2.5	63
1978	32	34	12	36	47	105	289	2.6	101
Mungbean									
1975	26	52	39	57	29	108	207	0.7	220
1976	12	26	36	29	40	112	184	0.5	80
1977	26	57	79	67	42	146	260	0.9	273
1978	39	40	59	47	32	98	190	0.5	117

[a] Rice = US$0.15/kg, mungbean = US$0.62/kg, 1 labor h = US$0.14.

Table 6. Yields of rice and cowpea, and costs and returns in cropping pattern trials. Iloilo, Philippines, 1976-78.[a]

Crop, year	Fields (no.)	Insect control			Material cost		Total variable cost (US$/ha)	Yield (t/ha)	Net returns (US$/ha)
		Insecticide (US$/ha)	Labor (h/ha)	Total cost (US$/ha)	Fertilizer (US$/ha)	Total (US$/ha)			
First crop rice									
1976	90	21	15	24	41	100	267	5.23	518
1977	70	40	83	51	40	95	271	5.50	554
1978	41	8	15	10	50	105	263	4.82	460
Second crop rice									
1976	86	18	19	21	35	86	215	3.31	282
1977	30	30	7	31	39	103	244	1.84	32
1978	32	32	16	34	52	115	260	3.71	297
Cowpea									
1976	23	19	34	33	31	97	160	0.44	51
1977	17	11	26	14	38	84	150	0.72	195
1978	14	6	14	7	36	71	108	0.25	12

[a]Rice = US$0.15/kg, cowpea = US$0.38/kg, 1 labor h = US$0.14.

Pangasinan, crop year 1978-79

Dry-seeded rice. All farmers (48) applied carbofuran granules as recommended and obtained DSR yields (3.6 t/ha) comparable to those in researcher-managed trials (3.7 t/ ha). Farmers even used more insecticide than recommended, as 63% sprayed for rice bug (Table 7). Insect monitoring showed that rice bugs were well below the economic thresholds and insecticide was unnecessary.

Consequently, farmers' insecticide cost (US$24/ ha) was higher than the recommended (US$15/ha). They obtained lower net returns (US$164/ha) than in researcher-managed trials (US$189/ha), which is partly explained by the unnecessary insecticide usage.

In the existing system, 13 farmers obtained much lower yields (2.2 t/ha) than in cropping pattern trials (Table 2). The low yields were traced to lower level of material inputs (US$69/ha) than in the cropping pattern trials (US$129/ha) (Table 5); the farmers applied less herbicide and fertilizer.

In their existing system, farmers sprayed an average of 1.5 times using US$6/ha worth of insecticide. The low cost of insecticide was traced to their habit of underdosing. Their spraying was probably unnecessary because no insect pests were observed on the researcher-managed plots. Labor requirements for insecticide application do not appear to pose any constraints: in the cropping pattern trials, farmers consistently matched or surpassed the labor hours called for to perform the recommended practices (Table 5).

Single crop transplanted rice. All farmers (10) applied and incorporated carbofuran granules correctly to control whorl maggot and caseworm, which were above economic threshold levels on the single crop TPR (Table 8). No farmer sprayed for the late-season stem borer even though populations exceeded the economic threshold (3% deadhearts) in some researcher-managed fields.

Farmers in the cropping pattern trials (Table 5) obtained higher yields (3.9 t/ha) than researchers did (3.1 t/ha) even though the research trials got more insecticide (US$31/ha) for late-season stem borer. Consequently farmers obtained higher net returns (US$238/ha vs US$110/ha) (Table 1).

In 32 fields, farmers in the existing system harvested low yields (2.6 t/ha), although their net returns (US$190/ ha) were higher than in the researcher-managed trials (Table 2). The farmers averaged only 0.5 insecticide applications valued at US$2/ha, indicating that few used insecticide. They also applied less inputs (US$59/ha) than recommended (US$101/ha). The low-input expenditure and farmers' failure to control insect pests in their fields may explain the recorded yield difference.

Second crop transplanted rice. All farmers (32) applied carbofuran for the second crop TPR, but 10 used only half of the recommended dosage (Table 9). Fifteen farmers also applied additional sprays from 3 to 5 weeks after transplanting (WT) and 5 farmers applied 6-9 WT. Insect pests were below economic thresholds in the researcher-managed trial, and there was no reason for the additional sprays. It is highly improbable that pests were present in cropping pattern fields but not in the researcher-managed fields.

Cropping pattern yields were higher (2.6 t/ ha) than for the researcher-managed trials (2.2 t/ ha) or farmers' existing system (2.0 t ha). The overall low yields were due to drought.

Table 7. Insect control recommendations in researcher-managed and farmer-managed cropping pattern trials with dry-seeded IR36 rice. Pangasinan, Philippines, 1978-79.

Growth stage	1978 insect control recommendation[a]			Researcher-managed trial[c]		Farmer-managed trial[d]		
	Target insect	Insecticide[b] application	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Fields treated No.	Fields treated %	Comments
				Prophylactic treatment				
Seedling	Unknown	Carbofuran (0.5) basal in seed furrow	15	–	Carbofuran as plant stimulant	48	100	3 farmers reapplied because of re-seeding
				Corrective treatment				
Vegetative	Stem borer[e]	Endosulfan (0.75) apply if 10% deadhearts	13	1.4% deadhearts	Insecticide unnecessary	2	4	Both farmers sprayed azinphos methyl
Reproductive	Leaf folder[f]	Carbaryl (0.75) apply if 10-15% damaged leaves	5	2% damaged leaves	Insecticide unnecessary	1	2	–
	Stem borer[e]	Endosulfan (0.75) apply if 3% deadhearts	15	0.4% whiteheads	Insecticide unnecessary	2	4	–
Ripening	Rice bug[g]	Carbaryl (0.75) apply if 4 bugs/m^2	5	1 bug/m^2	Insecticide unnecessary	30	63	7 farmers sprayed endosulfan

[a]Made before the 1978-79 crop season. [b]Dosage in kg a.i./ha is in parentheses. [c]Av of 6 fields (untreated). [d]Av of 48 fields. [e]*Tryporyza incertulas.* [f]*Cnaphalocrosis medinalis.* [g]*Leptocorisa* spp.

Table 8. Insect control recommendation in researcher-managed and farmer-managed cropping pattern trials with single crop transplanted IR36 rice. Pangasinan, Philippines, 1978-79.

Growth stage	1978 insect control recommendation[a]			Researcher-managed trial[c]		Farmer-managed trial[a]		
	Target insect	Insecticide application[b]	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Fields treated No.	Fields treated %	Comments
				Prophylactic treatment				
Vegetative	Whorl maggot[e]	Carbofuran (1) soil-incorporated before transplanting	30	>5 in 5 fields	Insecticide unnecessary	10	100	All farmers application correct
	Caseworm[f]			>10% defoliation in 1 field	Insecticide unnecessary			
	Stem borer[g] (deadhearts)			<10% in all fields	Insecticide unnecessary			
				Corrective treatment				
Reproductive	Stem borer[g] (whiteheads)	Endosulfan (0.75) spray if 3% dead-hearts	13	>3%, in 1 field	Spray when needed	0	0	
	Leaf folder[h]	Carbaryl (0.75) spray if 10-15% damaged leaves	5	<10% in all fields	Insecticide unnecessary	0	0	
Ripening	Rice bug[i]	Carbaryl (0.75) spray if 4 bugs/m^2	5	< 1 bug/m^2	Insecticide unnecessary	0	0	

[a] Made before the 1978-79 crop season. [b] Dosage in kg a.i./ha is in parentheses, [c] Av of 6 fields (untreated). [d] Av of 10 fields. [e] *Hydrellia sasakii.* [f] *Nymphula depunctalis.* [g] *Tryporyza incertulas.* [h] *Cnaphalocrosis medinalis.* [i] *Leptocorisa* spp.

Table 9. Insect control recommendations in researcher-managed and farmer-managed trials with second crop transplanted IR36 rice. Pangasinan, Philippines, 1978-79.

Growth stage	1978 insect control recommendation[a]			Researcher-managed trial[c]		Farmer-managed trial[d]		
	Target insect	Insecticide application[b]	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Fields treated		Comments
						No.	%	
				Prophylactic treatment				
Vegetative	whorl maggot[f]	Carbofuran (1) soil-incorporated before trans-planting	30	3 rating (1-5) in 1-9 scale	Carbofuran as growth stimulant	32	100	10 farmers under-dosed carbofuran (0.5 kg a.i./ha); 15 farmers also sprayed endosulfan during 3-5 WT
	Caseworm[g]			3% (0-5) defolia-tion				
	Stem borer[h] (deadhearts)			2.8% (24%)				
				Corrective treatment				
Reproductive	Stem borer[h] (whiteheads)	Endosulfan (0.75) spray if 3% dead-hearts	13	1% (0.5-1%)	Insecticide unnecessary	5	16	3 farmers sprayed a second application of monocrotophos from 6-9 WT
	Leaf folder[i]	Carbaryl (0.75) spray if 10-15% damaged leaves	5	2% (0.5-2%) damaged leaves	Insecticide unnecessary	0	0	–
Ripening	Rice bug[j]	Carbaryl (0.75) spray if 4 bugs/m^2	5	2 (2-4/m^2) bugs/m^2	Insecticide unnecessary	0	0	–

[a]Made before the 1978-79 crop season. [b]Dosage in kg a.i./ha is in parentheses. [c]Av of 3 fields (untreated). [d]Av of 32 fields. [e]WT = weeks after transplanting. [f]*Hydrellia sasakii.* [g]*Nymphula depunctalis.* [h]*Tryporyza incertulas.* [i]*Cnaphalocrosis medinalis.* [j]*Leptocorisa* spp.

The high risk associated with growing a second rice crop in Pangasinan makes it impractical to recommend high levels of inputs. Net returns were higher in the farmers' existing system (US$121/ha) than in the farmer-managed cropping pattern (US$101/ha) or researcher-managed trial (US$46/ha). The net returns were related to the differences in input cost — US$66/ha and US$105/ha — between the existing system and cropping pattern trials.

Farmers in the existing system spent only US$8/ha for an average of 1.5 insecticide applications; farmer- and researcher-managed cropping pattern trials spent US$34/ha and US$30//ha.

Because of the high risk of drought on this crop, the need for carbofuran must be carefully examined even though in the researcher-managed trials it resulted in significant yield gains.

Mungbean. No farmer strictly followed the recommended insect control practice for mungbean, although 18% made at least 2 insecticide applications during both the preflowering and postflowering growth stages (Table 10). Consequently, yields from cropping pattern trials (0.5 t/ha) were well below those in the researcher-managed trials (1.1 t/ha). This points to the fact that even though farmers are given the insecticide free of charge, they lack the necessary knowledge of proper timing of applications. This error is traced to their lack of understanding of the main insect pests attacking mungbean (Litsinger et al 1977). They simply do not appreciate the fact that small insects such as bean fly, flea beetle. and thrips can cause high yield losses.

The constraint to high mungbean yields is insects. To overcome this constraint, farmers need help in the form of instruction rather than credit.

Farmers' technical deficiencies could not be readily overcome through only one meeting where the recommendations were explained. An extension education program will have to be developed if farmers are to realize the high potential net returns possible for mungbean.

In many cases farmers applied more insecticide than recommended and failed to spray early enough to control pod borers (*Heliothis*). Farmers in the cropping pattern trials applied more insecticide (US$40/ha) than recommended US$28/ha; 7 of the 39 fields yielded nothing.

Farmers also realized low yields in the existing system (0.2 t/ha), but spent only US$S/ha for an average of 2.3 applications (Table 2). Contrast their net returns of US$63/ha with the researcher-managed returns of US$502/ha (Table 1).

Iloilo, crop year 1978-79

First-crop wet-seeded rice. The recommended practice for first crop WSR is based on economic thresholds. The insect pests that occurred in 1978 on researcher-managed trials were caseworm, late-season stem borer, and rice bug (Table 11). Farmers basically followed the recommended practice — 41-46% applied insecticide at the time these pests were present for an average of 1.3 sprays/farmer (Table 4). However, they did not always apply the recommended insecticide for the right pest and when they sprayed, they underdosed. Insecticides and average dosages (kg a.i./ha) applied were methyl-parathion (0.57), azinphos-methyl (0.47), endosulfan (0.29), and monocrotophos (0.14).

Table 10. Insect control recommendations in researcher-managed and farmer-managed cropping pattern trials with mung bean, CES1D-21. Pangasinan, Philippines, 1978-79.[a]

Growth stage	1978 insect control recommendation[b]		Researcher-managed triai[c]		Farmer-managed trial[d]					
	Insecticide application	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Sprays/growth stage (no.)		Fields treated		Yield[e] (t/ha)	Comments
					Preflowering (1-3 WE)	Postflowering (4-6 WE)	No.	%		
				Prophylactic treatment						
Preflowering										
Bean fly[f]	Monocrotophos (0.25 kg a.i./ha) 2 and 12 DE (2 sprays)	15	74-80% infested plants	Timing of sprays in first 2 wk essential	1	0	3	8	0.06 b	2 failures
Flea beetle[g]			18-24%; defoliation		1	1	10	26	0.22 b	4 failures
Leafhopper[h]			Not a problem		1	>2	7	18	0.61 a	1 failure
				Prophylactic treatment						
Postflowering										
Pod borer[i]	Carbaryl (0.75 kg a.i./ha) 25 and 35 DE (2 sprays)	10	14-24 Heliothis larvae/ 25 plants	Timing of sprays between 25 and 35 DE essential	2	0	3	8	0.40 ab	No failures
					2	1	9	23	0.60 b	No failures
					2	>2	7	18	0.63 b	No failures
										Dosages are adequate for all sprays

[a]DE = days after crop emergence, WE = weeks after crop emergence. [b]Made before the 1978-79 crop season. [c]Av of 7 fields (untreated). [d]Av of 35 fields. [e]Means followed by a common letter are not significantly different ($P \leq 0.05$). [f]*Ophiomyia phaseoli.* [g]*Medythia suturalis.* [h]*Amrasca biguttula (= Empoasca).* [i]*Heliothis armigera, Maruca testulalis, Etiella zinckenella.*

Table 11. Insect control recommendations in researcher-managed and farmer-managed cropping pattern trials with first crop wet-seeded IR36 rice. Iloilo, Philippines, 1978.

Growth stage	1978 insect control recommendations[a]			Researcher-managed trial[c]		Farmer-managed trial[d]		
	Target insect	Insecticide application[b]	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Fields treated No.	Fields treated %	Comments
				Corrective treatment				
Vegetative	Caseworm[e]	Carbaryl (0.75) apply if 15% defoliation	5	15-90% defolia-tion	Spray necessary	17	41	Farmers used non-recommended insec-ticides and under-dosed
	Stem borer[f]	Endosulfan (0.75) apply if 10% deadhearts	13	<2% deadhearts	Insecticide unnecessary			
Reproductive	Leaf folder[g]	Carbaryl (0.75) apply if 15% damaged leaves	5	<4% damaged leaves	Insecticide unncccssary	19	46	”
	Stem borer[f]	Endosulfan (0.75) apply if 3% deadhearts	13	2 fields with 4% deadhearts	Spray necessary in 2 fields			”
Ripening	Rice bug[h]	Carbaryl (0.75) apply if 4 bugs/m²	5	1 field >4 bugs/m²	Spray necessary in 1 field	17	41	”

[a]Made before the 1978-79 crop season. [b]Dosage in kg a.i./ha is in parentheses. [c]Av of 5 fields (untreated). [d]Av of 4 fields. [e]*Nymphula depunctalis.* [f]*Tryporyza innotata.* [g]*Cnaphalocrosis medinalis.* [h]*Leptocorisa* spp.

Yields from the cropping pattern trials were very favorable (4.8 t/ha) and gave a net return of US$460/ha (Table 6). The value of insecticide used was US$8/ha, representing only 8% of material costs. Yields were lower (4.2 t/ha) in the researcher-managed trial (Table 3) and gave a lower net return (US$363/ha). The complete-protection plot in the researcher-managed trial yielded significantly higher (5 t/ha) than the recommended practice — which included soil-incorporated carbofuran — but not appreciably higher than the cropping pattern yield (4.8 t/ha).

The farmers' existing system yielded only 2.9 t/ha with US$257 in net returns (Table 4). Farmers averaged 1.3 insecticide applications valued at US$2.6/ha. The lower yields were due to less material inputs and the use of varieties other than IR36, rather than lack of insect control.

Second crop transplanted rice. Yields in farmer-managed cropping patterns were again substantially higher (3.7 t/ha, Table 6) than in researcher-managed trials with the recommended practice (2.9 t/ha, Table 3). Ninety-one percent of the farmers followed the recommended practice of soil-incorporating carbofuran at transplanting, but 47% of those who applied carbofuran also sprayed a second application of insecticide during the vegetative period (Table 12). Carbofuran was unnecessary for insect control but is recommended because it gives high yields and profits.

Few farmers (5%) sprayed for rice bug even though the populations were above economic thresholds. The 8% who sprayed during the reproductive stage were consistent with the sometimes abundant stem borer populations.

Although some farmers sprayed, they again used nonrecommended insecticides and they underdosed. The following insecticides and dosages (kg a.i./ha) were recorded: methyl-parathion (0.57), endosulfan (0.29). and monocrotophos (0.13). Insecticide misuse was not excessive in terms of cost (US$2/ha) averaged over all farmers, but it brought out a consistently observed problem of wider significance. Farmers must be taught how to calculate correct dosages for sprays.

Farmers in the existing system spent considerably less for insecticide (US$3.20/ha) for an average of 1.2 applications/field (Table 4). Again this implies underdosing because a single application usually costs from US$8 to 10.

As with the first rice crop, yields in the existing system were low (2.7 t/ha), but the net returns (US$244) were comparable to those in the cropping pattern trial (US$297/ha), reflecting lower material costs (US$65/ha vs US$115/ha).

Cowpea. The yield potential for cowpea after two rice crops is low because of the abrupt onset of the dry season in Iloilo. The yields in the cropping pattern trial (0.25 t/ha) and researcher-managed trials (0.3 t/ha) are discouraging. But if the rainfall period is lengthened, yields in some years can reach 0.7 t/ha.

Insect pests are severe on a drought-stressed crop and insect control becomes necessary (Table 13).

Problems on cowpea in Iloilo were similar to those recorded on mungbean in Pangasinan. No farmer followed the recommended practice. The yield differences between farmers who did not follow the recommended practice and the researchers were, however, not detectable because of the low yield potential. The few and ill-timed farmer sprays did give a yield response because their yields were higher than those of the untreated control (0.07 t/ha) in the researcher-managed trials (Table 3).

Farmers used US$6/ha worth of insecticide in cropping pattern trials (Table 6)

Table 12. Insect control recommendations in researcher-managed and farmer-managed cropping pattern trials with second crop IR36 rice. Iloilo, Philippines, 1978-79.

Growth stage	1978 insect control recommendations[a]			Researcher-managed trial[c]		Farmer-managed trial[d]		
	Target insect	Insecticide application[b]	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Fields treated No.	Fields treated %	Comments
				Prophylactic treatment				
Vegetative	Caseworm[e] Stem borer[f]	Carbofuran (1) soil-incorporated before transplanting	30	<5% defoliation <2% deadhearts	Carbofuran unnecessary for insect control but provided growth stimulation	29	91	47% of farmers who applied carbofuran also sprayed during this growth stage
				Corrective treatment				
Reproductive	Leaf folder[g]	Carbaryl (0.75) 15% damaged leaves	5	<1% damaged leaves	No insecticide necessary	8	25	Underdosed
	Stem borer[f]	Endosulfan (0.75) 3% deadhearts	13	2 fields >3%. deadhearts	Insecticide necessary			
Ripening	Rice bug[h]	Carbaryl (0.75) 4 bugs/m^2	5	All fields >4 bugs/m^2	Insecticide necessary	5	16	Underdosed

[a]Made before the 1978-79 crop year. [b]Dosage in kg a.i./ha is in parentheses. [c]Av of 4 fields (untreated). [d]Av of 32 fields. [e]*Nymphula depunctalis*. [f]*Tryporyza innotata*. [g]*Cnaphalocrosis medinalis*. [h]*Leptocorisa* spp.

Table 13. Insect control recommendations in researcher-managed and farmer-managed cropping pattern trials with cowpea, Iloilo, Philippines, 1978-79.

Growth stage	1978 insect control recommendations[a]		Entomology trial[c]		Farmer-managed trial[d]					
	Insecticide application[b]	Insecticide cost (US$/ha)	Observed insect incidence	Comments	Insecticide application (no.)		Fields treated		Yield (t/ha)	Comments
					Preflowering (1-3 WE)	Postflowering (4-6 WE)	No.	%		
				Prophylactic treatment						
Preflowering										
Bean fly[e]	Monocrotophos (0.25 kg a.i./ha) 2 and 12 DE	15	70% infested plants	Insecticide necessary	0	0	3	21	0.27	No one sprayed during the first week; 4 of the total applications were adequately dosed
Thrips[f]			Not sampled		0	1	2	14	0.19	
Leafhopper[g]			2 hoppers; plant		0	2	1	7	0.13	5 farmers used carbaryl for preflowering protection
				Prophylactic treatment						
Postflowering										
Pod borer[h]	Carbaryl (0.75 kg a.i./ha) 25 and 35 DE	10	Not sampled	Insecticide necessary	1	1	5	36	0.18	9 farmers used monocrotophos for postflowering protection
Aphid[i]			Rating of 7 in 1-9 scale		1	2	1	7	0.40	No farmer followed the recommended practice
					1	0	2	14	0.44	

[a]Made before the 1978-79 crop year. [b]Dosage in kg a.i./ha is in parentheses. [c]Av of 4 fields (untreated). [d]Av of 14 fields. WE = weeks after crop emergence. [e]*Ophiomyia phaseoli*. [f]*Thrips palmi*. [g]*Amrasca biguttula*. [h]*Maruca testulalis*. [i]*Aphis craccivora*.

compared to US$28/ha for the recommended practice (Table 3) and US$0.90 in the existing system (Table 4). The yield in the existing system was 0.14 t/ha.

DRYLAND-RAINFED WETLAND ENVIRONMENT

Agusan del Sur

The current cropping patterns being evaluated in Agusan del Sur are:

Dryland

- Maize + peanut – maize + mungbean – dryland rice,
- Maize – maize + mungbean – maize + peanut,
- Maize – maize + peanut – sweet potato,

Wetland

- WSR – TPR
- WSR – TPR – TPR
- Mungbean – TPR – TPR

Maize. Maize is an important crop in dryland patterns and the expected insect pests are ants attacking seeds and corn borer. Other possible pests are corn seedling maggot, corn root aphid, and corn leaf aphid. Although defoliating insects such as armyworms and the rice leaf folder are present, their incidence is expected to be low.

Trials to evaluate a possible insect control recommendation and determine yield loss are planned for 1980. As many of the expected insect pests may be highly seasonal, the trials will cover a range of planting dates.

The current recommended insect control practice is based on research in Bukidnon — a kerosene seed treatment for ants (2 tablespoons kerosene/1 kg seed) and corn borer insecticide sprays (1.25 kg a.i. carbaryl/ha) based on economic thresholds.

It is not expected that farmers will adopt spraying insecticide as a practice for insect control because water for sprayers is a constraint (farmers plant 2-4 ha fields). Farmers now use no insecticide, although some treat seeds with kerosene. As an alternative practice for corn borer control, carbofuran granules applied in the whorl will also be tested.

There is a need to evaluate the controlled droplet applicator, which may be the solution to lack of water and large fields.

Dryland rice. The expected insect pests of dryland rice are ants, rice root aphid, armyworm, leaf folder, and rice bug. However, high infestations are not expected. On the basis of research results in Bukidnon and Capiz, a yield response due to growth stimulation is expected from carbofuran applied in the seed furrows.

The recommended practice is 1 kg a.i. carbofuran/ha in the seed furrow plus treatment where economic thresholds are reached. If thresholds are exceeded, water for spraying will be a constraint. Farmers do not use insecticide on dryland rice in Agusan del Sur. No trials have been carried out to date in Agusan.

Mungbean. A yield loss of 0.6 t/ha was recorded in 1979 as the yield difference between complete protection (0.65 t/ha) and an untreated mungbean check (0.06 t/ha). At the current price of mungbean (US$0.62/kg), the loss amounts to US$372/ha.

The recommended practice (0.25 kg a.i. monocrotophos/ha 2 and 12 DE; 0.75 kg

a.i. carbaryl/ha on 25 and 35 DE) valued at US$28/ha yielded only 0.26 t/ha, significantly lower than complete protection. Yield loss partitioning showed that 73% of the yield loss occurred during the preflowering period. Bean fly populations were low, and thrips or leafhoppers were expected to be the major pests. The recommended practice failed to adequately protect the postflowering stage in this high-rainfall area; methyl-parathion will replace carbaryl in the 1980 recommendation.

Water for spraying will again be a constraint, and there is a need to evaluate insecticide seed treatments for preflowering insects and the controlled-droplet insecticide applicator for postflowering protection.

Wetland rice. Two trials conducted in the wetland area, one TPR (second crop) and the other WSR (first crop of the double-crop rice pattern), had no significant yield response to insecticide. Complete protection involved soil-incorporated carbofuran at 1.5 kg a.i./ha followed by 3 foliar sprays using monocrotophos during the reproductive stage and carbaryl at ripening.

The TPR crop yields — 7.9 t/ha in the complete protection plot and 7 t/ha in the untreated — were not significantly different. The recommended practice of 1 kg a.i. carbofuran/ha, soil-incorporated, yielded 7.3 t/ha. The 1980 recommended practice will not include prophylactic insecticide treatments and will be based on economic thresholds.

Results with WSR were similar. The complete protection and untreated yields were 5.2 t/ha and 4.5 t/ha, but they were not significantly different. The recommended practice (1 kg a.i. soil-incorporated carbofuran/ha) yielded 5 t/ha. Therefore, as with transplanted rice, the 1980 recommendations will be based on economic thresholds only.

Monitoring of both crops failed to show significant insect pest infestations.

Bukidnon

The current cropping patterns being evaluated at Bukidnon are:

Dryland

- Maize - maize - mungbean
- Maize - peanut
- Rice - maize - mungbean
- Rice + maize - mungbean

Wetland

- TPR - TPR - TPR
- TPR - TPR - WSR

Maize. A maize yield loss due to insect pests was calculated as the difference between complete protection (3.6 t/ha) and the untreated check (2.1 t/ha). With maize price at US$0.12/kg, the yield loss represents a value of US$180/ha.

The recommended practice (0.5 kg a.i. carbofuran/ha as seed treatment and 0.75 kg a.i. carbaryl/ ha sprays 30, 45, 65, and 85 DE) yielded 3.4 t/ha, which represents a benefit to insecticide of US$160/ha and a B:C of 4.2.

The value of insecticide used was US$38/ha. Future trials should reduce the cost as it may be excessive. The 1980 recommendation will therefore replace carbofuran

with the farmers' practice of using kerosene as a seed treatment.

Corn borer was the principal pest, and future trials will test an alternative practice of applying carbaryl only after corn borer damage is noticed (economic thresholds). We are concerned not so much with the cost of insecticide (1 carbaryl application costs only US$7/ha) as with labor involved in obtaining water for a knapsack sprayer and spraying large fields.

Dryland rice. A surprisingly high yield response to insecticide was recorded (1.9 t/ha) on dryland rice. Complete protection (1 kg a.i. carbofuran/ha in seed furrow followed by two 1 kg a.i. monocrotophos sprays ha during the reproductive stage and two 1 kg a.i. carbaryl/ha sprays at ripening) led to 4.2 t/ha of C171-136. The untreated plants yielded 2.3 t/ha. The recommended practice for 1980 will be 0.5 kg a.i. carbofuran/ha in seed furrows.

Mungbean/cowpea. No trials have yet been performed on mungbean and cowpea in either dryland or wetland environments. The recommended practice for 1980 is 0.25 kg a.i. monocrotophos/ha 2 and 12 DE (wetland) or 0.5 kg a.i. carbofuran ha in seed furrows (dryland) followed by 0.75 kg a.i. methyl-parathion/ha at flowering and 10 days later.

Irrigated transplanted rice. An extremely high yield response to insecticide (2.2 t/ha) occurred in a 1979 trial with irrigated transplanted rice, in the apparent absence of a serious pest problem. Complete protection (6.3 t/ha) included soil-incorporated carbofuran in the seedbed (0.5 kg a.i. ha) and before transplanting (1.5 kg a.i./ha) followed by monocrotophos and carbaryl sprays during the reproductive and ripening stages. The untreated plots yielded 4.1 t/ha. The high yield gains might have been due to direct growth stimulation by carbofuran.

The recommended practice (1 kg a.i. carbofuran ha, soil-incorporated before transplanting) valued at US$38/ha yielded 5.3 t/ha, giving a B:C of 4.7. The 1980 recommendation will include soil-incorporated carbofuran in the seedbed (0.5 kg ai./ha) and before transplanting (1 kg a.i./ha).

Capiz

The current cropping patterns being evaluated at Capiz are:

Dryland

- Rice + maize - sweet potato - cowpea
- Rice - maize - mungbean or cowpea
- Maize - peanut - mungbean or cowpea

Wetland

- DSR - WSR, TPR - mungbean
- WSR/TPR - WSR/TPR - cowpea
- WSR/TPR - WSR/TPR - TPR

Dryland rice. Again carbofuran (0.5 kg a.i./ha) was responsible for a large yield increase in the complete protection plots (3.5 t/ha) of C171-136. The untreated plots yielded 1.1 t/ha. Insect pests apparently caused the damage that led to the high yield difference.

A treatment not involving carbofuran yielded 2.5 t/ha. It used 6 monocrotophos (0.75 kg a.i./ha) sprays 5-55 DE and 2 malathion (0.75 kg ai/ha) sprays during the ripening stage.

The recommended practice for 1980 will be 0.5 kg a.i. carbofuran/ha in the seed furrow.

This is the only 1979 trial where results are available. The insect control recommendations are similar to those already presented for Agusan del Sur and Bukidnon.

The environments of the three World Bank-Ministry of Agriculture program sites are very similar and the insect pest problems appear to reflect that. However, the eventual recommendations may not be alike, for future studies will no doubt reveal significant differences between pest numbers and importance.

The consistency of and high yield response to carbofuran in dryland rice between sites were remarkable.

DEVELOPING INSECT-FREE PRACTICES TO MEASURE TOTAL YIELD LOSS

It is useful for interpretative purposes to include complete-protection treatments in all trials that test insect control recommendations. These treatments are designed to eliminate yield loss from insects in each growth stage by the yield loss partition method (Litsinger et al 1980b).

However, monitoring of insect pests has shown that the complete-protection plots have not always been successful in totally reducing yield loss. Therefore we have continually sought to increase the efficacy of the complete-protection practice and have made many adjustments during the 5-year testing period in Iloilo and Pangasinan. These adjustments for rice, grain legumes (mungbean and cowpea), and maize are discussed.

Rice

Carbofuran was used for complete protection in the seedbed and the vegetative stage from 1976 to 1978. It always produced the desired results in reducing insect pest damage, with one exception. On wet-seeded rice, the initial soil-incorporated application did not persist long enough to prevent caseworm attack at the late vegetative period. The vegetative period of WSR is long (5-6 weeks). Soil-incorporated carbofuran persists only up to 4 weeks (Seiber et al 1978).

Because of its growth stimulation properties, carbofuran was replaced with monocrotophos sprays. Monocrotophos gives good control if applied frequently at a high dosage. For transplanted rice, the application is 2 sprays to the seedbed (0.75 kg a.i./ha 7 and 14 DE), and 3 sprays after transplanting (1 kg a.i./ha 5, 15, and 25 DT). For wet-seeded rice, it is 5, 15, 25, and 35 DE (1 kg a.i./ha) for complete protection.

There have been problems with the reproductive stage protection. Initially, too few applications were made. Chlorpyrifos + BPMC commercial mixture (Brodan) at 1 kg a.i./ha 35, 45, and 55 DT for TPR and 45, 55, and 65 DE for WSR is now used.

Ripening stage protection is still highly questionable as there are no insecticide field trials from which to select a good insecticide. Carbaryl, endosulfan, monocrotophos, g-BHC, and decamethrin have been used. Because of a lack of appropriate sampling techniques for the rice bug and because yield loss from that pest has rarely

been measured, the appropriate insecticide has not been determined. Monocrotophos (1 kg a.i./ha — 3 sprays at weekly intervals from postflowering to the hard dough stage) is now used because it has provided excellent control in the greenhouse.

Grain legumes

Preflowering. Monocrotophos gives excellent control of bean fly and other preflowering insect pests. In 1979 a new preflowering insect pest — *Thrips palmi* — was identified. It is prevalent but was overlooked in the past. There are no insecticide trials on which to base a decision on efficacy. Therefore monocrotophos (0.5 kg a.i./ha) 2, 9, and 16 DE is used.

Postflowering. Monocrotophos was originally used on postflowering insects, but insecticide trials have shown the new synthetic pyrethroids to be superior. In 1978 decamethrin (0.03 kg a.i./ha 25, 35, and 45 DE) was used and gave excellent control of pod borers and other postflowering insect pests. There is still lack of efficacy data on *Etiella,* but it is not an important pod borer for mungbean and cowpea.

Maize

Carbofuran granules were originally used for protection of maize seed or seedlings, but they resulted in high populations of corn borer *Ostrinia furnacalis.* In 1979 carbofuran was replaced with bendiocarb (5 g a.i./kg seed), which gave excellent control of ants and corn seedling maggot *Atherigona* spp.

Corn borer control has been a perennial problem, and no insecticide has given adequate control. However, 1979 data from one trial have shown that decamethrin has promise. Therefore, decamethrin (0.05 kg a.i./ha) is now used at 10-day intervals from 21 DE until posttasseling.

DEVELOPMENT OF SAMPLING METHODS

In choosing control options, it is important to sample insect populations to determine which pests are causing yield losses. Many sampling methods developed for basic research objectives require higher precision than is appropriate for cropping systems work.

Because cropping systems work involves many trials, the task of sampling must be reduced to the minimum. Sampling methods developed for host plant resistance work are not appropriate as their basic objectives differ.

Monitoring insect pests is useful only if they are present in numbers above economic injury levels. There is no need to monitor every insect pest — a practice in experiment station research. The untreated control plot must first be observed to determine which insects are sufficiently abundant to measure. Our objective limits the number of insects to be concerned with and differs from experiment station objectives.

Adjustments in sampling techniques have continually been made to maintain precision while limiting the work required. Adjustments for rice, grain legumes, maize, and sorghum are now discussed.

Wetland rice

Whorl maggot. A rating scale 1-9 is used on a per-plot basis. 1 = no damage, 3 $\leqslant$ 25% damaged leaves, 5 $\leqslant$ 50% damaged leaves, 7 $\geqslant$ 50% damaged leaves, 9 $\geqslant$ 50%

damaged leaves with some leaves broken.

Caseworm. One can use % defoliation (on a per-plot basis) or % cut leaves (20-hill sample).

Stem borer deadhearts. A 5-m^2 area is staked out in a plot and % deadhearts is recorded as no. of deadhearts ÷ total tillers. If labor is scarce a 3-m^2 plot can be used. Time to sample is 45-55 DT or 55-65 DE.

Stem borer whiteheads. The same 5- or 3-m^2 area is used in the same manner at 10 days before harvest.

Leaf folder. % damaged leaves (not necessarily with larvae present) is the best character (20-hill sample per plot). After booting, the % damaged flag leaves is determined.

Armyworms/defoliators. % defoliation on a visual per-plot basis is best determined at time of peak infestation if this exceeds 10%.

Rice bug. There are several ways of monitoring rice bug populations. If time and resources are limiting, bugs at the milky stage of the 5- or 3-m^2 stem borer plot are counted early in the morning or late in the afternon. An improvement would be to determine rice bug days by getting the average of weekly or twice weekly counts of rice bugs from the same 5-m^2 plot from postflowering to hard dough, and multiplying that by the number of days from postflowering to hard dough (van Halteren 1979).

A new technique now in practice promises to give more precise results. It involves counting the grains (20-panicle sample) with stylet sheaths stained with acid fuchsin (Bowling 1979). When a rice bug feeds on a grain, it produces a proteinaceous stylet sheath which can be stained.

Dryland rice

Several other insect pests attack dryland rice.

Ants. Plant stand can be taken from 20-m rows (4 random sets each of 5-m row) 14-21 DE.

Seedling maggot. %infested plants (20-m-row sample) or % deadhearts (20-plant sample minimum) 21-28 DE.

Grain legumes

Bean fly. % infested plants (25-plant sample dissected) 21 DE. There is no advantage in counting larvae and pupae, nor in sampling on several dates.

Flea beetle. No. of feeding holes/plant (25-plant sample), 14-21 DE.

Thrips. No./25 leaf bud terminals, 14-21 DE. Leaf buds can be pinched from the plants and preserved in 70% alcohol for counting later, or thrips can be counted in the field.

Leaf miners, leaf folders. No./plant (25-plant sample) when abundant.

Leafhopper. No. of nymphs/plant (25-plant sample) when abundant. Adults can also be counted, but they may be more easily disturbed and results will be less precise.

Aphids. 1-9 scale on a per-plant basis rated per plot. 1-9 scale: 1 = no aphids, 3 = adults only, 5 = several colonies, 7 = many distinct colonies, 9 = many colonies, indistinct and coalesced.

Pod borers. No. of *Heliothis* larvae/plant (25-plant sample) or % *Maruca* damaged flowers (50-flower sample), or % *Etiella* damaged seeds.

Seed bugs. No./plant (25-plant sample), dry pod stage.

Maize

Ants. See **Dryland rice.**

Seedling maggot. See **Dryland rice.**

Aphids. See **Grain legumes.**

Armyworm/defoliators. % defoliation (per-plot basis) when abundant.

Corn borer. No. of tunnels/plant. Split 25-50 plants/plot at harvest.

Sorghum

Heliothis. No. of larvae/grain head (25- to 50-plant sample) at milky stage.

Rice weevil, webworm. No. of adults/grain head (25- to 50-plant sample) at hard dough stage.

Yield and yield components

Yield in farmers' fields is highly variable and should be estimated in 15- to 20-m^2 plots for rice and legumes, 25-35 m^2 plots for maize or sorghum.

Legumes. No. of pods /plant, plant stand, plant height.

Economic thresholds

The use of economic thresholds has been discussed elsewhere (Litsinger et al 1980b). However, some changes have recently taken place, particularly on rice. As a result of new information, many thresholds have been raised to reflect the rising cost of insecticides.

Rice.

1. Seedbed. If >50% defoliation, spray 0.75 kg a.i. carbaryl/ ha.
2. Whorl maggot. At 14 DT, if >50% damaged leaves/plot, and leaves are broken, spray 0.75 kg a.i. monocrotophos/ha.
3. Caseworm. If >15% defoliation, spray 0.75 kg a.i. malathion/ha.
4. Stem borer deadhearts. From 14-35 DT, if deadhearts apply insecticide.
   — If > 5 cm water in paddy, broadcast 1 kg a.i. g BHC/ha.
   — If < 5 cm water, spray 0.75 kg a.i. chlorpyrifos + BPMC (Brodan)/ha.
   From 35 to 65 DT, if > 5% deadhearts, spray 0.75 kg a.i. Brodan/ha.
5. Leaf folder
   — Vegetative stage
     If >25% damaged leaves, spray 0.75 kg a.i. BPMC/ha.
   — Reproductive stage
     If > 15% damaged flag leaves, spray 0.75 kg a.i. BPMC/ha.
6. Defoliation (armyworm, cutworm, etc.)
   — Vegetative stage
     If > 25% defoliation, spray 1.25 kg a.i. BPMC/ha
   — Reproductive stage
     If > 15%, spray 1.25 kg a.i. carbaryl/ha.
     If panicles are cut, immediately spray 1.25 kg a.i. carbaryl/ha.

7. Rice bug. If > 8 bugs/m^2, spray 0.75 kg a.i. carbaryl/ha.
8. Green leafhopper. If tungro is present in surrounding municipalities, sample your seedbed and crop with a sweep net during the vegetative stage. Apply 1 kg a.i. carbofuran when > 0.5 GLH/sweep occurs.
9. Brown planthopper
   — 20 to 50 DT if > 1 adult or 2 nymphs/tiller.
   — 50 to 70 DT if > 2 adults/ tiller, spray 0.75 kg a.i. BPMC/ha.

Grain legumes. Economic thresholds are being evaluated and the following have been proposed.

Preflowering stage 1-25 DE

Bean fly. Observe field 5-10 DE early in the morning. If ⩾ 1 adult/5-m row, then spray 0.25 kg a.i. monocrotophos/ha.

Flea beetle. Observe field 5 DE. If ⩾ 5 feeding holes plant or if 3 10 feeding holes/plant 10 DE, spray 0.75 kg a.i. carbaryl ha.

Thrips. Observe field 5-10 DE. Spray 0.25 kg a.i. monocrotophos/ha if ⩾ 1 thrips/plant.

Amrasca leafhopper. Observe field 5–1 0 DE. If ⩾ 1 nymph/ plant, spray 0.25 kg a.i. monocrotophos/ha.

Leaf folder. Observe field 10 DE. If ⩾1 / 5 plants, then spray 0.5 kg a.i. monocrotophos/ha.

Defoliation. Observe field frequently. Spray 1.25 kg a.i. carbaryl/ha if ⩾ 20% defoliation 1–15 DE, or ⩾ 15% defoliation 16–25 DE.

Postflowering stage 25 DE

Aphid. Observe field 25-45 DE. If aphid rating > 5, then spray 0.75 kg a.i. carbaryl/ ha.

Heliothis. From 25 to 35 DE, if ⩾ 1 egg/2 plants, spray 0.75 kg a.i. monocrotophos/ha. If ⩾1 larva/2 plants, or from 45-65 DE, if ⩾ 1 larva/plant, spray 1.25 kg a.i. carbaryl/ ha.

Maruca. Observe field at flowering. If ⩾ 1 damaged flower/ plant, spray 0.75 kg a.i. carbaryl/ ha. A flower is damaged if a larva is seen feeding, feeding holes are present, or silk threads are observed.

Amrasca. Spray 0.75 kg a.i. carbaryl/ ha if ⩾ 1 nymph/ leaf.

Leaf miner. Spray 0.75 kg a.i. carbaryl/ ha if ⩾ 1 tunnel/2 leaves.

Defoliation. If ⩾ 15%, spray 1.25 kg a.i. carbaryl/ha.

Maize.

Corn borer. Pretasseling. If ⩾ 10% of the plants show characteristic larval feeding symptoms (small holes in a line on a leaf), spray 1.25 kg a.i. carbaryl/ha.

Post-tasseling: If ⩾ 2 larvae/plant are seen on the tassel, spray 1.25 kg a.i. carbaryl/ha.

NEEDS FOR FUTURE RESEARCH

Testing insect control practices for efficacy and economic efficiency at Philippine cropping systems sites has revealed the following problem areas with respect to the currently available technology.

Insecticide efficacy

Complete protection. The partitioned yield loss method using insecticides has proven of value as an aid in the evaluation of potential insect control recommendations (Litsinger et al 1980b). But to measure yield losses, insect populations must be kept below economic injury levels (complete protection).

Insecticide cost is not a factor in determining yield losses; therefore the best available insecticides should be used.

More field evaluation of insecticides is needed for the following crops and insect pests:

- Rice — stem borers (vegetative and reproductive stages), rice bug, and rice root aphid
- Legumes — thrips, and *Etiella* pod borers
- Maize — Asian corn borer

Low-cost insecticide recommendations. The ever-rising cost of insecticides in the past few years and the expected cost increases in the future pose serious questions on the use of insecticides. More of the low-cost insecticides should be evaluated and better methods of application that will reduce costs should be developed.

More field trials to identify low-cost insecticides are needed for the following crops and insect pests:

- Rice — caseworm, stem borers, leaf folder, rice bug. rice root aphid. and brown planthopper
- Legumes — thrips, pod borers (*Heliothis, Maruca, Etiella*)
- Maize — Asian corn borer

The following methods of insecticide application deserve more attention:

- The controlled droplet applicator should be evaluated on legumes and maize. This device, which reduces application time (1 hour/ha) and requires only small amounts of water (2 liters,/ha), would be ideal for dryland areas. Knapsack sprayers require too much water to be practical in dryland areas.
- Seed treatment of pregerminated rice and grain legumes for preflowering insects. Seed treatments present an economically attractive option for controlling early season pests, and eliminate problems of teaching farmers optimal times to spray, which is particularly relevant to legumes. Legume seed treatment should also be ideal for areas where water for knapsack sprayers presents a problem.

Phytotonic insecticides

In the measurement of yield loss due to insect pests, the insecticides used must not directly affect plant growth either positively or negatively. Carbofuran, which was used from 1976 to 1978, has been dropped because it has been found to promote plant growth and yield in its own right. Insecticides should be screened for growth stimulation properties so that only those that are plant neutral are used.

Resistant varieties

The work pioneered at IRRI in developing insect-resistant rice varieties should be expanded to other crops, particularly legumes. With the development of resistant varieties, the use of economic thresholds would be feasible.

Economic thresholds

Economic thresholds are a mixed blessing. On one hand, their proper use means less insecticide usage, a cost savings, or a yield increase; on the other hand, their correct use demands a level of knowledge farmers do not currently have.

There is little need for experiment station trials to develop economic thresholds. But on-site evaluation of threshold levels, even if they are only "best guesses," will have to be done. Our experience has shown that experiment station-developed thresholds need to be modified anyway to reflect local yield potentials and crop production practices. Experiment station thresholds are developed under ideal growing conditions, which rarely occur at sites.

Thresholds also need to be reassessed for each increase in the price of insecticides. All those factors are too numerous for experiment stations to evaluate. It is therefore recommended that thresholds be developed on site after several years of testing.

IMPLICATIONS FOR EXTENSION

The cropping pattern trials revealed that farmers did not always follow the recommended insect control practice. Discrepancies between recommendations and farmers' performance occurred in rice and grain legumes with prophylactic treatments and the use of economic thresholds. The problem is more than financing because, even though farmers in cropping pattern trials were given free insecticides, they did not always apply them at the correct time.

Recommendations for rice called for insecticide applications when the economic thresholds were surpassed. Farmers did not recognize some of the rice insect pests or signs of damage (Litsinger et a1 1980a). If farmers are to use economic thresholds, they must be taught how to use them.

The problem is most acute on grain legumes where insecticide timing is critical. Farmers did not realize that preflowering insect pests cause high yield losses.

Farmers were given several insecticides, but they did not always apply the correct one. They lacked knowledge of efficacy ranges of insecticides.

Farmers consistently underdosed when spraying. They need to be taught how to properly compute dosages so they can deliver lethal levels. Farmers were also ignorant of the potential danger to themselves of insecticide misuse. Farmer educational programs need to focus on:

- insect pest and damage recognition,
- knowledge of economic thresholds,
- proper choice of insecticides,
- ability to calculate dosages, and
- safe use of insecticides.

This is a challenge to extension services. The use of insecticides is a highly technical operation and it is obvious that farmers lack the necessary skills. Failure to master these skills will result in lower production, lower profits, pest resurgence, illness or even death.

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COMPONENT TECHNOLOGY–WEED SCIENCE

Farmers' concepts about weeds and weed control practices in rainfed areas of the Philippines

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Farmers in most rainfed areas of the Philippines have been growing one transplanted rice crop or one transplanted rice crop and an upland crop per year. The upland crop may precede or follow the rice crop, depending on soil moisture conditions or rainfall occurrence. The farmers' management and cultural practices are dependent on their knowledge, experiences, and resources. Hence, the degree to which farmers will adopt newly introduced pest control techniques is determined largely by their understanding of the pests, their familiarity with the techniques, and the availability of resources for executing them (Litsinger et al 1978).

Weeds have been one of the limitations of increased production with the traditional cropping pattern. They are even more of a problem in the new cropping patterns utilizing short-statured, early-maturing rice cultivars. Weeds are particularly serious in dry-seeded rainfed bunded rice, an important component of the new intensive cropping patterns, because soil and moisture conditions favor rapid weed growth. In determining appropriate weed control methods for a new improved cropping pattern intended for introduction into rainfed wetland areas, it is necessary to know the farmers' concepts about weeds and weed control practices. This information will serve as a basis for selecting or developing weed control techniques, which are likely to be accepted and adopted by the farmers.

This paper summarizes the results of surveys conducted in several rainfed rice areas of the Philippines, which aimed to determine the farmer's knowledge about weeds and weed control practices for each crop grown in his cropping pattern.

METHODOLOGY

The survey was conducted in Pangasinan, Iloilo, Cagayan Valley, and Nueva Ecija provinces. Sixty farmers from 4 barrios of Manaoag, Pangasinan, representing 30% of farmers in each barrio, were interviewed during February and March 1979. A complete list of farmers in each barrio was obtained from the barangay captain and sample respondents for interview were determined by systematic sampling. If a farmer had more than one parcel of land planted to different cropping patterns, the

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pattern grown in the largest parcel was considered. Only farmers who grew at least one rice crop in their cropping pattern were included in the samples.

In Iloilo, 48 farmers from several barrios of the municipalities of Tigbauan, Oton, Alimodian, and San Miguel were randomly selected and interviewed during April and May 1979.

Partial data from three barrios of Solana, Cagayan Valley, were obtained from the benchmark survey of the Department of Agricultural Economics, IRRI. The survey conducted in January 1980 had 77 farmer respondents.

The Nueva Ecija survey was conducted by the Department of Agricultural Engineering, IRRI, during September 1979. The municipalities of Cabanatuan and Guimba were selected to represent irrigated and rainfed sites. A total of 74 farmer respondents were from 2 barangays in Cabanatuan and 76 were from 3 barangays in Guimba.

Awareness of weeds and problems associated with them

Most farmers in the survey areas recognize that weeds compete with their crops. They were generally aware that when weeds competed with rice growth was stunted, yield was low, and the quality of the harvested product was poor.

The important weeds varied depending on such factors as the environment, the crop grown, and the cultural practices.

In Pangasinan, the farmers reported that sedges *Cyperus difformis* L. and *Fimbristylis littoralis* Gaud. — they have the same common name — were the major weeds growing in association with transplanted rice (Table 1). Other weeds in order of importance were *Monochoria vaginalis* (Burm.) Presl., *Commelina diffusa* Burm.f., *Echinochloa colona* (L.) Link, and *Cynodon dactylon* (L.) Pers. In mungbean and maize, the major weeds were *C. dactylon, E. colona,* and *Cyperus rotundus* L. Some weeds that normally occur under upland conditions were reported growing in association with transplanted rice. Because most of the transplanted rice in the area is grown under rainfed conditions, the weeds probably became established under aerated conditions and could not be eliminated when the fields were flooded.

The presence of *E. colona* in mungbean and maize is probably due to the residual moisture from the previous wet season and the flush irrigation practice used by some of the farmers for crop establishment.

Table 1. Major weeds[a] growing in association with different crops in Manaoag, Pangasinan, Philippines, 1979.

Weeds growing in association with	
Transplanted rice	Mungbean and maize
Fimbristylis littoralis/ Cyperus difformis	*Cynodon dactylon*
Monochoria vaginalis	*Echinochloa colona*
Commelina diffusa	*Cyperus rotundus*
Echinochloa colona	*Panicum repens*
Cynodon dactylon	*Ischaemum rugosum*
Ischaemum rugosum	
Panicum repens	
Cyperus rotundus	

[a]Listed in order of importance.

In Iloilo, we observed that the major weeds growing in association with dry-seeded rice were *E. colona, Ischaemum rugosum* Salisb., and *Cyperus iria* L.(Table 2). But farmers interviewed reported that *F. littoralis,* and *M. vaginalis* were the major weeds in this crop. We observed that those weeds became associated with dry-seeded rice in the later stage of crop growth when the fields were saturated or flooded, and *E. colona* had completed its life cycle or the fields had been weeded. These weeds are less important than the grasses. Perhaps, the farmers based their observations on this stage of crop growth. In rice that was pregerminated and broadcast-seeded on puddled soil, the major weeds were *F. littoralis, I. rugosum,* and *M. vaginalis,* but in transplanted rice, *I. rugosum, F. littoralis.* and *C. dactylon* were reported to be most important.

In Nueva Ecija, the major weeds varied with the water regime (Table 3). *Echinochloa crus-galli* ssp. *hispidula* (Retz.) Honda was the major weed in irrigated transplanted rice, and *I. rugosum* was the major weed under rainfed conditions.

Preliminary results from the Cagayan Valley indicated that *M. vaginalis, F. littoralis, C. difformis, Ipomoea aquatica* Forsk., *Echinochloa stagnina* (Retz.) Beauv., *E. colona,* and *C. dactylon* are the dominant weeds growing in association with transplanted rice.

Weed control practices

Land preparation. Land preparation practices help in controlling weeds in some crops.

- *Maize.* Only 15% of the people interviewed in Pangasinan planted maize either before or after transplanted rice. The majority (67%) plowed their land once

Table 2. Weeds[a] most commonly growing in association with rainfed rice grown with different cultural practices. Iloilo, Philippines, 1979.

Weeds growing with		
Dry-seeded rainfed bunded rice	Pregerminated seed broadcast on puddled soil	Transplanted rice
Echinochloa colona	*Fimbristylis littoralis*	*Ischaemum rugosum*
Ischaemum rugosum	*Ischaemum rugosum*	*Fimbristylis littoralis*
Cyperus iria	*Monochoria vaginalis*	*Cynodon dactylon*
Fimbristylis littoralis	*Echinochloa colona*	*Echinochloa colona*
Monochoria vaginalis	*Cynodon dactylon*	*Monochoria vaginalis*

[a]Listed in order of importance.

Table 3. Effect of irrigation regime on major weeds[a] growing in association with transplanted rice in Nueva Ecija, Philippines, 1979.

Weeds of transplanted rice	
Irrigated	Rainfed
Echinochloa crus-galli spp. *hispidula*	*Ischaemum rugosum*
Paspalum paspalodes	*Fimbristylis littoralis*
Monochoria vaginalis	*Echinochloa crus-galli* spp. *hispidula*
	Monochoria vaginalis

[a]Listed in order of importance.

Table 4. Labor input utilization for land preparation, hand weeding, and interrow cultivation for crops grown in cropping pattern fields and in farmers' fields in Pangasinan and Iloilo, Philippines (Anon. 1978, Genesila and Servano 1979a, b).

Operation	Labor input (labor hours/ha) in			
	Cropping pattern plots		Farmers' fields	
	Pangasinan	Iloilo	Pangasinan	Iloilo
	Dry-seeded, rainfed bunded rice			
Land preparation	251	167	172	118
Hand weeding	672	529	364	44
	Transplanted rice			
Land preparation	176	288	115	137
Hand weeding	30	40	84	0
	Rice broadcast-seeded on puddled soil			
Land preparation	242	196	101	132
Hand weeding	0	38	0	22
	Mungbean			
Land preparation	13	–	31	–
Hand weeding	0	–	0	–
	Maize			
Land preparation	89	113	92	–
Hand weeding	41	48	34	–

before planting maize; the others plowed twice. Eighty-nine percent of the farmers who planted maize harrowed once, and the remainder harrowed twice. The plowing and harrowing operations were generally done several days after the field was flush irrigated. In Iloilo, none of the farmers interviewed planted maize; in the Cagayan Valley, none planted maize in rainfed bunded fields.

In Pangasinan, the average time spent by farmers in preparing their land for maize establishment was 92 labor hours/ ha (Table 4). In the cropping pattern plots, almost the same length of time (89 labor hours, ha) was used for plowing and harrowing. In maize trials in Iloilo, a greater amount of time (113 labor hours/ha) was needed for land preparation, probably because of the heavier soil type.

- *Dry-seeded, rainfed bunded rice.* In rainfed areas, dry-seeding the first crop is one of the prerequisites to planting two crops of rice in a year. The impact of this technology was not observed in the areas surveyed.

Of the 178 farmers interviewed in Pangasinan, Iloilo, and Cagayan Valley, only 2 in Iloilo reported that they had planted dry-seeded rice. One of the farmers did two plowings for land preparation, the other did three. Both harrowed their fields twice.

In Pangasinan, some farmers who were not part of the survey planted dry-seeded rice. Land preparation took 172 labor hours/ ha. About 47% more time was spent in the cropping pattern fields planted to dry-seeded rice. In Iloilo, the farmers spent less time on land preparation (118 labor hours/ ha), but in the cropping pattern plots, 42% more time was spent on land preparation (Table 4).

- *Pregerminated seed broadcast on puddled soil.* None of the farmers interviewed in Pangasinan and the Cagayan Valley planted rice by broadcasting pregerminated seed on puddled soil. But in Iloilo it was the predominant method of rice culture. Seventy-three percent used this method for the first crop, and 60% used it for the second crop. According to most of the farmers, broadcasting preger-

minated seed on puddled soil required less labor for land preparation and planting than transplanted rice. Most of the farmers did two plowings and two harrowings before the establishment of the first crop, and one plowing and two harrowings before the establishment of the second crop (Table 5).

The time involved in preparing the land for this type of rice establishment is less under the farmers' existing system than in the cropping pattern trials in Pangasinan and Iloilo.

- *Transplanted rice.* All the respondents in Pangasinan and Cagayan Valley and 27% of those in Iloilo transplanted rice. In Pangasinan, about 75% of the farmers plowed and harrowed their fields twice before transplanting. In Iloilo, most farmers did two plowings and two harrowings for the first transplanted rice crop. Two farmers planted a second transplanted crop in Iloilo. Both farmers plowed once (Table 6).

Land preparation for transplanted rice took longer on the cropping pattern plots than under the existing system. It took longer in Iloilo than in Pangasinan; it was 19% longer in farmers' fields and 64% longer in cropping pattern plots (Table 4).

- *Mungbean and cowpea.* The normal practice of Pangasinan farmers with irrigation is to plow either before or after a flush irrigation. The field is usually plowed dry, the weeds are allowed to dry, the field is flush-irrigated, the excess

Table 5. Farmers reporting a certain number of plowings and harrowings done before establishing rice that was broadcast-seeded on puddled soil. Iloilo, Philippines, 1979.

	Farmers reporting			
	First crop		Second crop	
	Number	Percent	Number	Percent
1 plowing	11	31	18	62
2 plowings	22	63	10	35
3 plowings	2	6	1	3
1 harrowing	4	11	5	17
2 harrowings	23	66	15	52
3 harrowings	6	17	7	24
4 harrowings	2	6	2	7

Table 6. Farmers reporting a certain number of plowings and harrowings done before establishing transplanted rice in Pangasinan and Iloilo, Philippines, 1979.

	Farmers reporting					
	Pangasinan		Iloilo			
			First crop		Second crop	
	Number	Percent	Number	Percent	Number	Percent
1 plowing	4	7	1	9	2	100
2 plowings	45	75	9	82	0	0
3 plowings	8	13	1	9	0	0
4 plowings	1	2	0	0	0	0
5 plowings	2	3	0	0	0	0
1 harrowing	2	3	0	0	0	0
2 harrowings	38	63	7	70	1	50
3 harrowings	15	25	1	10	0	0
4 harrowings	4	7	2	20	1	50
8 harrowings	1	2	0	0	0	0

water is allowed to percolate into the soil, the mungbean seeds are broadcast, and a peg-tooth harrow is passed over the field to cover the seeds. Eighty-eight percent of the respondents said that they plowed once.

All the farmers interviewed in Iloilo broadcast mungbean or cowpea seeds into the standing rice stubble. Sometimes they harrowed once after seeding to ensure that the seeds are in contact with the soil or to partially cover the seeds. In the Cagayan Valley, most farmers used zero (37%) or minimum tillage (59%) (one plowing followed by one harrowing) before mungbean establishment, and drill the seeds in rows. Ten percent broadcast seed.

In Pangasinan, no tillage (the crop is grown without the use of any tillage except that necessary to plant the mungbean seed) was recommended for the cropping pattern plots. As a result, there was a 58% saving in time required for land preparation compared to the farmer's existing practice (Table 4).

Hand weeding. Hand weeding was not extensively used for weed control.

- *Maize.* Farmers in Pangasinan and Iloilo reported that they never hand weeded maize.
- *Dry-seeded, rainfed bunded rice.* Of the two farmers who planted dry-seeded rainfed bunded rice in Iloilo, one hand weeded once and the other twice. In one field, the first weeding was done 22 to 28 days after emergence; in the other field it was done 1 week later.
- *Pregerminated seed broadcast on puddled soil.* Most farmers in Iloilo hand weeded rice grown under this type of culture once or twice, and some said that they weeded more than five times (Table 7). There was a tendency for farmers to do less hand weeding in the second crop than in the first crop. The majority of the farmers did the first weeding between 15 and 28 days after seeding.
- *Transplanted rice.* In Pangasinan, Iloilo, and the Cagayan Valley, the majority of the farmers reported that they weeded transplanted rice once (Table 7). In Iloilo, none of the farmers did no weeding, but in Pangasinan and the Cagayan Valley, 7 and 47% of the farmers respectively reported that they did not weed transplanted rice. In Nueva Ecija, a higher percentage of the farmers (61 vs 16) used hand weeding as their control method in rainfed transplanted rice than in irrigated transplanted rice.

The time of the first hand weeding in transplanted rice varied greatly from earlier

Table 7. Frequency of hand weeding of rice by farmers in rainfed areas of the Philippines, 1979-80.

Weeding frequency	Farmers (no.)				
	Transplanted rice in Pangasinan	Iloilo			Transplanted rice in Cagayan Valley
		First crop		Second crop of rice broadcast-seeded on puddled soil	
		Rice broadcast-seeded on puddled soil	Transplanted rice		
0	4	0	0	0	36
1	38	11	8	13	41
2	15	12	2	6	0
3	3	5	1	2	0
4	0	1	0	1	0
>5	0	2	0	2	0

than 14 days after transplanting to later than 42 days after transplanting. In Pangasinan and the Cagayan Valley, the majority of the farmers hand weeded transplanted rice 29 to 35 days after transplanting; in Iloilo the majority did hand weeding 2 weeks earlier.

- *Mungbean and cowpea.* None of the farmers in Pangasinan or Iloilo hand weeded mungbean, although during crop growth, weeds in fields were collected for animal feed. In the Cagayan Valley, 51% of the farmers reported that they hand weeded mungbean once.

Source of labor and cost of hired labor

Eighteen percent of the farmers in Pangasinan and 23% in Iloilo reported insufficient family labor for hand weeding. The majority, 50% in Pangasinan and 33% in Iloilo, had 3 or 4 family members who helped with hand weeding (Table 8).

Farmers who did not have enough family labor said that they had no difficulties in hiring laborers to do the job when needed. There was considerable variation in the type and amount of payment for hired labor for hand weeding: the daily range was from $0.54 plus a meal to $1.09 without a meal. The majority of the farmers in Iloilo paid $0.68/day with or without a free meal. At the Capiz Resettlement Project, Panay Island, the farmers paid $0.54 without a meal.

Effect of the introduction of modern rice cultivars

Farmers in Pangasinan and Iloilo generally said that they weeded the modern rice cultivars more than they did the traditional cultivars. Farmers in Pangasinan, Iloilo, and Nueva Ecija reported that more weeds grew in association with the modern cultivars, and the farmers in Pangasinan and Iloilo reported that the weeds grew faster than the rice crop.

Interrow cultivation. Some farmer respondents reported interrow cultivation as one way of controlling weeds.

- *Maize.* Pangasinan farmers who planted maize said that they did interrow cultivation once (45%), twice (33%), or three (22%) times. Two types of cultivation were used: off-barring (moving the soil away from the maize rows to the centers between the rows) during early growth stages and hilling-up (the opposite of off-barring) after fertilizer sidedressing. The reasons given for interrow cultivation were weed control, to facilitate furrow irrigation, and for better maize growth and yield.

Table 8. Number of family members who helped the farmer operator in hand weeding in Pangasinan and Iloilo, Philippines, 1979.

Helpers (no.)	Farmers reporting			
	Pangasinan		Iloilo	
	Number	Percent	Number	Percent
0	10	18	11	23
1-2	9	16	11	23
3-4	28	50	16	33
5-6	9	16	5	10
7-8	0	0	2	4
9-10	0	0	2	4
>10	0	0	1	2

Interrow cultivation in farmers' fields in Pangasinan averaged 34 man or animal hours/ha, but in experimental plots in Pangasinan and Iloilo, it took 41 and 48 man or animal hours/ha (Table 4).

- *Rice.* None of the farmers in Pangasinan and Iloilo used interrow cultivation to control weeds in rice. Some farmers mentioned that they sometimes passed a spike-toothed harrow through the field for weed control when many weeds were present. We observed this practice being used in rice that was broadcast-seeded on puddled soil in Iloilo.
- *Mungbean.* No interrow cultivation is used for mungbean even in the Cagayan Valley where the crop is seeded in rows.

Herbicides.

- *Maize.* None of the farmers interviewed used herbicides for weed control in maize.
- *Rice.* A number of farmers used herbicides for weed control in rice in all areas. Low-cost phenoxy herbicides (2,4-D and MCPA) were the only herbicides used in Pangasinan, Iloilo, and the Cagayan Valley (Table 9). The majority of the farmers applied these herbicides 21 days after seeding or transplanting.

In Nueva Ecija, 84% of the farmers who grew transplanted rice with irrigation used herbicides, but only 39% of the farmers who grew rainfed transplanted rice did. Of the farmers that used herbicides, 82% with irrigated fields used butachlor and 18% phenoxy herbicides. Of those with rainfed fields only 35% used butachlor and 65% phenoxy herbicides. As the water supply became less reliable, herbicide performance was poorer and yields were lower. Therefore, less farmers used herbicides and those that used them tended to use cheaper compounds.

The majority of the farmers in both the irrigated (70%) and rainfed (55%) areas applied the herbicides 3 to 7 days after transplanting.

In Pangasinan and Iloilo the herbicide rate ranged from 0.24 to 0.57 kg acid equivalent (a.e.)/ha. The farmers said that they used the recommended rate, but the recommended rate was 0.8 kg a.e./ha. Thus, they were applying from 29 to 70% less than the recommended rate.

When applying herbicides the farmers used less than 100 to more than 300 liters water/ ha. Most used 200 liters/ha or less. The farmers interviewed used an average of 185 liters water/ha. For good weed coverage, 380 liters/ha is recommended. Because the farmers were using less than the recommended rates for both herbicide and water, the weed control achieved with herbicides was probably less than satisfactory.

Some of the farmers interviewed were aware that phenoxy herbicides controlled broadleaf weeds (*C. diffusa, M. vaginalis*) and sedges (*C. difformis, F. littoralis*) only and had no effect on grasses such as *E. colona* and *I. rugosum* when applied 21 days after seeding or transplanting. The farmers reported that grassy weeds were difficult to control.

- *Mungbean.* Herbicides were not used in mungbean in Pangasinan and Iloilo. One farmer in Cagayan Valley reported using 2,4D as a band application between the rows for weed control in mungbean. He followed that with a hand weeding to control weeds not killed by the herbicide application.

Table 9. Number of farmers who used herbicides for weed control in rice in rainfed areas in the Philippines. 1979.

Herbicide	Farmers (no.)					
		Iloilo				
		First crop				
	Transplanted rice in Pangasinan	Rice broadcast-seeded on puddled soil	Transplanted rice	Dry-seeded rice	Second crop of rice broadcast-seeded on puddled soil	Transplanted rice in Cagayan Valley
2,4-D liquid	11	16	3	1	10	17
MCPA liquid	2	7	5	1	5	0
2,4-D granule	3	0	0	0	0	0

Implications of farmers weed control practices

The farmer's weed control practices are determined largely by his concept about weeds and their relationship with the crop, his resources, his knowledge of the available technologies, and the environmental conditions under which the crop is grown. Differences in weed control practices for a given crop within and across sites were noted. Within a site, the primary determinants of the weed control method used are the financial and labor resources of the farmer.

Very few farmers in the areas surveyed used herbicides because of the expense and limited cash. For a treatment of 2,4–D granules applied at 0.8 kg a.e./ha, the farmer had to spend $8.16/ ha. Assuming that labor costs $1.09/day, that is equivalent to 60 labor hours (at a labor cost of ₱0.68/day, it would be equivalent to 96 labor hours). If granular butachlor were used at 1.0 kg a.e./ ha, the cost would be $9.80/ha, which is equivalent to 72 labor hours (115 labor hours at $0.68/day). The time taken to weed transplanted rice grown in cropping pattern plots in Pangasinan and Iloilo was 30 and 40 labor hours/ha. In farmers' fields, it was 84 labor hours/ha.

The recommendation for the cropping pattern plot was thorough land preparation followed by spot weeding in both Pangasinan and Iloilo. If sedges and broadleaf weeds were a problem in Pangasinan, 2,4–D should be applied at 0.5 kg a.e./ha, 21 days after transplanting.

Assuming that the farmer hires all labor for weeding, the use of herbicides for weed control in transplanted rice in most cases would not be economical. The fact that the most widely used source of labor for hand weeding is family labor further explains the reluctance of farmers to use herbicides in transplanted rice.

Use of 2,4–D liquid 21 days after transplanting would cost less — $6.95/ha (equivalent to 51 labor hours) — but this treatment does not control grassy weeds and labor would be needed to remove them by hand.

The time required for hand weeding is much greater in dry-seeded rice than in transplanted rice, and herbicides could play a major role in weed control in the former. However, lack of cash is the major reason most farmers were hesitant to plant dry-seeded rainfed bunded rice where weeds are the major problem (Lavapiez et al 1978).

Our results have indicated that for optimum yields in dry-seeded rice, the field must be hand weeded twice or a preemergence herbicide treatment must be followed by a hand weeding about 5 weeks after crop emergence to control the second generation of weed growth.

Table 10. Time required for weeding 3 weeks after emergence, and cost of weeding of dry-seeded IR36 rice as affected by herbicide treatments. Pangasinan, Philippines, 1979 wet season.

Treatment	Herbicide rate[a] (kg a.e./ha)	Time required for weeding (labor-h/ha)	Cost of weeding ($)		
			Herbicide	Hand	Total
Butachlor	2.0	778	28.76	105.85	134.61
Thiobencarb	3.0	639	50.05	86.93	136.98
Butachlor	1.0	944	14.38	128.44	142.82
Thiobencarb	2.5	750	41.71	102.04	143.75
Hand weeding	–	1,292[b]	—	175.78	175.78

[a] a.e. = acid equivalent. [b] For 1 hand weeding, 2 weeks after emergence.

In Pangasinan, butachlor and thiobencarb are two commercially available herbicides that give about the same degree of weed control. Butachlor costs $28.76/ha (at 2.0 kg a.e./ha) and thiobencarb costs $50.05/ha (at 3.0 kg a.e./ha). Reduction in the rate of herbicide applied would reduce the herbicide cost but increase the time spent in weeding the dry-seeded rice field because of reduced weed control. This was studied in a 1979 trial in Pangasinan and comparisons were made with a plot that was hand weeded twice, the first weeding requiring 1,292 labor hours/ ha (Table 10).

Yield differences between treatments were not significant. With regard to costs, the high rate of herbicide followed by hand weeding was superior to the low rate of herbicide followed by hand weeding. The increased cost in hand weeding due to the reduction in herbicide rate was greater than the reduction in cost due to the use of less herbicide.

One hand weeding by itself was more than 20% costlier than the most expensive herbicide-plus-hand-weeding treatments. Based on the data, the use of herbicides followed by hand weeding is better than hand weeding alone for dry-seeded rice provided that the farmer has cash to purchase them. Based on those figures, the cost of weeding in dry-seeded rice at the present time is about 20 times as expensive as that for transplanted rice.

For any crop, the weed control measures that are developed for introduction into either the existing or an improved cropping system should be compatible with the farmers' resources.

Emphasis should be placed on systems that require a minimum cash input and a moderate level of labor. The labor requirement should not exceed that which the farmer can afford. We are concerned that the inputs needed for weeding dry-seeded rice may be beyond the resources of the farmer. Thus, we should continue to search for more economic ways of controlling weeds in dryseeded rice.

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DISCUSSION

Malla: How far are extension agencies active in subsidizing hand weeding and chemical weeding in farmers' fields?

Estorninos: The extension agency (Bureau of Agricultural Extension) is not subsidizing weed control in farmers' fields. However, all extension men help the farmers secure loans for rice production under the Masagana 99 program of the government. The loan is intended for all the material inputs.

Malla: How do extension people convince farmers to adopt weed control measures?

Estorninos: Government technicians extend weed control recommendations to the farmer. I think in some cases, they have demonstration plots for this purpose.

Malla: Is the low percentage of herbicide use due to lack of credit? cash? or ignorance?

Estorninos: Few farmers use herbicides, particuarly in rainfed areas, because of limited cash. Another reason given by the farmer is that 2,4-D, which is the commonly available cheap herbicide, does not control grassy weeds.

Ahmad: How did you collect information regarding weed control practices and farmers' concepts toward weeds?

Estorninos: We collected information from the farmers using the same questionnaires in Pangasinan and Iloilo. In Nueva Ecija, Miss Perla Carbonell of the Agricultural Engineering Department also used the questionnaire to gather data for irrigated and rainfed areas. In Cagayan Valley, data were taken from the base line study of the cropping systems economics personnel.

Ahmad: What percentage of farmers used herbicides? What reasons were given by those who did not?

Estorninos: A small percentage of farmers in rainfed areas used herbicides for weed control. A greater percentage of farmers used herbicide in irrigated areas In Nueva Ecija. Two main reasons for some farmers' non-use of herbicides were lack of cash and the fact that phenoxy herbicides do not control, or give poor control of, grassy weeds.

Review of yield loss studies in different crops in Sri Lanka

T. G. D. Siriwardana and L. Amarasingha

Weeds continue to be a major, but often neglected, aspect in crop protection. In Sri Lanka, no organized weed research program has been conducted although weed control studies have been carried out from time to time by various research workers. This paper reports yield losses due to weeds in different crops in experiments conducted in different parts of the country since 1969.

RICE

About 60% of the rice land in Sri Lanka is weeded. Assuming that complete weed control is achieved in this area and in the remainder of the area, a 15% to 20% yield loss occurs. In 1978, 0.12-0.16 million tons of rice was lost due to weeds. Because 100% weed control cannot be achieved, the actual losses are probably higher than this estimate. Because rice in Sri Lanka is grown under wetland as well as dryland conditions, the weeds under the two conditions vary widely and have to be discussed separately.

Wetland rice

Due to complexities such as crop establishment, cultivars, agroclimatic conditions, application of fertilizer, and water management, it is difficult to find a direct relationship between yield loss and weed growth under different management practices. Some factors that have to be considered follow:

- *Rice cultivar.* Two cultivars, Bg 34-8, a 3-3 1/2 month cultivar, and Bg 11-11, a 4-4 1/2 month cultivar, have been studied. The yield loss due to a unit weight of weeds was greater for Bg 11-11 than for Bg 34-8 (Table 1). This loss can be compensated for by the higher yield potential of Bg 11–11. The higher yield reduction in the 4-4 1/2 month crop can be due to either a physiological factor or the age of the cultivar used.
- *Method of plant establishment.* In an experiment conducted in *maha* 1969-70, there was less yield reduction per unit weed dry weight in transplanted than in broadcast-seeded rice (Table 2). This indicates that another factor, rather than

Agricultural Research Station, Maha Illuppallama, Sri Lanka.

Table 1. Yield losses in 2 rice varieties under broadcast wet land conditions at the agricultural research station at Nalanda, Sri Lanka.

Cultivar	Maha 1970-71		Yala 1971		Maha 1971-72		Yala 1972		Maha 1972-73		Yala 1974		% yield reduction/ g weeds
	Yield reduction (%)	Weed wt (g/m^2)	Yield reduction (%)	Weed wt (g/m^2)	Yield reduction (%)	Weed wt (g/m^2)	Yield reduction (%)	Weed Wt (g/m^2)	Yield reduction (%)	Weed Wt (g/m^2)	Yield reduction (%)	Weed Wt (g/m^2)	
BG 34-8	–	–	–	–	–	–	79.4	1,587	30.1	618	93.4	1,354	–
	–	–	–	–	–	–	28.5	719	–	–	80.6	1,381	0.057
	–	–	–	–	–	–	78.7	1,103	–	–	–	–	–
	–	–	–	–	–	–	59.4	1,184	–	–	–	–	–
Bg 11-11	34.5	236	48.6	547	38.7	416	–	–	41.3	637	–	–	–
	10.0	95	–	–	37.2	791	–	–	24.2	188	–	–	0.083
	45.5	478		–				–	–	–	–	–	–

Table 2. Yield losses due to weeds and dry weight of weeds in transplanted and broadcast rice in 5 localities (I-V) during 1969-70 maha, Sri Lanka.

Site	Cultivar	Transplanted		Broadcast	
		Yield reduction (%)	Weed dry wt (g/m^2)	Yield reduction (%)	Weed dry wt (g/m^2)
I	Bg 11-11	21.6	49	27.3	88
II	IR8	−1.2	30	14.3	31.7
III	Bg 11-1 1	5.9	300	32.3	161
IV	IR8	4.7	78	18.6	182
V	Pd 46-A	6.8	24	1.2	90
% yield reduction/g weeds		0.078		0.169	

Table 3. Effect of nitrogen fertilizer on grain yield of Bg 11-11 rice and yield losses due to weeds at 2 sites in Sri Lanka. 1971-72 maha.

Nitrogen applied (kg/ha)	Paranthan		Karadiyan aru		Mean % yield reduction due to weeds
	Yield (t/ha) of weeded control	Yield reduction (%) due to weeds	Yield (t/ha) of weeded control	Yield reduction (%) due to weeds	
0	2.9	17.5	3.1	−16.7	0.4
45	3.8	14.5	3.8	4.2	9.3
90	4.8	21.8	4.8	2.0	11.9
135	5.2	23.3	4.8	6.3	14.8

mere suppression of weeds, is responsible for the higher yield under transplanted conditions.

- *Effect of nitrogen fertilizer.* Two experiments indicated that although a higher percentage of yield reduction occurred with higher applications of nitrogen, such reduction was compensated for by the higher yields obtained with added nitrogen (Table 3).

Dryland rice

The damage done by weeds in dryland rice is considerably more than in wetland rice (Table 1, 4). Due to relatively poor land preparation and lack of standing water under dryland conditions, populations of weed species partly depend on the length of time after land clearing, cultivation practices, and crop history in the particular locality (Agricultural Research Station, Maha Illuppallama). Therefore, damage due to weeds under dryland conditions can vary from place to place. Table 4 gives the yield losses obtained in experiments conducted at the Maha Illuppallama Agricultural Research Station.

Effect of plant type on weed competition is shown in Table 5. Bg 34-8 has a plant height of 60 cm; 62-355, which is also a 3-3 1/2 month cultivar, has a plant height of 90 cm. For optimum yields, the shorter cultivar needed a longer weed-free period

Table 4. Percentage yield losses in dryland unbunded rice in experiments conducted at Maha Illuppallama, Sri Lanka.

Maha season	Cultivar	Yield losses[a] (%)
1970-71	MI 329	96.1
1971-72	MI 329	66.0
1975-76	Bg 34-8	99.8
	62-355	95.9
1977-78	Bg 34-8	92.6
1978-79	Bg 34-8	88.9
	62-355	86.0
Mean		91.4

[a]Av of 4 experiments.

Table 5. Effect of periods of weed competition on the yield of 2 rice cultivars. Maha Illuppallama, Sri Lanka.

Cultivar	Weed-free period (weeks) after rice emergence	Yield reduction (%) due to weeds	Weedy period (weeks) after rice emergence	Yield reduction (%) due to weeds
Bg 34-8	0	99.9	0	0.0
Bg 34-8	2	97.3	2	2.0
Bg 34-8	3	97.4	3	11.2
Bg 34-8	4	86.0	4	42.3
Bg 34-8	5	68.3	5	58.3
Bg 34-8	6	50.0	6	70.3
62-355	0	95.8	0	0.0
62-355	2	65.2	2	4.3
62-355	3	62.0	3	-12.4
62-355	4	58.1	4	59.3
62-355	5	36.9	5	83.6
62-355	6	22.5	6	90.9

than the taller cultivar. But the initial weedy conditions did not reduce the yield in the short cultivar as much as they did in the tall cultivar. Although a tall cultivar is more competitive against weeds, better results can be achieved by enhancing the competitive ability with the use of a herbicide (Agricultural Research Station, Maha Illuppallama).

UPLAND CROPS

Yield losses due to weeds in upland crops can vary with the crop species. Chili was the most sensitive to weeds, followed by sesame, cowpea, soybean, and peanut (Table 6).

The nature of the yield loss is partly explained in Table 7, 8, and 9. The highest weed weights were found in chili and the major weeds in this crop were *Eleusine indica* (L.) Gaertn. and *Echinochloa colona* (L.) Link. Soybean and maize were

Table 6. Percentage yield losses in upland crops in experiments conducted at the agricultural research station, Maha Illuppallama, Sri Lanka.

Crop	Yield losses[a] (%)									
	Maha 1970-71	Yala 1971	Maha 1971-72	Yala 1973	Yala 1974	Yala 1976	Yala 1977	Yala 1978	Maha 1978-79	Mean
Chili	88.7	83.3	–	–	–	–	–	–	–	86.9
Soybean	–	–	–	32.1	53.3	24.0	–	–	–	36.5
Sesame	–	–	–	–	–	69.6	–	69.5	–	69.6
Cowpea	–	–	–	–	–	–	48.2	–	37.2	42.4
Peanut	–	–	25.3	–	–	–	–	–	–	25.3

[a] Av of 2 experiments.

Table 7. Distribution of weed species in 3 crops at Maha Illuppallama, Sri Lanka, in 1978-79 maha.[a]

Weed	Fresh wt of weeds (kg/m^2)			
	Soybean	Chili	Maize	Mean
Eleusine indica	0.13 defg	0.84 a	0.16 defg	0.38 q
Echinochloa colona	0.53 c	0.74 ab	0.79 a	0.69 p
Dactyloctenium aegyptium	0.07 defg	0.59 bc	0.23 de	0.30 q
Digitaria adscendens	0.77 ab	0.08 defg	0.27 d	0.37 q
Ipomoea sp.	0.03 g	0.03 g	0.22 def	0.09 r
Cynodon dactylon	0.01 g	0.13 defg	0.16 defg	0.10 r
Other weeds	0.02 g	0.15 defg	0.09 defg	0.09 r
Total	1.56 x	2.56 v	1.92 x	

[a]Means followed by the same letter are not statistically different at the 5% level. LSD (0.05) for variety × weed species interaction = 0.28 kg/m^2.

Table 8. Distribution of weed species in 3 different crops at Maha Illuppallama, Sri Lanka, in 1978-79 maha.[a]

Weed	Dry wt (kg/m^2)			
	Soybean	Chili	Maize	Mean
Eleusine indica	0.04 d	0.48 a	0.03 d	0.18 p
Echinochloa colona	0.13 c	0.32 b	0.15 c	0.20 p
Dactyloctenium aegyptium	0.02 d	0.24 b	0.05 d	0.10 q
Digitaria adscendens	0.21 c	0.04 d	0.06 d	0.10 q
Total	0.40 x	1.08 y	0.29 x	

[a]Means followed by the same letter are not significantly different at the 5% level. LSD (0.05) for variety x weed species interaction = 0.16 kg/m^2.

equally competitive with weeds. *Digitaria adscendens* (H. B. K.) Henr. was more important in soybean and *E. colona* was more important in maize (Table 7, 8). Different weed flora were found growing in association with maize, sorghum, mungbean, and cowpea (Table 9). The data show either crop selectivity of certain weeds or crop repellance of others.

Therefore, yield loss cannot be determined by weed weight or weed number alone. The loss could depend on the crop's rate of growth, its physiological and ecological interactions with the crop-specific weeds and other agronomic practices involved such as fertilizer and water management. The crop cultivar could also play a role, as was found for rice. As the weeds in a given locality are determined by many factors, the yield losses due to weeds could vary highly from place to place even within the same district. This is supported by the data in Table 10, where cowpea yield losses due to weeds in different villages in the Anuradapura district for 1978-79 maha are given.

CONCLUSIONS

More basic information on the distribution of weeds under different cultivation practices, and on damage to specified crops is therefore necessary.

Table 9. Weight of weeds in different crops at Maha Illuppallama, Sri Lanka, in 1978 yala.

Weed	Weed wt (kg/m^2)									
	Maize		Sorghum		Mungbean		Cowpea		Mean	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Boerhavia diffusa	0.26	0.07	1.22	0.29	0.07	0.02	0.03	0.01	0.39	0.10
Eleusine indica	0.03	0.01	0.07	0.03	–	–		–	0.02	0.01
Dactyloctenium aegyptium	0.03	0.01	0.24	0.08	–	–	0.21	0.11	0.12	0.05
Digitaria adscendens	0.07	0.02	0.08	0.03	–	–	0.05	0.02	0.05	0.02
Echinochloa colona	0.39	0.12	0.31	0.13	0.69	0.33	–	–	0.35	0.14
Other weeds	0.02	0.01	–	–	–	–	–	–	–	–

Table 10. Cowpea yield losses due to weeds in farmers' fields in 1978-79 maha.

Farmer no.	Yield reduction (%)	Weeds ($no./m^2$) 3 wk after planting
1	44.4	261
2	7.0	110
3	20.0	155
4	5.0	41
5	6.3	356
Mean	27.9	184.6

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Crop losses due to weeds in Thailand

Rungsit Suwanketnikom

In Thailand, weed science research is limited to herbicide screening trials. No specific research on yield losses due to weeds has been conducted. The yield loss data reported in Table 1 were extracted from herbicide screening trial data. The important weeds growing in association with these crops are listed in Table 2.

Farmers in Thailand control weeds by many methods including hoeing, interrow cultivation, and herbicides. The average cost of hoeing or interrow cultivation is difficult to determine because labor costs differ in different parts of the country.

The amounts of herbicide imported in 1976 and 1977 are given in Table 3.

Table 1. Crop yield losses due to weeds in Thailand.

Crop	Cultivar	Yield (t/ha)		Reference
		Hand or hoe weeded	Not weeded	
Rice				
Dry-seeded	Lepmunarng	1.85	1.23	Supatanakul 1975
Wet-seeded	RD5	3.70	3.08	Wongsarot and Pratoomwong 1974
Transplanted	RD5	3.84	3.52	Wongsarot et al 1975
Maize				
Location:				
Takli	Suwan I	1.92	0.77	Karnjanajirawong and Teerawatsakul 1976
Phraputtabat	Suwan I	2.66	1.12	Karnjanajirawong and Teerawatsakul 1976
Sorghum	TSS7-5	4.71	2.75	Kongsangdown 1979
	KU.257	2.28	1.18	Kongsangdown 1979
Soybean				
Rainy season	S.J. 2	100	62.6	Supatanakul 1975
Dry season	S.J. 2	100	94.5	Supatanakul 1975
Mungbean	–	1.29	1.12	Teerawatsakul et al 1974
Peanut	–	2.25[a]	0.90[a]	Cheewaprasert and Chaising 1972
Cotton	Reba B50	0.93[b]	0.46[b]	Soodmai et al 1977
Kenaf	Cuban	15.0[c]	6.4	Teerawatsakul et al 1975a
Cassava	–	32.11[d]	27.89[d]	Teerawatsakul et al 1974
Sugarcane	Q.83	100[d]	61.7[d]	Lueang-a-papong 1977
Mint	Japanese	100[d]	49.9[d]	Suwanketnikom 1971

[a]Dry pods. [b]Seed cotton. [c]Nitralin applied. [d]Fresh weight.

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Table 2. Weed species growing in association with various crops in Thailand.

Crop	Season	Weed species
Rice		
Dry-seeded	Dry	*Oryza* spp. *Fimbristylis littoralis* Gaud. *Cyperus proceros* Rottb. *Eleocharis dulcis* (Burm.f.) Henschel *Aeschynomene aspera* L. *Cyperus rotundus* L. *Commelina benghalensis* L.
Wet-seeded	Rainy	*Echinochloa crus-galli* (L.) Beauv. *Cyperus difformis* L. *Cyperus haspan* L. *Scirpus grossus* L.f. *F. littoralis* *Sphenoclea zeylanica* Gaertn. *Monochoria vaginalis* (Burm.f.) Presl. *Ludwigia hyssopifolia* (G. Don) Exell *Utricularia aurea* Lour.
Transplanted	Rainy	*S. zeylanica* *L. hyssopifolia* *Ludwigia adscendens* (L.) Hara *M. vaginalis* *Paspalum scrobiculatum* L. *F. littoralis* *Cyperus pulcherrimus* Willd. ex Kunth *E. dulcis* *Scirpus articulatus* L. *C. difformis*
Sorghum	Rainy	*Amaranthus viridis* L. *C. benghalensis* *Brachiaria reptans* (L.) Gard. & C.E. Hubbard *Digitaria ciliaris* (Retz.) Koel. *Echinochloa colona* (L.) Gaertn. *Eleusine indica* (L.) Link *Pennisetum pedicellatum* Trin. *Pennisetum polystachyon* (L.) Schult.
Maize		
Location: Takli	–	*Brachiaria* spp. *D. ciliaris* *Euphorbia heterophylla* L. *Dactyloctenium aegyptium* (L.) Beauv. *Pennisetum* spp.
Phraputtabat	–	*Echinochloa colona* (L.) Link *D. ciliaris* *D. aegyptium* *Brachiaria* spp.
Soybean	Rainy and dry	*P. pedicellatum* *P. polystachyon* *E. indica* *D. ciliaris* *E. colona* *Cynodon dactylon* (L.) Pers.

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TABLE 2 CONTINUED

Crop	Season	Weed species
		C. rotundus
		C. benghalensis
		Amaranthus spinosus L.
		Ipomoea gracilis R.Br.
Mungbean	Dry	*E. heterophylla*
		Commelina spp.
		Brachiaria spp.
		D. aegyptium
		E. indica
		Abutilon sp.
		Boerhavia diffusa L.
		Alysicarpus spp.
Cotton	Rainy	*B. reptans*
		C. benghalensis
		D. ciliaris
		E. indica
		Leptochloa chinensis (L.) Nees
		A. spinosus
		Corchorus aestuans L.
		Sida acuta Burm.f.
		E. heterophylla
		I. gracilis
Kenaf	Rainy	*B. reptans*
		E. indica
		D. aegyptium
		Gomphrena celosioides Mart.
		B. diffusa
		Digitaria spp.
		Richardia braziliensis (Moq.) Gomez
Cassava	Rainy	*D. ciliaris*
		D. aegyptium
		B. reptans
		G. celosioides
		E. heterophylla
		Borreria alata (Aubl.) DC.
		Commelina spp.
		E. colona
		E. indica
		Cleome viscosa L.
		Amaranthus sp.
		Melochia corchorifolia L.
Sugarcane	Rainy	*C. benghalensis*
		B. reptans
		D. ciliaris
		Trianthema portulacastrum L.
		Tribulus terrestris L.
		Amaranthus spinosus L.
Mint	Dry	*A. spinosus*
		T. portulacastrum
		Alternanthera pungens Kunth

Table 3. Herbicides imported into Thailand in 1976 and 1977.

Common name	Imported 1976		Imported 1977	
	Quantity (kg)	Value (US$)	Quantity (kg)	Value (US$)
Alachlor	18,760	76,893	52,659	193,334
Ametryn	97,675	472,109	195,995	971,161
Ametryn-atrazine	43,570	197,532	78,000	344,305
Asulam	–	–	10,000	40,217
Atrazine	77,055	296,905	220,570	760,146
Bromacil	46,264	505,646	112,718	1,300,248
Bromacil-diuron	15,708	125,517	21,273	182,711
Butachlor	–	–	152,084	72,558
Chlornitrofen	–	–	20,000	10,074
Cyanazine	12,000	45,543	–	–
Dalapon	197,000	324,488	226,351	301,246
2,4-D	750,000	824,081	1,346,700	948,065
MSMA-diuron-2,4-D	–	–	4,000	7,282
Chlorthal-dimethyl	1,306	5,253	2,6 12	10,054
Diphenamid	5,010	28,920	7,500	32,186
Diuron	126,523	460,947	359,051	1,238,617
EPTC	–	–	25,000	13,247
Glyphosate	–	–	4,093	46,760
Ioxynil	24,000	88,020	1,200	6,455
Linuron	1,000	6,892	4,000	27,521
Mecoprop-diuron-amitrole	5,400	21,024	–	–
Metolachlor	–	–	4,000	21,436
Metribuzin	55,000	99,713	15,000	99,880
MSMA	2,085	4,538	3,000	5,043
MSMA-diuron	5,112	16,672	4,619	13,669
Napropamide	–	–	1,529	11,336
Nitrofen	–	–	2,875	10,813
Oxadiazon	–	–	1,300	13,905
Paraquat	449,383	1,006.009	699,615	1,554,589
Paraquat-diuron	1,640	7,101	2,000	8,659
Propanil	20,220	30,838	–	–
Simazine	–	–	1,000	4,067
Sodium pentachlorophenate	5,000	7,549	–	–
2,4,5-T	160,163	371,027	14,968	57,548
TCA	–	–	29,000	15,920
Thiobencarb	3.960	13.272	9,900	33,182

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DISCUSSION

Ahmad: Do you have any information from the farmers regarding herbicide availability and farmers' reaction and enthusiasm in using those?

Suwanketnikon: The farmers are willing to use the herbicide except when cost is high. However, in the area where we are doing the research herbicides are not available. Hopefully in the next few years they will use herbicides.

Ahmad: Do the Thai farmers use herbicides on rice or on other upland grain or legume crops?

Suwanketnikon: In Bangpae, farmers don't but in the other areas of Thailand, farmers use herbicides on upland crops.

Studies of yield loss due to weeds in different upland crops and rice

Wayan Sabe Ar, Agus Sudiman, and Sutisna Noor

This paper discusses the effects of weeds on the yield of transplanted rice, gogo rancah (dry-seeded) rice, dryland rice, maize, peanut, and soybean.

TRANSPLANTED RICE

Effect on yield of weed competition during early growth

As the date of planting weeds was delayed from 1 to 4 weeks after transplanting, their weight decreased and the yield losses they caused also decreased (Table 1). All weeds caused about 30% yield reduction when planted 1 week after rice was transplanted, but when planted 3 weeks after transplanting *Paspalum vaginatum* Sw. was the most competitive. Yield losses caused by the three weeds when transplanted at that time were 15% for *P. vaginatum*, 4% for *Monochoria vaginalis* (Burm. f.) Presl., and 0 for *Marsilea crenata* Presl.

Effect of weed density on yield

Different weed species planted at different weed densities (0-32 plants/0.125 m^2) affected the height of the rice plant, tillering capacity, date to flowering, and yield of transplanted IR30 rice. *P. vaginatum* reduced rice yields from 26 to 43%, and *M. vaginalis*, from 61 to 66% as the number of weeds per 0.125 m^2 increased from 8 to 32 (Table 2). The less competitive *M. crenata* caused only a 15% yield reduction when 32 weeds were in competition with rice.

GOGO RANCAH RICE

Yield losses due to weeds were 70% in Indramayu and 55% in Jakenan (Table 3). Oxadiazon failed to control the dominant weeds adequately in Indramayu, but gave excellent control in Jakenan. As a result, yields obtained with this treatment were much lower than those from the manually weeded check at Indramayu, but did not differ from those of the check at Jakenan. Bentazon did not control the dominant weeds as well as oxadiazon did at Jakenan.

Site coordinators and assistant researcher, Cropping Systems Project Baheraja, Department of Agronomy, Central Research Institute for Agriculture, Bogor, Indonesia,

Table 1. Yield of IR34 rice and weight of 3 weed species as affected by time of planting of weeds after rice is transplanted. Central Research Institute for Agriculture, Bogor, Indonesia, 1976 dry season.

Time of planting weeds (weeks after transplanting)	*Paspalum vaginatum*		*Monochoria vaginalis*		*Marsilea crenata*	
	Rice yield (t/ha)	Weed wt (g/0.125 m^2)	Rice yield (t/ha)	Weed wt (g/0.125 m^2)	Rice yield (t/ha)	Weed wt (g/0.125 m^2)
1	4.6	17.3	4.3	25.3	4.5	10.6
2	4.6	7.2	4.9	14.9	4.4	8.2
3	5.5	2.8	5.9	4.6	6.4	2.2
4	6.7	1.8	5.4	2.0	6.8	1.9
No weeds	6.5	0	6.1	0	6.2	0
	Rice		Weeds			
	Main plot	Subplot	Main plot	Subplot		
HSD 5%	0.46	0.95	2.9	5.7		

Table 2. Yield of transplanted IR30 rice and weight of 3 weed species as affected by different weed densities Central Research Institute for Agriculture, Bogor, Indonesia, 1977 dry season.

Weed seedlings (no./0.125 m^2)	*Paspalum vaginatum*		*Monochoria vaginalis*		*Marsilea crenata*	
	Rice yield (t/ha)	Weed wt (g/0.125 m^2)	Rice yield (t/ha)	Weed wt (g/0.125 m^2)	Rice yield (t/ha)	Weed wt (g/0.125 m^2)
0	5.8	0	8.0	0	1.6	0
8	4.3	46.9	3.1	22.2	6.9	6.6
16	4.2	31.5	3.1	28.3	7.3	4.1
32	3.3	52.7	2.8	33.7	6.4	8.1
	Rice		Weeds			
	Main plot	Subplot	Main plot	Subplot		
HSD 5%	1.57	1.75	8.5	11.6		

Table 3. Weed weight and yield of gogo rancah IR26 rice as affected by different weed control treatments at 2 sites. Indramayu and Jakenan, Java, Indonesia, 1976-77 wet season.

Treatment	Indramayu		Jakenan	
	Weed wt[a] (g/0.125 m²)	Yield (t/ha)	Weed wt[b] (g/0.125 m²)	Yield (t/ha)
Manual weeding, twice	0.5	3.6	2.8	3.4
Oxadiazon (0.25 kg a.i./ha)	12.0	2.3	1.3	3.5
Bentazon	–	–	16.7	3.0
No weeding	60.1	1.1	55.9	1.5
HSD 5%	33.8	1.4	49.4	1.2

[a]Major weeds were *Echinochloa colona* and *Paspalum vaginatum.* [b]Major weeds were *Cyprus iria, E. colona, Fimbrislylis* sp., and *Alternanthera sessilis.*

DRYLAND RICE

In a trial conducted at Bandajaya, Sumatra, the yield of the cultivar Bicol grown under dryland conditions was reduced 38% by competition from *Digitaria sanguinalis* (L.) Scop., *Spigelia anthelmia* L., *Heliotropium indicum* L., and *Borreria latifolia* L. Oxadiazon and bentazon gave good control of these weeds, and plots treated with those compounds yielded as well as the manually weeded check.

MAIZE

Before land preparation for maize, the area was covered with *Imperata cylindrica* (L.) Beauv. The methods of land preparation produced no significant difference in yields (Table 4). In the unweeded plots, the yield loss due to weeds primarily *B. latifolia* ranged from 70-97%. One weeding 21 days after emergence was not adequate. Yield losses of 29-45% occurred when one weeding was done compared to the yields that were obtained when the plots were weeded twice.

PEANUT

The major weeds in the experimental area were *D. sanguinalis* and *B. latifolia.* The average yield of peanut from the plots that were treated with paraquat and then

Table 4. Effect of land preparation methods and degrees of weed control on maize yield. Lampung, South Sumatra, Indonesia, 1976-77 wet season.

Method of weed control	Maize yield (t/ha)			
	Normal tillage	No tillage (paraquat, 0.5 kg a.i./ha)	Strip tillage + paraquat (0.5 kg a.i./ha)	Strip tillage + mulch
Manual weeding, twice	2.3	2.2	2.1	2.2
Manual weeding, once	1.3	1.6	1.2	1.6
No weeding	0.7	0.6	0.2	0.7
	Main plot	Subplot		
HSD 5%	0.32	0.30		

Table 5. Effect of land preparation methods and degrees of weed control on peanut yield. Lampung, South Sumatra, Indonesia, 1977-78 wet season.

Method of weed control	Peanut yield[a] (t/ha)			
	Hoed twice	Hoed once fb paraquat (0.5 kg a.i./ha)	Paraquat (0.5 kg a.i./ha) fb one hoeing	Paraquat (0.5 kg a.i./ha) fb scraping
No weeding	0.6	0.6	0.8	0.3
Weeded once	0.9	0.8	0.9	0.4
Weeded twice	1.1	0.9	1.2	1.0
Oxadiazon (0.13 kg a.i./ha)	1.0	0.9	0.9	0.7
	Main plot	Subplot		
HSD 5%	0.20	0.20		

[a]fb = followed by.

Table 6. Effect of weed control methods and land preparation on soybean yield in an upland bunded area. Central Research Institute for Agriculture, Bogor, Indonesia, 1976-77 wet season.

Method of weed control	Soybean yield (t/ha)		
	Two hoeings	One hoeing fb[a] paraquat (0.5 kg a.i./ha)	No tillage (scraped)
No weeding	1.5	–	1.1
Weeded twice	1.7	1.7	1.5
Alachlor (0.72 kg a.i./ha)	1.9	1.9	1.5
	Main plot	Subplot	
HSD 5%	0.23	0.2	

[a]Followed by.

Table 7. Effect of weed control methods and land preparation on soybean yield in an upland bunded field. Central Research Institute for Agriculture, Bogor, Indonesia, 1977 dry season.

Method of weed control	Soybean yield[a] (t/ha)			
	Two hoeings	One hoeing fb paraquat (0.5 kg a.i./ha)	Paraquat (0.5 kg a.i./ha) fb one hoeing	No tillage (scraped)
No weeding	1.3	1.3	1.3	0.7
Weeded twice	2.0	1.9	1.7	1.5
Alachlor (0.72 kg a.i./ha)	1.8	1.2	1.2	0.9
	Main plot	Subplot		
HSD 5%	0.52	0.44		

[a]fb = followed by.

scraped was significantly lower than that from the plots that were hoed twice and those that were treated with paraquat and then hoed (Table 5). No other differences among land preparation methods were significant.

The yield loss caused by weeds in the unweeded check plots, which yielded the

lowest, ranged from 26 to 42%. The highest yields were obtained from the plots that were weeded twice — 21 and 42 days after planting. The second lowest yields were obtained from the plots that were weeded once — 21 days after planting. Oxadiazon failed to control *D. sanguinalis.*

SOYBEAN

Soybean yields were unaffected by the method of land preparation in the 1976-77 wet season (Table 6), but in the 1977 dry season, yields from the no-tillage plots were significantly lower than those from the plots that had been hoed twice (Table 7).

The yields from the unweeded plots were 12-30% lower than those from the plots weeded twice in the wet season, and 25-36% lower than those in the dry season. Alachlor performed well in the wet season and poorly in the dry.

DISCUSSION

Estorninos: Based on the high yields of the strip-tillage + mulch and the no-tillage with paraquat treatments, what do you think is the most economical method, considering the expenses for strip-tillage, cutting of alang-alang for mulch, and the price of paraquat?

Wayan: The farmer is still doubtful about the use of paraquat, because of its price and because it is not easy to get. So I think tillage + alang-alang mulch is more practical for the farmer without cash.

Ahmad: Regarding Table 1, 2, 3: Weed seed should not be planted in the fields at different times. If experimental requirements are such, the weed seeds may be planted initially and can be minimized and reduced to a distinct number of combinations. Would you like to comment on this?

Wayan: We observed that weeds germinated 1-2 weeks after rice is transplanted, depending on the type of land preparation. So, in this experiment we simulated this by using different times of weed planting.

Patel: Since you are going to plan long-term experiments to study weed competition during critical periods in certain multiple cropping patterns in Indonesia. I suggest you consider a multidisciplinary approach that includes the study of the weed flora, the effect of microclimate on weed ecology and on the crop, uptake of nutrients, bioassay, degradation, and an integrated approach to weed control methods in the different cropping patterns.

Malla: Do you have some idea on the cost-benefit ratio of the use of alachlor on soybean?

Wayan: We have not analyzed the cost-benefit ratio of using this herbicide, because we do not yet know its price.

Janiya: Have you observed any regrowth of *Imperata cylindrica* after using different land preparation methods and weed control?

Wayan: Yes. we observed alang-alang regrowth. But the regrowth was less than 5% at these levels of land preparation.

Past research on weeds and weed control in Bangladesh and future directions

Nizam U. Ahmed

A review of the available literature concerning weeds and weed control studies in Bangladesh indicates that the first study was initiated in 1958-59 and reported in 1962 by Alim. He concluded that weeding was essential for peanut.

Only one weed control study has been conducted on wheat, the second most important cereal crop in the country. Khan and Rahman (1975) reported that methabenzthiazuron effectively controlled the weeds present and gave wheat yield significantly better than that of the unweeded control.

Most of the studies on jute, the most important fiber crop of the country, tested the effectiveness of different chemicals in controlling jute field weeds (Ali and Haq 1963; Ali and Bhuiyan 1964, Agronomy Division, Pakistan Central Jute Committee 1965, 1967; Bakar 1971; Talukder and Ali 1976a, 1976b; Choudhury et al 1977; Talukder and Waseque 1978).

Hoque and Rahman (1976) studied the number of viable weed seeds present per hectare of land under different soil conditions. They reported a maximum of 214.3 million weed seeds/ hectare in the plow depth of a cultivated upland soil.

Upland soils had a higher number of viable weed seeds than lowland soils. More weed seeds were present in cultivated soils than in noncultivated soils. Surface soils always had a higher number of viable weed seeds than subsurface soils (Table 1).

Most studies on weed control have been for rice, the most important cereal crop of the country (Division of Mycology and Plant Pathology 1964,1968,1971; Mian and Rahman 1969; Mamun 1969; Rahman 1969; Hussain and Mian 1970; Mian and Gaffer 1971; Rahman and Karim 1974; Gaffer and Rikabder 1974; BRRI 1976, 1977, 1979; Ahmed and Talukder 1977; Hoque et al 1978).

The highlights of this research are in the following section.

WEED CONTROL IN RICE

Degree of land preparation

The effect of number of plowings and harrowings on weed growth and yield of direct-seeded rice was studied in Bangladesh Rice Research Institute (BRRI) in the

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Table 1. Number of viable weed seeds per hectare under different soil situations (Hoque and Rahman 1976).

Soil situation	Number of viable weed seeds (million/ha)			
	Grasses	Sedges	Broadleaf weeds	Total
	Upland soil			
Cultivated soil				
Surface soil	195.0	2.5	16.8	214.3
Subsurface soil	2.8	1.3	0.5	4.6
Noncultivated soil				
Surface soil	63.3	82.5	60.5	206.3
Subsurface soil	5.5	8.3	1.0	14.8
	Lowland soil			
Cultivated soil				
Surface soil	16.0	16.8	17.8	50.6
Subsurface soil	1.8	1.5	1.8	5.1
Noncultivated soil				
Surface soil	13.3	7.8	1.5	22.6
Subsurface soil	0.3	1.0	0.3	1.6

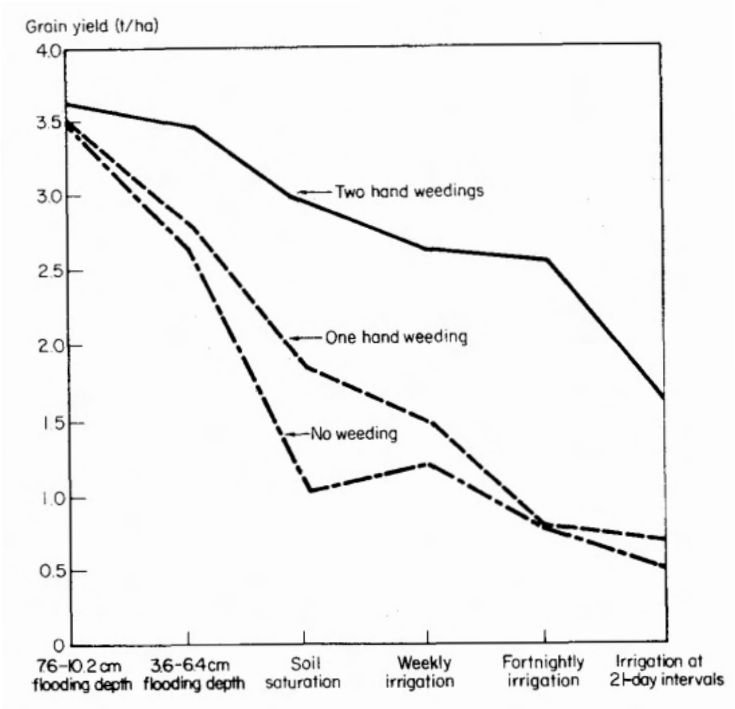
1973-74 boro (BRRI 1976). Weed growth was maximum in the zero-tillage treatment, and next highest in the treatment with one plowing (Table 2). One plowing with power tiller, two plowings with country plow combined with one harrowing, and two harrowings reduced the total weed weight. Grain yield was not significantly affected by the type of land preparation (Table 2).

Water management and weeding intensity

Six levels of water management at three weeding intensities in a transplanted rice crop were compared in the 1973-74 boro (BRRI 1976). No significant interaction between water management and weeding intensity was reflected in grain yield. But within any particular weeding intensity, grain yield differences due to water management systems were observed (Fig. 1). Grain yield decreased with a decrease in the intensity and frequency of irrigation.

Table 2. Effect of degree of land preparation on weed growth and grain yield of direct-seeded wetland rice (BR3). Bangladesh Rice Research Institute, 1973-74 boro (BRRI 1976).

Treatment	Dry weed wt (g/plot)				Grain yield (t/ha)
	At first weeding	At second weeding	At harvest	Total	
Zero tillage	899	645	92	1,636	5.1
One plowing with country plow and no harrowing	843	332	33	1,208	6.1
One plowing with country plow and one harrowing	358	540	40	938	6.2
Two plowings with country plow and one harrowing	315	208	31	561	6.1
Two harrowings	143	340	33	514	6.5
One plowing with power tiller	226	332		591	7.4



1. Grain yield of transplanted rice (BR3) as influenced by water management and weeding regime (BRRI 1976).

Two hand weedings gave significantly higher grain yields than one hand weeding and no weeding, which were statistically identical.

Irrespective of weeding intensity, the highest weed weight was obtained from continuous soil saturation and the lowest was from flooding at depths of 7.6 to 10.2 cm. For the unweeded check, the lowest weed weight was obtained from the plots that were irrigated weekly (Fig. 2).

Fertility levels

A preliminary greenhouse study was conducted during the 1974 aus season to determine rice (cultivar Chandina) yield reduction due to competition from *Cyperus iria* L. and *Echinochloa colona* (L.) Link (BRRI 1977).

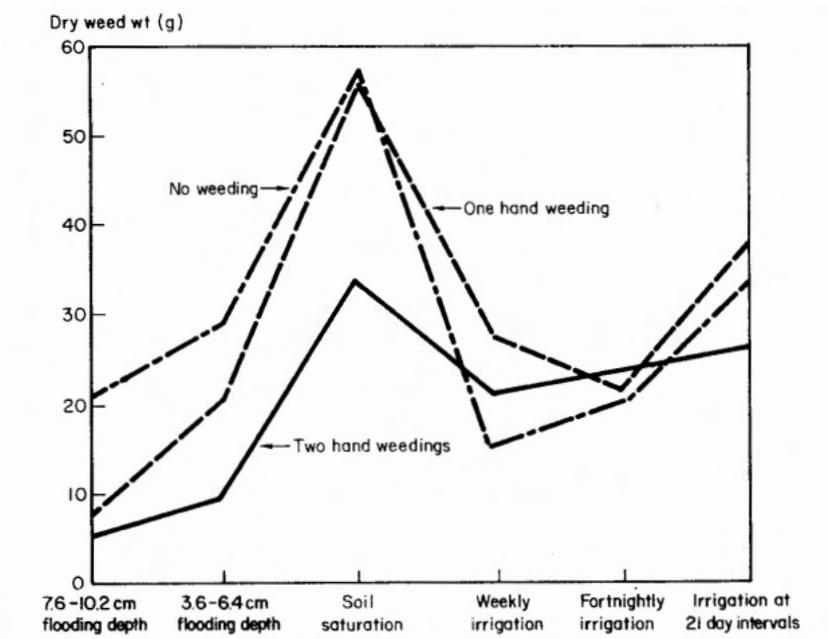
Rice plants and weeds were grown at 1: 1 at 3 fertility levels. Yield reduction due to weeds was greater at higher fertility levels (Table 3).

Frequency and time of hand weeding

BRRI (1977) reported that the optimum time for a single hand weeding in transplanted aman was between 21 and 28 days after transplanting. Increasing the frequency of hand weeding from 1 to 2 doubled the yield (Table 4).

A weed-free period between 0 and 49 days from transplanting resulted in highest yields for a transplanted aman crop of IR20 (Table 5).

In another study, it was observed that dry-seeded rice needed a minimum period of from 3 to 6 weeks from the date of seeding to produce a satisfactory yield (Table 5; BRRI 1979). The crop failed to compensate for the competition caused by weeds



2. Weed weight in transplanted rice (BR3) as influenced by water manage ment and weeding regime (BRRI 1976).

during the first 28 days from seeding, even though the field was kept clean during the rest of its life cycle.

Chemical control

Butachlor and piperophos-dimethametryn effectively reduced weed infestation in direct-seeded rice (BRRI 1977). Oxadiazon, fluorodifen, butralin, and prodiamine were less effective. Yield increases over the yield of the untreated check ranged from 140 to 260% (Table 6).

Transplanted aus crop plots treated with piperophos -dimethametryn and pipe-rophos - 2,4-D yielded just over 3 t/ha, in contrast to the 2.5 t/ha produced in the unweeded check plots (Table 7). Grain yield obtained from the plots that were hand weeded twice was significantly higher than that from the unweeded plots but not significantly different from that from the herbicide-treated plots.

Table3. Grain yield of rice(cu1tivar Chandina) as affected by competition from weeds at 3 fertility levels. Bangladesh Rice Research Institute, 1974 aus season (BRRI 1977).

Treatment	Grain yield[a] (g/pot)		
	0-0-0 N PK	60-40-20 kg NPK/ ha	120-60-40 kg NPK/ha
Rice alone	7.00 c	21.00 b	26.33 a
Rice + *Cyperus iria*	1.50 ef	5.17 cd	5.50 cd
Rice + *Echinochloa colona*	2.83 def	6.50 c	2.83 de
CV (%) 8.59			

[a]Means followed by a common letter do not differ significantly at the 5% level.

Table 4. Grain yield of rice (cultivar BR3) as affected by frequency of hand weeding. Bangladesh Rice Research Institute, 1974 t. aman season (BRRI 1977).

Hand weeding (days after transplanting)	Grain yield[a] (t/ha)
No weeding	0.9 e
14	2.0 d
18	2.1 d
21	2.1 d
25	2.4 d
28	2.0 d
35	1.5 e
14, 42	4.0 c
18, 42	4.2 bc
21, 42	4.3 abc
14, 28, 42	4.6 ab
18, 35, 49	4.8 a
CV (%)	1.5

[a]Means followed by a common letter do not differ significantly at the 5% level.

Table 5. Grain yield of rice as affected by weed-free period at different stages of growth.[a] Bangladesh Rice research Institute, 1975-76 aus and t. aman season (BRRI 1977).

Dry-seeded rice (cultivar Chandina) (aus season)		Transplanted aman rice (cultivar IR20) (t. aman season)	
Weed-free period (DS)[b]	Grain yield (t/ha)	Weed-free period (DT)[c]	Grain yield (t/ha)
0-maturity	2.9 a	0-14	2.5 d
0-21	1.7 bc	0-21	2.7 bcd
0-28	1.9 b	0-28	3.4 abc
0-35	2.0 b	0-35	3.5 ab
0-42	2.7 a	0-42	3.6 a
0-49	2.8 a	0-49	3.8 a
0-56	3.0 a	28-42	3.4 abc
0-63	2.8 a	28-49	3.2 abcd
0-70	3.0 a	35-42	3.3 abc
21-35	1.9 b	35-49	3.6 a
21-42	2.7 a	49-63	3.6 a
21-49	2.8 a	49-maturity	3.6 a
28-35	1.5 bcd		
28-42	1.7 bc		
28-49	2.0 b		
35-42	0.9 ef		
35-49	1.0 def		
35-56	1.3 cdef		
42-63	0.8 ef		
63-maturity	0.6 f		

[a]In a column, means followed by a common letter do nto differ significantly at the 5% level. [b]DS = days after seeding. [c]DT = days after transplanting.

Hoque et al (1978) reported that weeds were a problem in direct-seeded rice. The unweeded check plot yielded 39% less than the herbicide-treated and hand-weeded plots (Table 8). The best treatment for both direct-seeded and transplanted rice was a combination of a low rate (0.5 kga.i./ ha) of butachlor and hand weeding. The weed

Table 6. Comparison of 6 liquid herbicides, hand weeding, and no weeding for control of weeds in direct-seeded rice. Bangladesh Rice Research Institute, 1974 aus season (BRRI 1977).

Treatment	Visual weed control rating[a]	Grain yield[b] (t/ha)	% increase from control
Hand weeding	5	3.6 a	260
Butachlor	5	3.6 a	260
Piperophos - dimethametryn[c]	4	3.5 ab	250
Butralin	4	2.8 bc	180
Oxadiazon	3	2.6 c	160
Fluorodifen	4	2.5 c	I50
Prodiamine	4	2.4 c	140
Unweeded check	I	1.0 d	
CV (%)		13.8	

[a]Scale of 1-5: 1 =no control. 5=comuletecontrol. [b]In a column, means followed bva common letter do not differ significantly at the 5% level. [c]A spaced dash between two herbicide names indicates that the herbicides were formulated as a proprietary mixture.

Table 7. Comparison of 2 granular herbicides and hand weeding treatments for weed control in transplanted aus rice.[a] Bangladesh Rice Research Institute, 1974 aus season (BRRI 1977).

Treatment[b]	Rate (kg ai/ ha)[a]	Grain yield of rice (t /ha)	Dry weed wt (g/ m^2)
Piperophos - dimethametryn	0.15-0.60	3.1 ab	6.57 c
Piperophos - dimethametryn	0.30-1.20	3.4 a	6.25 c
Piperophos - 2,4-D	0.5-0.25	3.3 a	7.43 c
Piperophos - 2,4-D	1.0-0.5	3.2 ab	7.85 c
Hand weeding once, 25 DT	–	2.8 bc	18.57 b
Hand weeding twice, 20 and 40 DT	–	3.2 ab	7.60 c
Unweeded check	–	2.5 c	28.55 a
CV (%)		5.2	22.7

[a]In a column, meansfollowed by a common letter do not differ significantly at the 5% level. [b]A spaced dash (—) between two herbicide names indicates that the herbicides were formulated as a proprietary mixture. DT= days after transplanting. [c] ai= active ingredient.

Table 8. Yield of BR3 and Dharial rice under various weed management practices, 1976 aus season, Dacca, Bangladesh (Hoque et al 1978).

Treatment	Herbicide rate[a] (kg ai/ ha)	Yield[b] (t/ha)					
		Direct-seeded			Transplanted		
		BR3	Dharial	Mean	BR3	Dharial	Mean
Butachlor + hand weeding	0.5	6.0	3.0	4.5 a	6.7	1.5	4.1 a
Hand weeding	–	5.7	2.5	4.1 ab	6.4	1.5	4.0 a
Butachlor	1.5	4.7	2.1	3.4 b	6.1	1.4	3.8 b
Thiobencarb	1.5	4.4	2.5	3.5 b	6.0	1.4	3.7 b
Piperophos -dimethametryn[c]	1.2-0.3	4.7	2.0	3.4 b	6.0	1.4	3.7 b
Unneededcheck	–	3.3	1.3	2.3 c	6.0	1.4	3.7 b

[a]Applied 3 days after seeding. ai=active ingredient. [b]Any two means followed by the same letter are not significantly different at the 5% level. [c]A spaced dash between herbicide names means that the herbicides were formulated as a proprietary mixture.

species present in the plots of the taller (Dharial) and shorter (BR3) varieties differed. Weed weights in the unweeded direct-seeded plots were 92 g/m^2 for Dharial, and 133 g/m^2 for BR3.

Yield constraints

A study was conducted to determine the effect of fertilizer, insect control, and weed control on the production of irrigated transplanted rice (BRRI 1977). Fertilizer and weed control played a significant role in increasing the grain yield (Table 9). Weed control and fertilizer individually gave a yield increase of 36 and 44% from the control. When fertilizer and weed control were applied together, a 309% yield increase from the control was obtained (Table 9).

FUTURE DIRECTIONS

The following studies need attention.

- *Weed survey.* Weed survey should be done for every crop for 2 to 3 years. The known species should be listed and the unknown species collected for identification. The survey would provide information on the dominant weeds found in each crop across seasons.
- *Yield loss assessment studies.* Assessment of yield losses can be helpful in determining weed research priorities.
- *Studies on the biology of the problem weeds.* The biology of problem weeds would provide information as to the best approach for controlling a particular weed in any situation.
- *Weed control studies.* Weed control studies can be done within the framework of either an individual crop ora cropping pattern. Since weeds vary from site to site, most weed control studies should be done in farmers' fields. Some experiments, such as herbicide screening trials and studies on the biology of the problem weeds, should be conducted at research stations.

The economic aspects of various weed control methods should also be examined.

Table 9. Relative contribution of 3 inputs and their interaction on grain yield and weed weight.[a] Bangladesh Rice Research Institute, 1974-75 boro Season (BRRI 1977).

Inputs[b]	Grain yield (t/ha)	c/o increase from control	Weed wt (g/m^2)
None (control)	1.1 c	–	199.3 a
Fertilizer	1.5 b	44	194.0 a
Weed control	1.4 bc	36	5.9 b
Insect control	1.1 c	0	195.0 a
Fertilizer +weed control	4.5 a	309	5.6 b
Fertilizer + insect control	1.5 b	44	173.8 a
Weed control + insect control	1.5 b	44	5.9 b
Fertilizer + weed control + insect control	4.5 a	309	5.1 b
CV (%)	9.6	–	26.1

[a]In a column, means followed by the same letter do not differ significantly at the 5% level. [b]Fertilizer: 80-60-40 kg of N, P_2O_5, and K_2O/ha. Insect control: diazinon at 1.5 kg /ha at 21-day intervals.

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Weed control experiments on rice-based cropping systems

C. S. Patel and H. K. Pande

The enormous losses caused by weeds in crop production is well-known, but frequently, weed control does not receive sufficient emphasis.

The major weeds growing in association with crops that are important in cropping systems research are given in Table 1. The status of weed control in these crops is described in the next sections.

RICE

Rice yield reductions due to weeds are estimated to be 15-20% for transplanted rice, 30-35% for direct-seeded rice grown under puddled conditions, and more than 50%-60% for dryland rice (Pillai and Rao 1974).

Dryland rice

The cultivation of dryland rice poses a number of problems, such as poor crop stand, severe weed competition, and insufficient use of fertilizer. Therefore, the yield of dryland rice is low. Keeping dryland rice fields weed free between 20 and 40 days is important (Table 2). That can be achieved by utilizing mechanical methods available to the farmer (Singh 1978).

Because the weed flora growing in association with dryland rice is variable, it is difficult to achieve excellent weed control with a single method during early crop growth. Good weed control and high yields were achieved by various weed control methods (Table 3). Because hand weeding is laborious and costly, chemical or mechanical methods alone or in combination are preferred.

Patel and Moorthy (1979) reported that hand weeding was generally superior to herbicides for weed control in dryland rice. Of the herbicides tested, nitrofen and propanil performed the best. There was no residual carryover of the herbicides applied to rice on the succeeding crops of wheat, potato, or peanut.

In trials in 1977-78, yields from herbicide-treated plots were generally significantly lower than those from the weed-free plots at Chiplima and Kalyani, but differences at Bhubaneswar and Mantripokhari were not significant (Table4). Yield reductions

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Table 1. Major weeds growing in association with various crops in India.

Direct-seeded rice	Maize
1. Upland *Echinochloa colona* (L.) Link *Echinochloa crus-galli* (L.) Beauv. *Eleusine indica* (L.) Gaertn. *Paspalum* spp. *Panicum* spp. *Cynodon dactylon* (L.) Pers. *Cyperus rotundus* L. *Euphorbia hirta* L. *Celosia argentea* L.	*E. colona* *C. rotundus* *C. dactylon* *Eleusine aegyptiaca* Desf. *Setaria glauca* (L.) Beauv. *D. sanguinalis* *C. argentea* *Euphorbia hirta* L. *Tridax procumbens* L.
2. Medium land (shallow flooding) *E. colona* *E. crus-galli* *E. indica* *Paspalurn* spp. *Panicum* spp. *C. dactylon* *Cyperus* spp.	Wheat (rabi) *Phalaris minor* Retz. *Chenopodium album* L. *Avena fatua* L. *Convolvulus* sp. *Melilotus* sp. *Vicia* sp. *Asphodelus tenuifolius* Cav.
3. Lowland (deep water) *Heteranthera limosa* (Sw.) Willd. *Ammannia auriculata* Willd. *Bacopa rotundifolia* Wettst. *Chara* sp.	Peanut *C. rotundus* *Eragrostis pilosa* (L.) Beauv.
Transplanted rice *Cyperus iria* L. *E. colona* *E. crus-galli* *Digitaria sanguinalis* (L.) Scop *Scirpus* sp. *Marsilea quudrifolia* L. *Sphenoclea zeylanica* Gaertn. *Ludwigia perennis* L. *Commelina benghalensis* L.	Jute *Cyperus* sp. *D. sanguinalis* *E. indica* *C. dactylon* *E. colona* *E crus-galli* *S. glauca* *Phyllanthus niruri* L. *E. hirta*

due to the herbicides applied to rice were observed in the succeeding crops of wheat and mustard but not in potato.

Direct-seeded rice on puddled soil

Moorthy and Dubey (1979) reported that all plots treated with herbicides yielded significantly higher than the unweeded check in a trial conducted at the Central Rice Research Institute, Cuttack. Only the plot treated with WL 29226 yielded significantly less than the hand-weeded check (Table 5).

Transplanted rice

The weed problem in transplanted wetland rice is not as severe as in dryland rice because flooding largely controls the weeds. In various herbicide screening trials, the most effective chemicals have been propanil, butachlor, and a combination of 2,4-D and propanil (Patel and Moorthy 1979). At Mantripokhari, a significant reduction in the yield of the succeeding crop of wheat was attributed to the application of butachlor in rice. No residual effect of the herbicides used in rice was observed on

Table 2. Effect of duration of weed control or weed infestation on yield of Cauvery rice grown under upland conditions (Singh 1978).

Treatment	Rice yield (t/ha)			
	1972-73	1973-74	1974-75	Mean
Weed free				
For the first 10 days	1.9	1.8	1.4	1.7
For the first 20 days	2.1	3.2	2.4	2.6
For the first 30 days	2.3	3.5	2.8	2.9
For the first 40 days	2.1	3.7	3.0	2.9
For the first 50 days	2.3	3.6	2.8	2.9
Till maturity	2.6	4.5	2.1	3.2
Weed infested				
For the first 10 days	2.7	4.3	2.5	3.2
For the first 20 days	2.0	3.3	2.8	2.7
For the first 30 days	1.8	3.8	2.3	2.6
For the first 40 days	1.8	3.3	1.8	2.3
For the first 50 days	1.7	3.3	1.5	2.2
Till maturity	1.5	1.6	1.0	1.4
C.D. (5%)	0.4	0.6	0.1	

Table 3. Effect of different weed control treatments on the yield of dryland rice (Singh 1978).

Treatment	Rice yield (t/ha)				
	1971-72	1972-73	1973-74	1974-75	Mean
Alachlor + propanil	–	–	4.1	3.0	3.5
Weed-free check (3 hand weedings)	2.6	3.5	4.0	2.6	3.2
Butachlor + propanil	–	–	3.0	3.1	3.1
One mechanical weeding at 10 days + propanil and mechanical weeding at 40 days	–	–	3.1	2.2	2.9
Alachlor	–	2.6	3.6	2.4	2.9
One mechanical weeding at 10 days + propanil	–	–	3.1	2.6	2.8
Alachlor + 1 mechanical weeding at 40 days	–	–	2.6	2.9	2.7
Butachlor + 1 mechanical weeding at 40 days	–	–	2.6	2.7	2.6
Mechanical weeding (3-tined wheel hoe)	3.1	2.1	3.4	21	2.6
Butachlor	–	2.2	2.8	2.4	2.5
Propanil	2.8	2.0	3.1	1.9	2.4
Weedy check	2.0	0.8	2.2	1.4	1.6
C.D. (5%)	0.5	0.7	0.7	0.8	

maize in Bhubaneswar and wheat in Kalyani. At Kalyani, however, wheat showed a residual response to two hand weedings in rice.

UPLAND CROPS

For crops that are commonly grown in rotation with rice, Pande and Patel (1979) reported a critical weed-free period: 30 days for maize, 40 for peanuts, 30 for a dwarf wheat cultivar, and 50 for a tall wheat cultivar.

Table 4. Effectiveness and economics of herbicide-fertilizer mixture and weed control in dryland rice and its residual effect on succeeding crop in rotation, eastern and northeastern region, India, 1977-78.

	Yield[a] (t / ha)							
	Bhubaneswar (Laterite)		Chiplima (Red-yellow)		Mantripokhri (Red-yellow)		Kalyani (Alluvial)	
	Kharif rice Annapurna, D, Rf (50-50-50)	Rabi potato K. Chandra-mukhi, R, I (160-80-120)	Kharif rice OR-34-16, D, I (40-40-40)	Rabi mustard M-27, R, 1 (50-25-25)	Kharif rice CH-1039, D, I (30-60-60)	Rabi wheat Sonalika, R, I (30-60-60)	Kharif rice Pusa 2-21, D, N.R. (60-60-40)	Rabi wheat Sonalika. R, I (24-10-36)
Unweeded plots (control)	1.65	6.33	0.25	0.52	2.60	0.74	1.80	2.60
Two hand weedings + soil application of urea	0.67	1.58	0.74	-0.06	-1.08	-0.04	1.42	0.28
Two hand weedings+ foliar application of urea	1.17	4.00	0.64	0.08	-0.63	-0.06	1.54	-0.04
Presowing 2.4-D at 0.75 kg a.i. ha + post-emergence spray of 2,4-D at 1 kg/ha + 5% urea spray (20 kg ha) each in 2 splits at 20 and 40 days after sowing (DS)	1.07	3.33	-0.05	0.10	-1.02	0.10	1.22	-0.04
Postemergence propanil at 2.0 kga.i/ha + foliar application of urea (5%) to be applied together (20 kg N ha each in 2 splits at 20 and 40 DS)	0.49	1.86	0.03	0.04	0.00	0.14	0.75	0.15
Postemergence propanil at 2 kg a.i./ha + soil application of urea	0.50	0.33	-0.06	0.02	-0.48	0.01	0.60	-0.04
Presowing 2.4-D at 0.75 kg a.i. ha + post-emergence spray of propanil at 2.0 kg t urea through soil	0.93	3.14	0.01	0.03	-0.78	0.04	1.09	-0.07
Postemergence butachlor at 2 kg ai./ha + foliar application of urea (5%) to be applied together	0.49	0.17	-0.05	-0.06	-1.15	0.02	0.40	-0.01
Preemergence butachlor at 2 kg a.i./ha + application of urea through soil	0.42	0.17	0.00	-0.12	-1.22	-0.29	0.61	0.15
Postemergence nitrogen (Tok-E-25) at 2 kg a.i./ha + foliar application of urea (5%) to be applied separately (20 kg N ha each in 2 splits at 20 and 40 DS)	1.08	3.75	-0.05	0.03	-0.15	0.08	0.49	-0.01

TABLE 4 CONTINUED

	Yield[a] (t/ha)							
	Bhubaneswar (Laterite)		Chiplima (Red-yellow)		Mantripokhri (Red-yellow)		Kalyani (Alluvial)	
	Kharif rice Annapurna, D, Rf (50-50-50)	Rabi potato K. Chandra-mukhi, R, I (160-80-120)	Kharif rice OR-34-16, D, I (40-40-40)	Rabi mustard M-27, R, I (50-25-25)	Kharif rice CH-1039, D, I (30-60-60)	Rabi wheat Sonalika, R, I (30-60-60)	Kharif rice Pusa 2-21, D,N.R. (60–60-40)	Rabi wheat Sonalika, R, I (24–10-36)
Postemergence nitrogen (Tok-E-25) at 2 kg a.i./ha + foliar application of urea (5%) to be applied together	0.65	0.64	0.04	0.01	−1.13	−0.04	0.19	−0.17
Postemergence nitrogen (Tok-E-25) at 2 kg a.i. ha + soil application of urea	0.79	2.17	0.12	0.01	−0.92	−0.23	0.92	0.16
C.D. (5%)	703	2958	173	112	1168	474	414	339

[a] D = direct effect, R = residual effect. RF = rainfed, I = irrigated. The numbers in parentheses indicate fertilizer NPK in kilograms per hectare. Yields were low because of gall midge attack.

Table 5. Effect of weed control treatments on rice yield and nitrogen uptake by rice and weeds of broadcast-seeded rice grown on puddled soil (Moorthy and Dubev 1979).

Herbicide treatment[a]	Rate of application (kg/ha)	Weed wt (kg/ha) (dry)	Grain yield (t/ha)	N-uptake (kg/ha)			
				Weeds	Crop		
					Grain	Straw	Total
Piperophos - 2,4-D IPE	0.5-0.25	114	4.9	1.2	52.3	38.2	90.5
X-52 - 2,4-D IPE	1.4-0.5	85	4.5	0.8	49.0	35.7	84.7
Naproanilide - thiobencarb	1.0-0.7	117	4.0	0.13	42.1	34.4	76.5
Piperophos - dimethametryn	0.4-0.1	82	4.9	0.8	51.4	40.9	92.3
Oxadiazon	0.5	192	4.9	2.1	43.0	25.1	68.1
WL 29226	0.75	187	3.9	1.9	36.6	30.6	67.2
Butachlor + 2,4-D IPE	0.75 + 0.5	42	4.7	0.4	46.1	38.9	85.0
Tiocarbazil + 2,4-D IPE	3.0 + 0.5	65	4.6	0.7	48.0	39.8	87.8
Thiobencarb/2,4-D IPE	1.0/0.5	43	4.8	0.5	47.9	34.6	82.5
Dichlormate	1.5	412	4.2	4.3	40.2	34.6	74.8
Nitrofen	2.0	410	4.3	4.2	40.5	38.3	78.8
Hand weeded twice	–	178	4.4	1.7	45.5	36.0	81.5
Hand weeded three times	–	117	4.7	1.2	48.3	33.3	81.6
Untreated check	–	694	3.3	7.3	31.1	33.7	64.8
C.D. (5%)		184	457				

[a]A spaced dash (–) means that the herbicides were formulated as a proprietary mixture; + means that the herbicides were applied separately at about the same time; / means the two herbicides were formulated on the same carrier and applied as a single treatment.

MULTIPLE CROPPING

Maiti (1977) reported that from the third week of September, weeds in rice fields in West Bengal began to grow profusely. Flowering reached a maximum by 15 October when both temperature and humidity began to fall after reaching their peak. From mid-November, there was an abrupt decrease in the number of weed species.

In rice-based cropping systems such as rice - wheat -jute, rice - potato -jute, rice - pulse -jute, and rice - mustard -jute, most of the weeds that grew in association with a particular crop completed their life cycles along with the life cycle of that crop.

Reduction in weed growth by the adoption of multiple cropping and water management practices was reported by Patel and Mittra (1973). Including pulses as catch crops with rice or between rice-growing seasons, changing the cropping patterns wherever possible in upland fields, ensuring adequate crop density, timely fertilizer application, and water management practices can minimize weed competition in rice (Pillai 1977).

Biswas and Saraswat (1977) reported that the first crop of aus rice in a rice - rice - wheat rotation was badly infested with grasses and sedges. In the second year, weed density was less. In the first crop of jute in a jute - rice rotation, weed intensity was high in all treatments but was more intense in the manually weeded plots. In the second year, complete control of all types of weeds was obtained in jute after the planting of an aman rice crop (Biswas and Saraswat 1977). Gill and Brar (1977) reported that the population of *Phalaris minor* Retz. in wheat grown in rotation with transplanted rice can be reduced by inclusion of a berseem crop in the rotation.

HERBICIDE USE

Most farmers practice multiple cropping. At periods of peak labor demand, such as that which occurs when harvest of one crop and planting of the next occur simultaneously, the use of herbicides for weed control may be helpful so that the labor used for weeding can be released for other crop operations. In some areas where the soils are heavy and rains fall frequently, hand weeding at the correct time may not be possible. In such a situation herbicides may be a suitable alternative (Shetty et al 1977). Herbicides are also helpful in the control of perennial weed species such as *Cyperus rotundus* L. and *Cynodon dactylon* (L.) Pers.

Although herbicides are very costly and not readily available, chemical weed control may be a possibility in areas where the cost-benefit ratio is in favor of herbicides, such as when labor is costly or not readily available. Farmers are not trained in the use of herbicides and the possibility of improper usage with resultant serious crop damage exists.

FUTURE RESEARCH NEEDS

1. Herbicides with a broad spectrum of weed control for use in a particular crop in a cropping pattern grown on different soils and at different climatic conditions need to be identified.

2. The integration of different methods of weed control (chemical, physical, and mechanical) needs more attention.
3. Complete knowledge of the biology of weeds growing in association with different crops is needed for planning of appropriate weed control methods.
4. The residual effect of herbicides in different cropping systems grown on different soils needs to be studied.
5. A systematic study of weed ecology in multiple cropping needs to be undertaken.

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DISCUSSION

Navarez: What method do you adopt to convince the Philippine farmer to adopt weed control methods, inasmuch as IRRI is not directly involved with extension agencies?

Patel: Personnel from IRRI, UPLB, and Bureau of Plant Industry work together and come up with a weed control recommendation for transplanted and pregerminated broadcast-seeded rice on puddled soil and dry-seeded bunded rice. This recommendation is for the Masagana 99 government rice program. The personnel directly involved in disseminating this recommendation to the farmers are from the Bureau of Agricultural Extension.

In the IRRI cropping systems project, we directly teach the farmer-cooperators how to control the weeds in the crops grown in the cropping pattern.

Ahmad: Do you think that bioassay-type work should bedone at the present stage in India instead of working closely with the farmers to give them good solutions for weed control?

Patel: We conduct bioassay studies to know herbicidal buildup, toxicity effects, and polution hazards before we recommend their use in farmers' fields.

Ahmad: Does the Indian Government presently recommend herbicide use to farmers? What herbicides or type of herbicides are used by the farmers?

Patel: We have different herbicides for different crops. At present, Machete and Orofanil for paddy, Atrazine or Sicmaize for maize, 2,4-D (Na salt) for wheat and rice, and Lasso for Bajra are available.

Janiya: Have you ever looked into the effect of weed control practice in the rice crop on the weed intensity on the following crop (upland crops or rice)?

Patel: Yes. If we include a pulse crop in rotation with the dryland rice, the weed population is reduced to a great extent. Similarly with other rotations, such as jute - rice -wheat/ potato/ maize, etc., the weed control measures adopted in the dryland rice crop also affect the weed flora and intensity in the rest of the rotation.

Malla: Do you have any information on the use of herbicides on rice as also reducing the nitrogen requirement?

Patel: Yes, we have done some experiments that compared urea as foliar and as soil application. There was a better response to weed control measures with foliar application of urea compared to soil application.

COMPONENT TECHNOLOGY — VARIETAL TESTING FOR INTENSIVE CROPPING

Development of varieties to satisfy farmers' cropping systems requirements and the role of international cooperation

Takumi Izuno

The objective of this session is to share our thoughts on how to help crop breeders become more sensitive to the needs of farmers. All should realize that it is the farmer who makes the vital decisions that determine the success or failure of research programs. Our job is to present to him an array of alternatives to expand his options. The sooner he is accorded a role in the decision-making process, the more likely is our success in serving him.

This conference brings together many scientific disciplines and manifold talents to focus on the task of solving problems that first came to the attention of international agriculture through the initiative of Dr. Richard Bradfield, less than 20 years ago. Dr. Bradfield's pioneering efforts have evolved into what amounts to a cropping systems *fraternity*, which has become highly organized and communicative within an ever-expanding network.

DEVELOPING VARIETIES THAT SATISFY THE NEEDS OF FARMERS

A breeding program should begin with the definition of a successful variety — one that the farmers will plant. Based on this definition, the indigenous varieties in most of the countries represented by this group are still the most successful varieties for most of the crops with which we are concerned.

Rice varieties such as Masuli in the Nepalese terai and in Bangladesh, and C4–63 in Indonesia are spreading although they do not have superior yield in research trials. Semidwarf wheats cover the irrigated plains of northern India and Pakistan, but the farmers still grow the older tall varieties in the rainfed areas and maintain small fields of them in the irrigated tracts. Long-duration tropical maize varieties are grown in Thailand, in Bihar during the winter, but not in Indonesia or the Philippines.

Breeders have been prone to put yield first and to place less emphasis on factors such as eating quality, crop duration, yield stability, and, in the case of cross-pollinated crops, uniformity. We should provide options to the farmer. He obviously is satisfied with his variety; otherwise, he would not be growing it. So the

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task is to improve that variety. We can do this either by selection within (and this is useful if there is enough variability) or by hybridization with other varieties to expand variability.

There are examples where direct introductions of crops have become widespread, but whether cereals, tubers, vegetables, fruits, tree crops, or forage crops they are nearly always commercial or nontraditional crops for the area. Where there has been a traditional subsistence crop, adoption of direct introductions has been much slower except when the environment was not too dissimilar, the yield advantage was great (and a market for the surplus was assured), and the eating quality not greatly different.

I believe that we give ourselves the best chance possible if we use the most popular indigenous varieties of whatever crop we are working with as the foundation on which to breed varieties more responsive to the improved management that we hope the farmers will adopt.

Matching farmer needs

Indonesian maize breeders and I talked with a farmer in East Java who was growing a short-statured 70-day variety with small ears. In the next field, separated only by a bund, was a variety 50% taller, which matured in 85 days and had much larger ears. Given the apparent difference in yield between the two varieties, we thought it foolish not to grow the 85-day variety. Therefore, we asked him which variety he was going to grow next season. He came up with the expected answer: the 85-day variety. Had we stopped questioning him, we would have gone away thinking that all we needed to do was to develop a better 85-day variety and it would eliminate the 70-day variety in the area.

I was not satisfied, however, and asked the farmer why he would switch. The farmer replied that since this was the dry season and he was intercropping with mungbean, which does well then, he grew the 70-day variety because it gave mungbean a chance to flourish. In the rainy season when mungbean would not do well, he would grow maize as a monocrop. In that case the 85-day variety would produce more than the 70-day one.

From that we knew what we had to do — develop a better 70-day variety of small stature and a better 85-day variety of medium stature. The farmer who had grown the 85-day variety during the dry season had irrigation and had intercropped with cowpea, which grew much taller than mungbean. The crop duration fitted the moisture availability and the plant stature fitted the companion crop.

There are several 90-day varieties that not only are of longer duration, but also yield more and are more resistant to downy mildew because they have undergone recurrent selection at Bogor, Farm Suwan, and Los Baños. These varieties are directly usable in some other areas and some farmers in the same area where we talked to the farmer, i.e. some farmers would modify their cropping system to take advantage of these varieties' greater reliability (due to disease resistance) and higher yield.

We have crossed the 90-day varieties with both the 70-day and 85-day varieties and are trying to make the crosses earlier and more disease resistant. That's the

second step in improvement. We try to provide the farmers something akin to what they have but with greater yield stability at a higher level of production.

Management responsiveness

In general, maize yields in the tropics are lower than in the temperate zone because overall management is lower. So, if we improve management, including fertilizer use, the crop should respond favorably. In the tropics, maize does not respond to the same degree that it does in the temperate zone despite the fact that it is said to be of tropical origin. Why is this so? It may be that tropical varieties have only a short history of selection under improved management compared with temperate-zone maize. It could be that we need to cross the indigenous tropical varieties with U.S. Corn Belt material. This has worked out well in the subtropics. Would a small proportion of U.S. Corn Belt germplasm work out well in the tropics? Some indications to support this hypothesis can be found in crosses made in Thailand between Suwan 1 and Iowa State synthetics.

Then what?

The final arbiters of the success or failure of a breeding program are the farmers. We must obtain their reaction at the beginning. The Cropping Systems Network can be helpful in this effort, with several variety trials at each cropping systems site. The entries in these trials should be real alternatives that represent the cropping systems in vogue at each cropping systems research site, not merely duplications with different names.

If four replications can be grown at one site, I would prefer one replication each with four farmers to four replications with one farmer. More important than performance data is farmers' reaction to these varieties. If their reaction is favorable. we can go on to the next step.

Population improvement

Empirical evidence suggests that through any of the population improvement procedures that breeders employ, there can be sufficient progress in each cycle to make it worthwhile — as long as farmers will grow the varieties coming out of such programs.

There is a problem which the Cropping Systems Network may be able to help solve and therefore I would like it considered both in this group and individually with national program leaders. I use the example of maize again.

Experiment stations cannot hope to represent all environments — usually they do not represent even the major environments where a certain crop is grown. At a cropping systems research site in Nepal near Pokhara, cropping systems work has indicated that an attempt at extrapolation will succeed. At the same time a need was recognized for a shorter-duration variety than the national program was able to provide.

So, what can be done? First, take the prevalent farmer variety of maize and provide the seed to the national maize development program. They will cross it with several "improved" varieties, which can be tested at Pokhara. It is hoped that a

suitable cross is identified. In the next season select good ears from standing plants according to the criteria important to the farmers. The ears can be recombined during the off-season at the maize research station and simultaneously increased.

Seed production

Data, by themselves, cannot increase production and promote the rural welfare. It is impossible to overemphasize the importance of having a management-responsive variety acceptable to the farmers, but as you know so well, somebody has to make its seed available to those who want it. In most of the areas in which we work, a seed industry has not developed. Cropping systems research workers can do their part by encouraging the farmers to further spread the seed of varieties that they have found useful.

ROLE OF THE CROPPING SYSTEMS AGRONOMIST

As I see it, the cropping systems agronomist has many roles:

- identify farmers' requirements;
- propose researchable problems for discipline-oriented scientists;
- integrate these solutions into the farmers' agricultural system and test their effectiveness and acceptability; and
- if all works out well enough for a sufficient proportion of the farmers, relay the fact to policy makers and train extension personnel so that adoption can occur.

This is not all. There is no one solution for all farmers. The reasons may be climatic, economic, social, or even political. Whatever they are, the agronomist has a responsibility to communicate findings and to propose further study so that an ever-increasing proportion of the farmers will have an opportunity to benefit.

There are also stages of progress. The solution proposed, which promotes progress now, should not be considered the ultimate solution. It is time to contemplate the next step and the cropping systems agronomist has an important role to play in deciding what is needed next.

There is a good communications network within the Cropping Systems fraternity. However, there must be communication with farmers. Have the farmers adopted the recommendations? What must *we* do so that adoption by farmers will occur? That key question clearly defines an important role.

ROLE OF THE NATIONAL CROPS IMPROVEMENT PROGRAMS

The role of the national crops improvement programs should be easy enough to define. The national program is entrusted with the task of developing or identifying varieties that are an improvement over what the farmers currently have. Of course, others can help.

It is the responsibility of the breeder to learn what is available to the farmers now. The breeder must learn first why the farmers are growing their varieties before he can hope to design a breeding program that can come up with varieties the farmers will embrace with enthusiasm. Perhaps the breeders can use some help from agronomists in this regard.

The breeder must also know what is available in other programs with similar requirements. He can introduce and test. Sometimes, he finds that an introduction can do the initial job. Often he finds that an introduction crossed with an indigenous variety will be better than either one.

ROLE OF INTERNATIONAL COOPERATORS

Normally, cropping systems agronomists depend on the crop improvement teams in their own countries to provide the varieties needed for components of technology trials. In a system that works reasonably well, this usually suffices. But few countries have been able to make the necessary investment of personnel and funds to develop a strong breeding program for every crop. Within the Cropping Systems Network, however, each country has good varieties that can be tried in another with beneficial effects. An example for maize is Suwan 2 (formerly TC #1 Early DMR). In warm climates with good soil fertility and adequate moisture availability, Suwan 2 can produce 5 t grain/ha in 90-days. TC#1 Early has been good for at least 10 years. The downy mildew-resistant version has been available for at least 5 years and has been tested in all of the countries represented by this group. Thailand released it only in 1979 and in the same year Indonesia began increasing its seed preparatory to release. Indonesia has gone one step further by crossing it with several farmer varieties. These crosses appear to be useful for testing in some of the cropping patterns prevalent in parts of Indonesia and the Philippines. Through this type of cooperation, we will surely be able to meet more adequately the requirements of your farmers.

The International Crops Improvement Center can contribute toward the development of superior varieties for testing, but this is generally one step removed from the cropping systems agronomists because the normal procedure is for the centers to work through the national crop improvement programs. Centers have furnished varieties that have had considerable impact on production in many countries, but, in general, the Centers are moving toward supplying germplasm for use of national programs in developing varieties that are finely tuned to the requirements of their farmers.

COMPONENT TECHNOLOGY — CROPPING SYSTEMS ECONOMICS

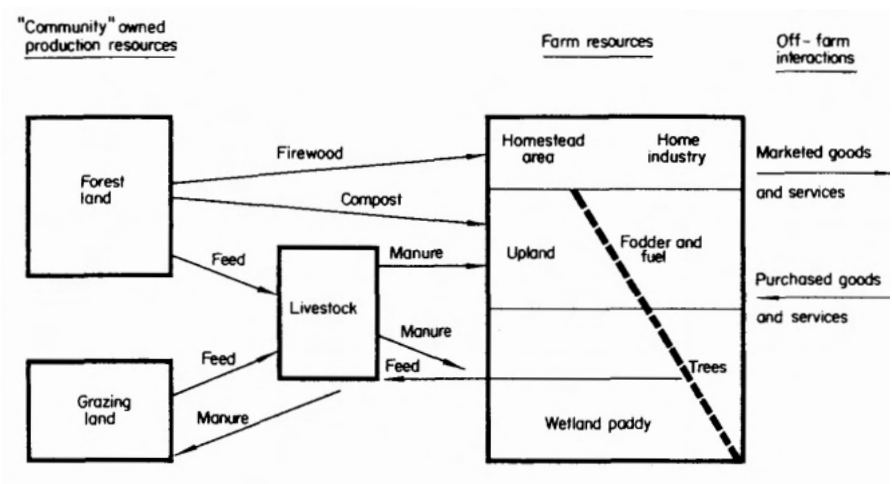
The role of livestock in the farming systems at two cropping systems sites in Nepal

Sudarshan B. Mathema

The integration of crops and livestock is not new to the Nepalese farmers, who have been growing major and minor crops on their farms and raising livestock.

Nepal has one of the world's highest livestock holdings, that is, about 5.8 animals/ household. The contribution of the livestock sector to the Nepalese economy has been estimated as 21% of total agricultural output and 15% of national gross domestic product (Upadhyay 1979).

The livestock enterprise is an important component of the farming system. Important interrelationships exist between the livestock enterprises and the cropping systems on a farm. Harwood (1976) developed a generalized model of the farming system showing these interrelationships (Fig. 1). Livestock contributes dung for composting, power for land preparation, and cash income for inputs in crop production. Grain and crop residue are important sources of animal feed. Both the



1. Conceptual model of a Nepal hill farm production system (Harwood 1976).

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crop and livestock enterprises require large amounts of labor input and may compete for the limited amount of labor available. Milk animals compete with bullocks for the limited amount of available fodder, and low bullock numbers can affect the cropping systems followed.

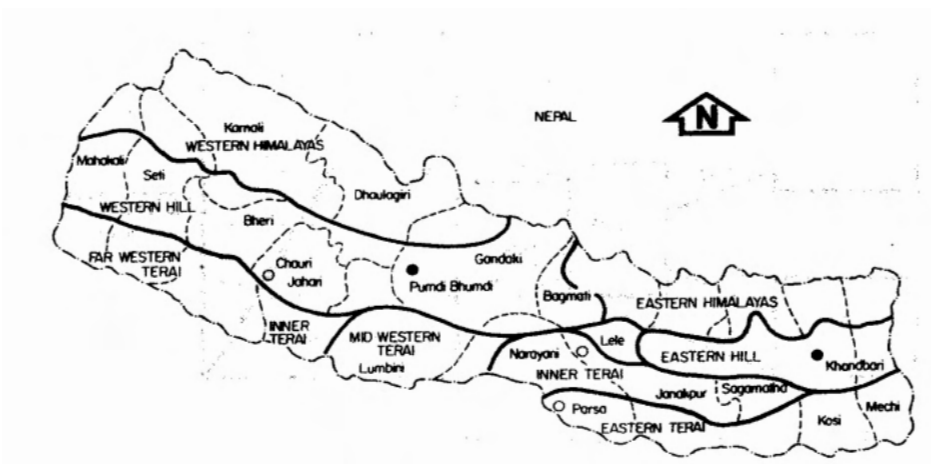
The government has put increasing emphasis on the livestock sector. Nepal's agricultural development strategy has focused mainly on improvements in crop production, which are dependent, in many cases, on the livestock sector. Because livestock contributes substantially to the well-being of the small Nepalese farmers, its improvement may be an important way of increasing farmers' income.

The cropping systems research program in Nepal aims to develop an understanding of the farming systems at the cropping systems sites. It is felt that knowing what farmers are doing and why they do so will help in the identification of practical and acceptable means of improving the farming systems, which will enhance crop and livestock production and farmers' welfare.

Toward this end, the Cropping Systems Survey and Livestock Survey were carried out at all cropping systems sites in Nepal. This paper presents initial results of the livestock survey conducted at the Pumdi Bhumdi site near Pokhara in the Kaski District, western hill region; and the Khandbari site in the Sankhuwa District, far eastern hill region (Fig. 2).

The main objectives of this paper are to:

1. Describe the existing livestock situation at two cropping systems sites in Nepal;
2. Examine the interdependence of the livestock activities and the crop activities of the different farm-size groups;
3. Show the benefits from combined crop and livestock farming systems; and
4. Assess the means for improvements in the livestock enterprise for increasing net benefits from the livestock system.



2. Nepal and its cropping systems sites.

METHODOLOGY

The questionnaire for the livestock survey was developed by the socioeconomic researchers of the cropping systems program, in consultation with experts of the Animal Science Division, and pretested by trained interviewers. The supervisors and the interviewers had received training in collecting information and spent 3 weeks at each site. Interviewers facing difficulties during the survey were assisted by the socioeconomic researchers. Eighty-two randomly selected farmers in Pumdi Bhumdi and 86 in Khandbari were interviewed. Data processors analyzed the collected information under the supervision of the researchers.

THE SITES

Although the average size of households was about the same in Khandbari and Pumdi Bhumdi, differences exist in the amount of cultivated area, cropping intensity, and in the relative and absolute numbers of the livestock owned (Table 1).

In Pumdi Bhumdi, a household with 5 to 6 members on the average subsisted on 0.87 ha of cultivated land. The average family labor available for farming was supplied by three members. The land utilization index (LUI) and the multiple cropping index (MCI) reached 56.14 and 168%.

The poultry and buffalo populations were higher than those of other animals. Thus, an average-size family owned 7 head of livestock — 1.70 buffalo, 0.61 bullock, 0.13 cow, 0.79 calf, 1.63 sheep and goats, 2.35 poultry, and 0.04 pig — valued at US$320.

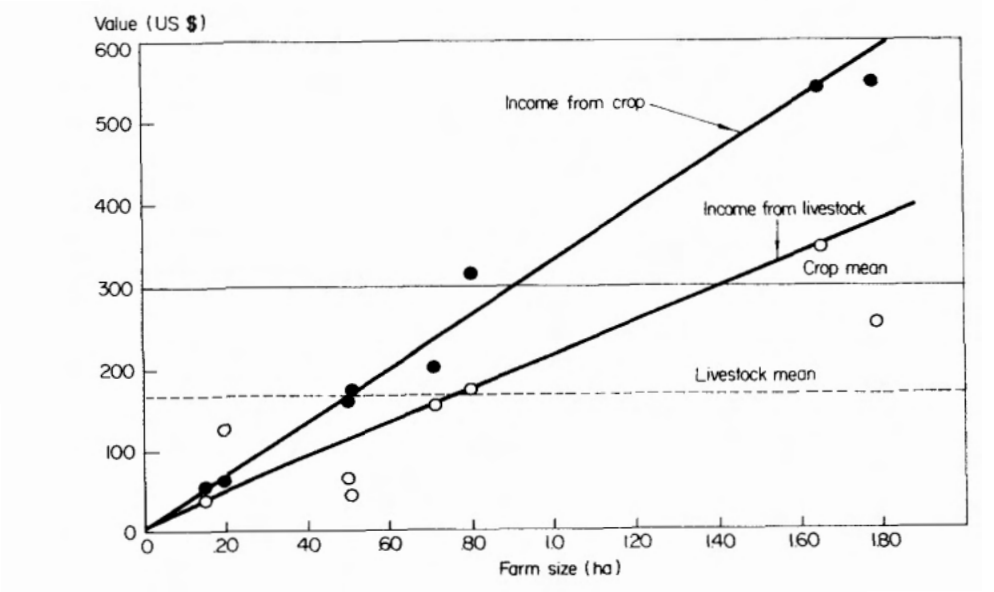
In Khandbari, the average family had 5 to 6 members and cultivated an average of 1.14 ha. The average family labor available for farming was supplied by two to three members. The LUI and MCI reached only 48.41 and 139%.

The Khandbari family has an average of 12 head of livestock — 0.45 buffalo, 1.45 bullocks, 1.0 cow, 1.15 calves, 2.36 goats, 4.90 poultry, and 0.36 pig. The site had

Table 1. Existing farm household resources of Pumdi Bhumdi and Khandbari sites, Nepal, 1979.

Particulars	Cropping systems sites	
	Pumdi Bhumdi	Khandbari
Av family size (no.)	5.7	6.0
Av farm laborers (no.)	3.1	2.8
Av size of cultivated area (ha)	0.87	1.1
Land utilization index (%)	56.14	48.41
Multiple cropping index (%)	168	139
Av livestock owned (no.)		
Buffalo	1.1	0.4
Cow	0.1	1.0
Bullocks	0.6	1.4
Calves [a]	0.8	1.2
Sheep and goats	1.6	2.4[b]
Poultry	2.4	4.9
Pigs	0.04	0.36
Av value of livestock owned (US$)	320	172

[a]Cow calves and buffalo calves. [b]Only goats in Khandbari.



3. Relation of farm size to income from crop and livestock, Pumdi Bhumdi, Nepal.

more poultry and goats than other animals. The value of livestock was US$172/farm.

Figures 3 and 4 show the relation between farm size and income from crop and livestock. Two regression equations were fitted to show the relation of the value of livestock owned per household to farm size and to family size for both sites. The regressions show that in Pumdi Bhumdi the value of livestock owned is related to farm size but not to family size. In Khandbari, it is positively related to both farm size and family size.

Pumdi Bhumdi:

$$Y = 12.76 + 21.69x_1^{**} = 1.38x_2^{n.s.}$$

$$R^2 = 0.40^{**}$$

** = significant at the 1% level; n.s. = not significant at 5% percent level

Khandbari:

$$Y = 0.43 + 0.79x_1^{**} + 0.13x_2^{**}$$

$$R^2 = 0.33^{**}$$

** = significant at the 1% level.

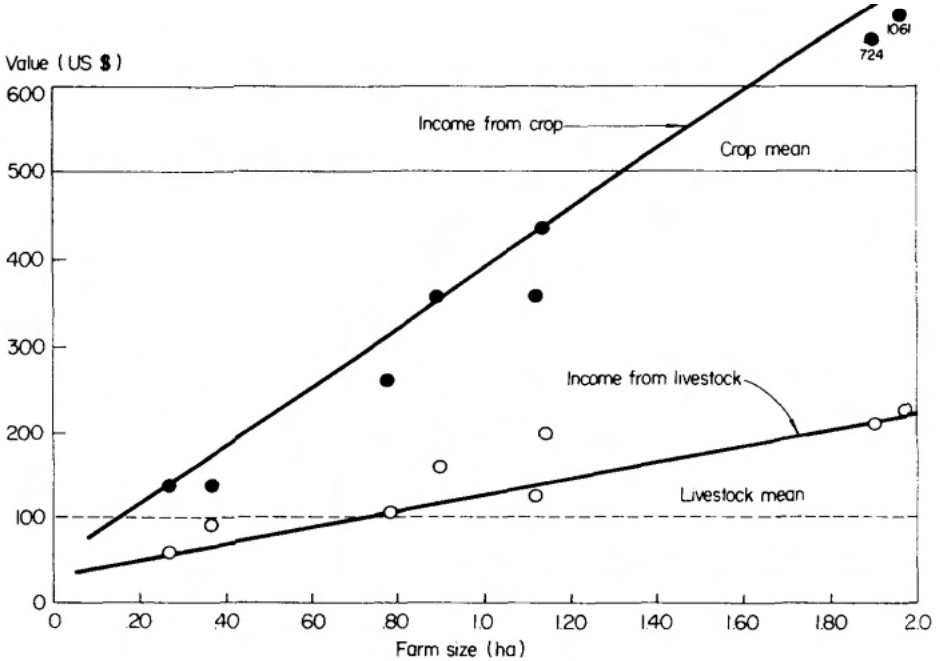
where:

Y = value of livestock in thousand rupees (US$83)

x_1 = farm size in hectares

and

x_2 = family size in number.



4. Relation of farm size to income from crop and livestock, Khandbari, Nepal.

LIVESTOCK NUMBER BY FARM SIZE

Pumdi Bhumdi

The number of livestock owned in Pumdi Bhumdi was correlated with farm size (r = .65); however, the relation between farm size and livestock number varied with the type of animal (Table 2). Only 18% of the cows were owned by the 41% of the farms smaller than 0.6 ha. Eighty-eight percent of the bullocks were on farms larger than 0.6 ha. However, buffalo were owned by farmers in all farm size groups. There was no relation between the number of sheep and goats owned and farm size, and more poultry per household were on farms less than 0.4 ha than on farms larger than 1.0 ha. Pigs were owned only on farms of less than 0.4 ha.

Khandbari

The number of livestock owned per household in Khandbari was also correlated with farm size (r = .49), and the relation between farm sue and livestock number also varied with type of animal (Table 3). Buffalo in Khandbari were generally owned only on farms larger than 1.0 ha. The number of bullocks was slightly correlated with farm size, but even the smallest farms had bullocks. There was no relation between the number of goats, pigs, and poultry owned and farm size.

CROPS GROWN AND CROP USE

Pumdi Bhumdi

The main crops in Pumdi Bhumdi were maize, millet, rice, and wheat. Mustard, pulse, and potato were also grown. Maize, millet, and rice were grown by more than

Table 2. Number of livestock owned, by farm size. Pumdi Bhumdi, Nepal, 1979.

Farm size (ha)	Farms (no.)	Livestock owned															
		Buffalo		Cows		Bullocks		Calves		Sheep and goats		Pigs		Poultry		Total	Av
		No.	Av	No.	Av	No.	Av	No.	Av	No.	Av	No.	Av	No.	Av		
Less than or equal to 0.4	24	24	1.08	2	0.20	3	0.08	8	0.51	31	1.04	3	0.08	81	3.61	152	6.58
More than 0.4, but less than or equal to 0.6	10	18	1.92	0	0	3	0.29	5	0.54	7	0.70	0	0	6	0.7 1	39	4.14
More than 0.6, but less than or equal to 1.0	21	31	1.51	5	0.27	14	0.73	21	1.03	39	1.89	0	0	84	4.19	194	9.61
More than 1.0	27	69	2.55	4	0.15	30	1.11	31	1.16	59	2.20	0	0	22	0.84	215	8.00
Totals and averages	82	142	1.76	11	0.13	50	0.61	65	0.79	136	1.46	3	0.02	193	2.35	600	7.09

Table 3. Number of livestock owned, by farm size, Khandbari, Nepal, 1979.

Farm size (ha)	Farms (no.)	Livestock owned															
		Buffalo		Cows		Bullocks		Calves		Goats		Pigs		Poultry		Total	Av
		No.	Av	No.	Av	No.	Av	No.	Av	No.	Av	No.	Av	No.	Av		
Less than or equal to 0.6	22	2	0.08	15	0.73	16	0.84	15	0.73	43	1.98	4	0.19	122	5.16	217	9.70
More than 0.6, but less than or equal to 1.0	18	6	0.34	16	0.89	23	1.27	24	1.38	40	2.30	6	0.33	76	4.54	191	11.03
More than 1.0, but less than or equal to 1.36	17	8	0.46	21	1.20	28	1.64	22	1.28	30	1.70	8	0.47	67	3.99	184	10.72
More than 1.36	29	23	0.83	34	1.14	58	1.99	37	1.29	91	3.08	13	0.42	156	5.66	412	14.39
Totals and averages	86	39	0.45	86	1.00	125	1.45	98	1.14	204	2.27	31	0.36	421	4.90	1004	11.47

80% of the farmers (Table 4). Potato was grown mainly for family consumption, whereas mustard was grown for oil for family consumption or as a cash crop. The common pulses were also primarily for family consumption.

Plant residues of rice, maize, millet, and pulse were fed to cattle. Mustard cake, the by-product after oil extraction, was also cattle feed. Wheat straw was used for bedding and composting. Some grain was also fed to livestock (Table 5).

Khandbari

In Khandbari, the main crops were maize, millet, mustard, and rice. Mustard was preferred to wheat because of its good market and cash income. More than 90% of the sampled farmers grew maize and millet in 1977-78 (Table 4). Rice and mustard were second in importance. Pulses — soybean, black gram, rice gram, horse gram, longbean and mungbean — were mainly for family consumption.

The plant residue of rice, maize, millet, and pulses were used as livestock feed. The maize plants were commonly thinned out when knee-high and were fed to cattle.

Some maize grain was fed to cows, bullocks, buffalo, and poultry during 1978-79. Poultry also received rice and millet (Table 5).

SOURCES OF RETURNS FROM LIVESTOCK

Table 6 shows the main sources of returns or benefits from owning livestock in Pumdi Bhumdi and Khandbari. Fresh milk and milk products contributed an average 67% of the benefits of owning livestock in Pumdi Bhumdi. In Khandbari, where the number of buffalo owned by each household is low, milk and milk products contributed an average 33% of the benefit from livestock. The return from milk and milk products was not related to farm size in Pumdi Bhumdi or Khandbari.

Gains from raising livestock include the value of animals sold, consumed, and born, and the increase in the value of livestock from growth during a year. In Khandbari, such gains averaged 22% of total returns from livestock. The gains were negative, on the average, on farms between 0.4 and 0.6 ha in size because of loss of animals through disease or wild animals. In the other farm size categories in Pumdi Bhumdi the average returns from livestock raising ranged from 40% on farms less than 0.4 ha to 16% on farms larger than 1.0 ha.

The value of bullock labor in land preparation gave the highest returns in Khandbari — 39% on farms less than 0.61 ha to more than 50% in all the other size categories.

In Pumdi Bhumdi the relative (and absolute) value of the contribution of bullocks was less — from 8% on farms less than 0.41 ha to an average of 19% on the larger farms.

The values of the eggs produced at both Pumdi Bhumdi and Khandbari were relatively small — 1-2% of total returns from livestock.

Table 7 shows the average per unit values of livestock and livestock products at both sites. In general, prices showed little difference between sites. The average values of buffalo, cows, goats, eggs, yogurt, butter, and bullock labor were about the same.

The price of a liter of fresh milk is slightly higher in Pumdi Bhumdi than in

Table 4. Number of farmers growing each major crop. Pumdi Bhumdi and Khandbari, Nepal, 1977-78.

Sites	Farms (no.)	Farmers (no.) that grow each major crop[a]						
		Rice	Wheat	Maize	Mustard	Millet	Potato	Pulses
Pumdi Bhumdi	82	71 (87)	53 (65)	80 (98)	50 (61)	77 (94)	6 (7)	50 (61)
Khandbari	86	73 (85)	8 (9)	84 (98)	61 (78)	80 (93)	1 (1)	32 (37)

[a]Figures within parentheses indicate percentages.

Table 5. Percent of livestock receiving grain in Pumdi Bhumdi and Khandbari, Nepal, 1978-79.

Livestock	Percent of livestock receiving grain				
	Rice	Wheat	Maize	Millet	Barley
		Pumdi Bhumdi			
Cow	20	0	70	10	0
Bullock	2	0	16	41	41
Buffalo	16	0	58	14	0
Chicken	83	17	97	87	0
		Khandbari			
Cow	9	0	51	0	0
Bullock	0	0	20	0	2
Buffalo	0	0	74	0	0
Chicken	96	2	96	59	0

Table 6. Sources of returns from livestock, by farm size. Pumdi Bhumdi and Khandbari, Nepal, 1978-79.

Farm size (ha)	Gains from raising livestock		Value of fresh milk		Value of milk products		Value of egg production		Value of bullock labor		Total returns (US$)
	US$	%	US$	%	US$	%	US$	%	US$	%	
Pumdi Bhumdi											
Less than or equal to 0.40	23	40	26	45	2	3	2	3	5	8	58
More than 0.40, but less than or equal to 0.60	-12	21	38	68	17	30	1	2	12	21	56
More than 0.60, but less than or equal to 1.0	39	23	63	38	34	20	2	1	28	17	166
More than 1.0	49	16	156	50	45	14	1	0	61	20	312
Khandbari											
Less than or equal to 0.60	18	25	17	24	7	10	2	3	28	39	72
More than 0.60, but less than or equal to 1.00	20	16	16	13	18	15	2	2	68	55	124
More than 1.0, but less than or equal to 1.36	14	9	32	21	27	17	2	1	80	52	155
More than 1.36	31	14	44	20	24	11	5	2	112	52	216

Table 7. Average values of livestock and livestock products. Pumdi Bhumdi and Khandbari, Nepal, 1978-79.

Livestock, livestock product	Av unit value (US$) of livestock or livestock product	
	Pumdi Bhumdi	Khandbari
Adult she-buffalo	129	103
Adult bullock	64	38
Adult cow	23	26
Adult goat	14	11
Adult chicken	2	1.29
Egg	0.06	0.05
Milk (liters)	0.26	0.22
Ghee (liters)	2.42	2.19
Yogurt (liters)	0.29	0.29
Butter (liters)	1.17	1.11
Bullock labor (pair/h)	0.83	0.83

Khandbari (US$0.26 vs $0.22); however, the price difference does not reflect the differences in the contribution of the dairy enterprise between the two sites. Pumdi Bhumdi faces a larger demand for dairy products — it lies close to the urban area of Pokhara, which has a large tourist trade. It has a much larger buffalo population per household, and the buffalo produces much more milk than the cow does. Khandbari farmers, on the other hand, face a lower demand for dairy products, and have fewer buffalo.

Bullock use in Khandbari is higher. The land area cultivated by the sampled farmers in Khandbari is about 40% higher than that in Pumdi Bhumdi. The farmers in Khandbari spend more time per hectare preparing their land for crop production and do a better job of tilling the soil. They also use bullocks for weeding maize.

Table 8 shows that although the farmers in Khandbari own more than twice the number of bullocks, the level of use in the two sites is about the same. Bullocks are used an average of 127 days/year in Pumdi Bhumdi and 115 days in Khandbari. But during the busy months of May-July, the bullocks are fully utilized at both sites.

The low bullock population in Pumdi Bhumdi, which may be due to the good returns from buffalo, has adverse effects on crop production in that site. Poor land preparation leads to weed problems and to poor germination. The lack of bullocks has been reported as a constraint to more intensive cultivation in Pumdi Bhumdi (Mathema and Van Der Veen 1978).

Compost is another major source of return from owning livestock. Compost, or farmyard manure, is the main source of plant nutrients at both sites. Because it is generally not bought and sold at the sites, its value has not been calculated. Green manure crops are not grown, and the only legumes grown are some lentils and beans mix-cropped with maize. Only small amounts of inorganic fertilizer are used at the sites; however, all farmers apply compost, frequently in large amounts. The average annual compost input in the upland area of Pumdi Bhumdi is 13 t/ha (Mathema and Van der Veen 1978).

Table 8. Average use of bullocks, Pumdi Bhumdi and Khandbari, Nepal, 1978-79.[a]

Mean use	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan	Jan-Feb	Feb-Mar	Mar-Apr	Whole year
Pumdi Bhumdi													
Number of hours per day when working	7.7	8.1	9.2	8.7	7.0	6.0	6.4	6.0	5.5	6.7	7.0	7.5	7.2
Number of days employed in own field	10.1	14.1	15.6	6.3	0	0.1	4.3	3.9	1.0	0.9	6.9	9.7	73.2
Number of days employed in other fields	7.2	9.6	10.8	5.0	0	0.3	4.4	3.5	0.5	0.7	5.0	7.3	54.3
Total number of days employed	17.3	24.0	26.4	11.3	0	0.4	8.7	7.4	1.5	1.6	11.7	17.0	127.5
Khandbari													
Number of hours per day when working	5.2	7.5	9.4	9.5	4.1	2.5	2.5	3.0	3.1	3.7	4.2	4.9	5.0
Number of days employed in own field	10.7	20.0	25.8	25.1	10.6	0.2	0.5	1.5	2.3	3.6	4.6	6.7	111.6
Number of days employed in other fields	0.9	1.1	0.7	0.8	0.2	0	0	0	0	0	0	0.1	3.8
Total number of days employed	11.6	21.1	26.6	26.0	10.8	0.2	0.5	1.5	2.3	3.9	4.5	6.7	115.4

[a]Each period is a month starting on the 15th of the first month and ending on the 14th of the next.

SOURCES OF HOUSEHOLD INCOME

The farmers in Pumdi Bhumdi and in Khandbari derive income from three main sources: 1) crop production, 2) livestock, and 3) off-farm employment (Table 9). The mean gross value of crop production per farm was directly related to farm size. However, there was no relation between farm size and mean income from off-farm employment, which averaged US$166/household per year in Pumdi Bhumdi and $120 in Khandbari.

The mean size of benefit from livestock increased with farm size at both sites, with livestock significantly contributing to household income even on the very small farms. Livestock contributed 27% of the income of households in Pumdi Bhumdi and 20% in Khandbari. Its contribution on the smallest farms compared with the income from crop production. Off-farm employment was the most important source of income on the smallest farms. (Pensions and income earned working on other farms are excluded.)

LABOR REQUIREMENTS FOR RAISING LIVESTOCK

Livestock benefited the farmers of Pumdi Bhumdi and Khandbari, but the benefits were costly. Besides the initial outlay in the purchase of animals, the main investment was labor. Table 10 shows the average household labor input by season and by type of labor. The households contributed an average of 530 to over 700 hours for the care of livestock over a 2-month period. That amounted to about 10 hours/day per household. The adult females contributed about one-third of the labor input, the adult males about one-fifth, and the children about one-tenth. The rest of the labor was contributed by whoever was available at the time.

The care of livestock and crop production seriously compete for labor, especially during the busy times of the year. From April to August when the land was being prepared and seeded or transplanted, adult males spent an average 1 to 3 hours a day on livestock care and adult women, 4 to 6 hours.

REASONS FOR OWNING LIVESTOCK

Farmers at the two sites gave five main reasons for owning livestock: cash income, food for household consumption, draft power, compost, and festivals and other occasions.

The relative ranking of these reasons differed according to the type of livestock. Providing food for the family was generally the most important reason for owning buffalo at both sites, and the provision of compost was second. Cash income from buffalo ranked third.

Compost was ranked first among the reasons for owning cows in Pumdi Bhumdi; provision of food for the family was second. In Khandbari, however, cows were valued more for food (milk and milk products) than for compost.

Goats were owned mainly for compost in Pumdi Bhumdi and for cash in Khandbari.

Bullocks were valued primarily for draft power and secondly for compost.

Table 9. Sources of household income. Pumdi Bhumdi and Khandbari, Nepal, 1978-79.

Farm category	Mean cultivated area (ha)	Mean value of crop production (US$/yr)	Mean benefit from livestock (US$/yr)	Mean income from off-farm employment (US$/yr)	Total income per household (US$/yr)	Contribution (%) to total income		
						From crops	From livestock	From employment
				Pumdi Bhumdi				
1	0.15	51	40	184	275	19	15	66
2	0.20	64	125	68	257	25	49	16
3	0.50	161	65	121	347	46	19	35
4	0.51	175	42	114	331	23	13	34
5	0.80	312	172	156	640	49	27	24
6	0.71	200	157	264	621	32	25	43
7	1.65	540	345	153	1038	52	33	15
8	1.79	549	268	178	995	55	27	18
Totals and averages	0.87	284	168	166	618	46	27	27
				Khandbari				
1	0.37	139	92	114	345	40	27	33
2	0.27	139	60	226	425	33	14	53
3	0.78	263	103	17	383	69	27	4
4	0.90	353	159	85	597	59	27	14
5	1.16	435	197	31	663	66	30	4
6	1.12	358	124	170	652	55	19	26
7	1.98	1061	225	167	1453	73	15	12
8	1.91	724	210	84	1018	71	21	8
Totals and averages	1.15	487	151	120	760	64	20	16

[a]Appendix I explains the farm categories for Pumdi Bhumdi; appendix II explains those for Khandbari.

Table 10. Average labor requirements per farm for raising livestock by type of labor and time period. Pumdi Bhumdi and Khandbari, Nepal, 1978-79.

Worker	Total labor (h) [a]					
	Mid-Apr to mid-Jun	Mid-Jun to mid-Aug	Mid-Aug to mid-Oct	Mid-Oct to mid-Dec	Mid-Dec to mid-Feb	Mid-Feb to mid-Apr
		Pumdi Bhumdi				
Adult male	100	66	68	84	107	99
	(185)	(147)	(140)	(158)	(193)	(190)
Adult female	222	258	267	215	200	224
	(217)	(248)	(255)	(242)	(242)	(258)
Children	67	61	54	42	28	48
	(173)	(163)	(144)	(117)	(95)	(130)
Male, female, or children	255	304	287	216	194	206
	(322)	(336)	(326)	(287)	(291)	(302)
Total	644	689	676	557	529	577
		Khandbari				
Adult male	182	158	168	160	163	184
	(245)	(250)	(231)	(231)	(208)	(228)
Adult female	356	336	343	359	318	354
	(329)	(324)	(316)	(335)	(323)	(357)
Children	82	89	91	77	67	67
	(187)	(203)	(214)	(168)	(159)	(167)
Male, female, or children	141	112	122	122	102	107
	(303)	(224)	(252)	(256)	(218)	(218)
Total	761	695	724	718	650	712

[a] Figures in parentheses indicate standard deviations.

Poultry, which were raised mainly for family food, also provided cash income and were used in religious festivals.

ADDITIONAL LIVESTOCK DESIRED AND CONSTRAINTS ON OWNERSHIP

Pumdi Bhumdi

Seventy-six percent of the farmers in Pumdi Bhumdi expressed a desire to own additional livestock (Table 11). All wanted more buffalo. Thirty-nine percent wanted more goats and 11% more bullocks. Few wanted more cows, sheep, or pigs.

The major problems in increasing the number of livestock owned were lack of grass and fodder, inadequate labor, and lack of grazing area.

Khandbari

Seventy-five percent of the farmers in Khandbari expressed the desire to own more livestock (Table 12). But the major constraints were lack of grazing land, grass, and labor. The farmers' biggest problem was finding fodder during winter. A common practice during June and July is to thin out the maize crop, which is deliberately overpopulated, and to feed the stalk and leaves to cattle. Livestock in Khandbari make better use of fallow fields, plant residue, green leaves, pasture, or jungle areas.

USE OF INCOME FROM LIVESTOCK

To a question on the use of additional income earned from livestock, the farmers gave these responses:

1. To purchase commodities required by the family;
2. To repay debts;
3. To expand or improve the farm;
4. To meet social necessities;
5. To purchase chemical fertilizers and other agricultural inputs; and
6. To maintain prestige in society.

In both sites, the purchase of household requirements and the repayment of debts had high priority for most farmers (Table 13).

The improvement of the farm by the purchase of more land, by constructing new buildings, by planting trees, by improving the bunds and irrigation canals, and by fencing, etc., was also considered as an important use for the additional earnings.

MORE BENEFITS THROUGH THE GOVERNMENTS HELP

The farmers were asked how the government can help them benefit more from livestock enterprises. The responses are summarized in Table 14.

In addition, the farmers had their own view of how to get more benefit from livestock. The most common ideas follow:

1. Providing good feeds;
2. Providing best fodder and grazing area;
3. Keeping improved breeds of livestock;

Table 11. Constraints to acquisition of additional livestock desired in Pumdi Bhumdi, Nepal, 1978-79.

Animal	Additional livestock desired (no.)	Farmers[a] (no.) citing the constraint				
		Lack of grass and fodder	Scarcity of labor	Insufficient grazing land	Shortage of cash	Miscellaneous
Buffalo	62 (76)	28 (45)	20 (32)	34 (55)	10 (16)	7 (11)
Goat	32 (39)	15 (47)	10 (31)	17 (53)	9 (28)	3 (19)
Bullock	9 (11)	4 (44)	6 (67)	4 (44)	–	–
Cow	6 (7)	2 (33)	2 (33)	5 (84)	3 (50)	1 (17)
Sheep	4 (5)	1 (25)	1 (25)	3 (75)	–	–
Pig	2 (2)	1 (50)	1 (50)	2 (100)	2 (100)	–
None desired	20 (24)	12 (60)	20 (100)	16 (95)	4 (20)	1 (5)

[a]Numbers within the parentheses are percentages.

Table 12. Constraints to acquisition of additional livestock desired in Khandbari, Nepal, 1978-79.

Animals	Additional livestock desired	Farmers[a] (no.) citing the constraint							
		Lack of grazing land	Lack of grass and straw	Lack of labor	Lack of money	Problem of wild animals	Lack of sheds	Prob1em of diseases	Miscella-neous
Buffalo	52 (62)	27 (52)	18 (35)	18 (35)	15 (29)	2 (4)	–	3 (6)	6 (12)
Goat	43 (50)	21 (49)	11 (26)	13 (30)	8 (19)	4 (9)	3 (7)	4 (9)	8 (19)
Cow	40 (47)	22 (55)	15 (38)	18 (45)	7 (18)	1 (3)	–	7 (18)	3 (8)
Chicken	30 (35)	–	–	10 (33)	7 (23)	2 (7)	–	7 (23)	3 (10)
Pigs	16 (19)	–	–	5 (31)	4 (25)	–	–	2 (13)	3 (19)
Bullock	16 (19)	6 (38)	4 (25)	5 (31)	3 (19)	–	–	4 (25)	2 (13)
None desired	25 (29)	10 (40)	8 (32)	14 (56)	4 (16)	–	–	–	–

[a]Figures in parenthesis indicate percentages.

Table 13. Intended uses of additional earnings from livestock. Pumdi Bhumdi and Khandbari, Nepal, 1979.

Rank	Farmers (%) ranking intended use of earnings						
	Household consumption goods	Repayment of debts	Improvement of farm	Social needs	Purchase of fertilizer	Maintenance of status	Miscellaneous
			Pumdi Bhumdi				
First priority	56	28	12	1	1	0	0
Second priority	26	18	41	2	6	5	0
Third priority	7	10	33	20	9	7	2
			Khandbari				
First priority	44	34	12	0	1	0	0
Second priority	34	22	23	10	10	0	1
Third priority	13	12	35	16	15	6	3

Table 14. Ways by which the government can help farmers to get more benefit from livestock. Pumdi Bhumdi and Khandbari, Nepal, 1979.

Government help	Farms			
	Pumdi Bhumdi		Khandbari	
	No.	%	No.	%
Providing credit facilities at low interest rate	41	50	51	59
Providing improved livestock	11	13	46	53
Establishing veterinary hospital and providing facilities for livestock development	–	–	34	39
Providing better grazing land and grass	9	11	19	22
Providing good management of medicine and treatment	6	7	–	–
Preventing diseases	11	13	2	2
Providing junior technical assistants for livestock	3	4	14	16
Providing good feeds	–	–	8	9
Providing vaccines for preventing diseases	–	–	11	13
No ideas	28	34	–	–
Miscellaneous	6	7	17	20

4. Taking good care of livestock;
5. Providing sanitated sheds;
6. Increasing the number of livestock; and
7. Giving the livestock timely medical treatment.

SUMMARY AND CONCLUSIONS

This paper describes the livestock situation at two cropping systems sites in Nepal: Pumdi Bhumdi in Kaski district and Khandbari in Sankhuwa Sabha District. It examines the interdependence of the livestock and crop activities in the different farm-size groups in terms of products produced and income. It also assesses the scope for improvements in the livestock enterprise to increase net benefits from combined crop and livestock farming systems. The results apply specifically to the hill areas of Nepal. A combined type of crop and livestock production system exists in the country. The livestock enterprise is an important component of the farming system because it provides cash income, high quality food, a source of security, draft power, and dung for compost.

All farmers interviewed owned livestock. The average family size was 5.7 in Pumdi Bhumdi, and 6 in Khandbari. The average cultivated area was 0.87 and 1.1 ha. The multiple cropping index varied from 168 to 139%, with a land utilization index of 56.14 and 48.41. The average family at Pumdi Bhumdi owned 7 head of animals valued at US$320. In Khandbari the low value (US$172) for 12 head was due to the higher frequency of smaller animals. The value of livestock owned in Pumdi Bhumdi was related to farm size, but that in Khandbari was positively related to both farm size and to family size. The most important livestock were buffalo,

goats, and poultry in Pumdi Bhumdi, and goats, bullocks, cows, calves, and poultry in Khandbari. Buffalo and cows were the main source of milk production. The sale of milk and milk products provided a significant amount of cash flow to the farmers at both sites.

Bullocks were the main source of draft power for field operations. The lower number in Pumdi Bhumdi creates draft power shortage during peak periods. Cows and calves were less in Pumdi Bhumdi than in Khandbari, but the number of goats was large at both sites. The sampled farmers kept some poultry for meat and eggs. The results indicate that the average number of livestock was directly related to the size of farm.

The cropping pattern was oriented to subsistence crops such as maize-millet and wheat in uplands and rice and wheat in lowlands in Pumdi Bhumdi. Some crops — mustard. pulses, and potato — were also grown for home consumption. In Khandbari, maize, millet, mustard, and rice were the main crops. Minor crops were wheat, mustard, pulses, and potato.

Fresh milk and milk products contributed 67% of the benefits of owning livestock in Pumdi Bhumdi, and 33% in Khandbari. The percentages were not, however, related to farm size at either site.

The contribution of bullocks to the benefits from owning livestock is much higher in Khandbari, mainly because of the higher bullock use.

For both sites, compost was the main source of plant nutrients. Only 7% of the cultivated area received chemical fertilizers.

The household income in Pumdi Bhumdi was derived from crop production (46%), livestock (27%), and off-farm employment (27%). Total average income for 82 farms was estimated at $618/ year per household.

In Khandbari, the contributions to total income were 64%from crop production, 20% from livestock, and 16% from off-farm employment. Total average income for 86 farms was estimated at $760/household per year.

Farmers gave five main reasons for owning livestock: cash income, food for household consumption, draft power, compost, and festivals and other occasions. The farmers were interested in keeping additional livestock on their farms, but major constraints were the lack of grass and fodder, inadequate labor, and lack of grazing area. These constraints indicate some reasons for not expanding the number of livestock more rapidly in Pumdi Bhumdi and Khandbari.

Most farmers would use the additional income from increasing the number of animals on their farms to purchase commodities required by the family. Other uses would be repayment of debts, improvements on the farm, social needs such as marriages, festivals, and other religious obligations, and purchase of chemical fertilizer. Farmers felt that the government could help them to get more benefit from livestock enterprises by providing credit facilities at low interest rate, improved breeds of livestock, and better grazing lands.

Farmers at both sites were apparently using their animals efficiently. Additional research is needed to provide practical ways of getting more benefit from the livestock system. The agricultural development policies and strategy of the country must be based on an understanding of the interrelations of the combined crop and livestock system.

Appendix I

Farm categories: Pumdi Bhumdi

Category 1 :	Less than or equal to 0.40 ha in size but less than 80% lowland
Category 2 :	Less than or equal to 0.40 ha in size but more than or equal to 80% lowland
Category 3 :	More than 0.40 ha but less than or equal to 0.60 ha and less than 80% lowland
Category 4 :	More than 0.40 ha but less than or equal to 0.60 ha and more than or equal to 80% lowland
Category 5 :	More than 0.60 ha but less than or equal to 1.00 ha and less than 80% lowland
Category 6 :	More than 0.60 ha but less than or equal to 1.00 ha and more than or equal to 80% lowland
Category 7 :	More than 1.00 ha and less than 80% lowland
Category 8 :	More than 1.00 ha and more than or equal to 80% lowland

Appendix II

Farm categories: Khandbari

Category 1 :	Less than or equal to 0.60 ha in farm size and mixed land type*
Category 2 :	Less than or equal to 0.60 ha in farm size and land type other than mixed**
Category 3 :	More than 0.60 ha in size but less than or equal to 1.00 ha and mixed land type
Category 4 :	More than 0.60 ha in size but less than or equal to 1.00 ha and land type other than mixed
Category 5 :	More than 1.00 ha in size but less than or equal to 1.36 ha and mixed land type
Category 6 :	More than 1.00 ha in size but less than or equal to 1.36 ha and land type other than mixed
Category 7 :	More than 1.36 ha in size and mixed land type
Category 8 :	More than 1.36 ha in size and land type other than mixed

*More than 20% of each land type (upland and lowland). **Either more than 80% of upland or more than 80% of lowland.

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Labor shortage as a constraint to increasing cropping intensity

Richard Bernsten and A. Rachim

West Java, one of the most highly populated provinces in Indonesia, has a land area of 4,630 km^2 and 23,454,000 inhabitants. Its population density exceeds 506 persons/ km^2 (1979). About 70% of the population farm 1,575,000 ha of lowland and 545,000 ha of upland. Assuming a mean family size of 5 persons, the average lowland and upland area per farm family is about 0.48 and 0.17 ha.

In response to intense pressure on land, the Government of Indonesia (GOI) has pursued a dual strategy to increase crop production. First, to increase output per unit of land per rice crop, the BIMAS-supervised credit program was initiated in 1965. Modern seed - fertilizer technology has been extensively diffused throughout West Java: more than 63% of the cultivated wetland was planted to modern varieties in the 1977-78 wet season (Direktorat Perlindungan Tanaman Pangan 1979), urea application by BIMAS farmers averaged 187 kg/ha (USDA 1979), and wetland rice yields averaged 3.2 t/ha (BPS 1979).

Second, to increase the number of crops per unit of land (cropping intensity), GOI financed the construction and rehabilitation of irrigation infrastructure. During Repelita II (1974-75 to 1978-79) 526,769 ha were rehabilitated, and new construction irrigated an additional 273,198 ha (Wyberg and Prabowo 1979). At the same time, the Cropping Systems Program at the Central Research Institute for Agriculture (CRIA) has experimented since 1972 with management systems that will enable farmers to increase the number of crops they grow in irrigated areas with the existing water supply (CRIA 1977, 1978).

SOURCES OF FUTURE OUTPUT INCREASE

Three years of constraints research in irrigated Subang showed that the yield gap between farmers' yield and the yield achieved when experimenters applied inputs to obtain maximum yield was only 1.0 t/ha for the wet seasons and 0.4 t /ha for the dry (CRIA Socio-Economics Department 1979). We would expect the yield gap to be even less in the marginal areas where the seed-fertilizer technology is generally less applicable.

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Alternatively, rice and food output may be increased by increasing the number of crops planted and harvested during the year. This is a viable possibility with the replacement of traditional 150-day varieties with early-maturing modern varieties like IR36 that may be harvested 90 days after transplanting. It appears possible to fit 2 wetland rice crops and a secondary crop like soybean, cowpea, or mungbean into areas with at least 5 months of irrigation. Yet, secondary data indicate that the wetland rice crop intensity is only 1.6 in West Java (Wyberg and Prabowo 1979), and even in irrigated areas fields are sometimes left fallow after the rice harvest. Hence, there is a substantial potential for increasing food production by increasing the cropping intensity.

CONSTRAINTS TO INCREASING CROPPING INTENSITY

The factors responsible for the low cropping intensity have not been adequately investigated at the farm level, but there has been much discussion of the probable causes. Factors identified by participants in this dialogue may be classified as technical and socioeconomic. The main technical factor is water availability. Inadequate or late supply of water may be responsible for delays in land preparation in a contiguous area, which delays transplanting in the whole area (farmers in the contiguous area must transplant relatively simultaneously to avoid rat damage to plots transplanted out of phase with the community). Also, delay in establishing the first crop delays the planting of the second rice crop. Water shortage at the grain-filling stage of the second crop reduces yield and prevents the planting of a third crop of legumes. Research in Indramayu District, West Java, showed that with appropriate management practices, 2 wetland rice crops can be successfully grown in areas irrigated for 5-6, 7-9, and 10 months even in years when the rainfall is irregular. The success of the third legume crop is more risky and highly dependent on the rainfall pattern.

Some observers suggest that socioeconomic factors cause the low cropping intensity. This argument suggests that labor shortage is responsible for the long land-preparation period, especially in areas nearest the urban centers. The harvesting of the first crop occurs at the time labor is required to prepare land for the second rice crop. Because harvesting pays more than land preparation, land preparation is delayed until the harvest is completed. Consequently, the second crop is either not planted or planted but now is susceptible to drought. Both the late initial land preparation and the long turnaround time make a third legume crop impossible. It is also argued that labor shortage will prevent the implementation of the government's integrated pest control program to control brown planthopper, which is built upon the principle of synchronized planting in large contiguous areas.

The policy measures required to increase cropping intensity will vary. If technical factors are a constraint, the government must invest in improvements of the physical irrigation infrastructure to guarantee that water sent through the primary canals actually gets to the farms and the water distribution schedule is realized. At the same time, the irrigation authorities would have to refine the minimum water requirements for the crop year to maximize the service area covered by the existing system. Extension efforts could be initiated immediately to encourage farmers to adopt

management practices like dry seeding and no-tillage rice (*walik jerami*), which CRIA demonstrated as feasible in Indramayu (Sudana, this volume).

If labor is a binding constraint, more draft power and/or mechanical power should be introduced to increase the land-preparation-power capacity of the area. An existing power constraint may also be overcome by increasing the mobility of labor through improved flow of labor market information to better equalize demand and supply over space and time.

The social cost of incorrectly diagnosing the binding constraint to increased cropping intensity is extremely great. If a technical problem is diagnosed as socio-economic, time will be lost in initiating the required investment in irrigation infrastructure and organizing community-level production programs, based on dry and no-tillage cultural practices. Policies implemented may lead to the premature introduction of mechanical power, with severe income distribution consequences. Individuals who obtain loans to buy power tillers tend to be large farmers or rural entrepreneurs. About 50-85% of the labor for land preparation is hired — primarily by landless labor (Hidajat et al 1979; Sudana, this volume), One power tiller replaces about 60 days of human labor/ha per rice crop. If there is actually no labor constraint, the complete introduction of power tillers in the 1,575,000 ha of wetland rice could mean about 94 million days of human labor/wet season and reduce the labor cash income to the landless or near landless by Rp 23.6-46.2 billion, but without a compensatory increase in cropping intensity.[1] The income distribution consequences of this development are significant, because intensive field studies indicate that 30-50% of the rural families are landless (Collier 1979).

On the other hand, if a social constraint is diagnosed as technical, the consequences are also considerable. The current investment for increasing the irrigation service area would not be recovered as projected, because increased cropping intensity would still be constrained by labor shortage. The attempt to control brown planthopper by synchronized planting also would not be realized. The wider gap between rice production and consumption would exacerbate the current shortfall that approached 2.3 million t in 1977-78.

THEORETICAL FRAMEWORK

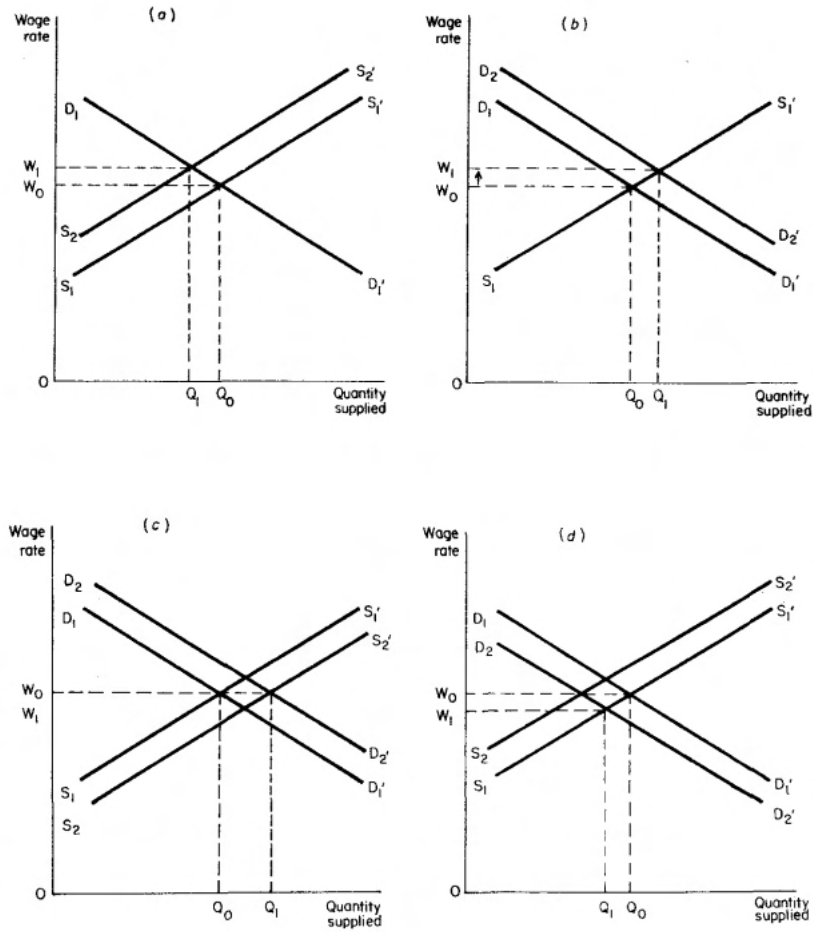
Economic theory provides a framework for evaluating changes in the scarcity of a factor of production (labor).

Real wage rate is the actual cash wage (nominal wage) divided by an index of inflation in order to eliminate the effect of changes in the purchasing power of the nominal wage paid. At a given point in time the prevailing real wage rate is determined by the supply and demand curve for labor. Hence, at any point in time there exists an equilibrium wage rate (W_0) and an equilibrium quantity of labor supplied (Q_0).

Over time, six possible developments exist.

- If the labor supply decreases and the demand is constant (supply curve shift

[1]The wage rate for land preparation is about Rp 500/day plus 2 meals (Sudana, this volume), computed as 94.5 million days × Rp 500/day × 50% (85%) hired labor.



1. Shifts in labor supply and demand curves and the impact on equilibrium wage and labor supplied.

from S_1S_1' to S_2S_2'), the wage rate rises from W_0 to W_1 and the quantity supplied falls from Q_0 to Q_1 (Fig. 1).

- If the labor supply increases but the demand is constant (supply curve shift from S_2S_2' to S_1S_1'), the wage rate falls from W_1 to W_0 and the quantity supplied increases from Q_1 to Q_0 (Fig. 1a).
- If the demand for labor increases but the supply is constant (a demand curve shift from D_1D_1' to D_2D_2'), the wage rate increases from W_0 to W_1 and the quantity of labor supplied increases from Q_0 to Q_1 (Fig. 1b).
- If the demand for labor decreases but the supply is constant (a shift in the demand curve from D_2D_2' to D_1D_1'), the average wage rate falls from W_1 to W_0 and the quantity supplied, from Q_1 to Q_0 (Fig. 1b).
- If there is an increase in both the demand for and the labor supply, the wage rate remains constant, but the quantity supplied increases from Q_0 to Q_1 (Fig. 1C).

- If both the supply of and demand for labor fall, the wage rate remains constant, but the quantity of labor supplied falls from Q_0 to Q_1 (Fig. 1d).

Identification of the possibilities characterizing the labor market in two sample villages was expected to allow us to evaluate the probable existence of a social constraint to increased cropping intensity. The absence of a social constraint could mean that the prevailing constraint was technical.

DATA COLLECTION

To explore the constraints to increasing cropping intensity in the cropping systems target area in the Jatiluhur irrigation system, a problem-focused survey was conducted in two technically irrigated lowland villages in Karawang District in January 1979.

In each village, 30 farmers — cropping systems agronomic cooperators and randomly selected farmers — were interviewed. To better interpret the survey data, a follow-up visit was made to interview key informants.

VILLAGE SETTING

Karawang District is on the north coastal plain of Java and is considered one of the most fertile areas in Indonesia. The study villages, about 60 km from the urban area of Jakarta, are irrigated by the Jatiluhur Authority, which services about 260,000 ha in West Java. They are in a *technical* system — the infrastructure is well-developed, water drainage is separate from the delivery channels, and incoming water can be measured at several points.

Almost all the land in both villages was planted to wetland rice (Table 1). Because water was available most of the year, at least two rice crops were grown.

The population density was very high — about 1,078 persons/km^2 in village A and 773 persons/km^2 in B. Consequently, the lowland area per family was extremely small, averaging 0.39 ha/family in village A and 0.51 ha/family in village B (Table 1).

Averages indicate the man-land ratio, but obscure the fact of unequal land distribution. Table 2 shows that in village A, about 47%, of the farm households owned all of the land and 25% were landless. In village B, 4l-53% of the farm households did not have access to land.

CHARACTERISTICS OF THE FARM SAMPLE

The social characteristics of the sample farmers are shown in Table 3. In both villages the sample farmers were mature and experienced and had spent almost all their life in their respective villages.

Tenure

Although the two villages are primarily lowland areas, the size of landholding of the sample farmers varied. Owned and operated land averaged 1.17 ha for village A, and 2.42 ha for village B (Table 4). Share-tenancy was much more common in village B, as would be expected because of the larger farms. Total land owned by the respond-

Table 1. Land and demographic characteristics[a] of 2 lowland rice villages in Karawang District, West Java, Indonesia, 1979.

Village	Land (ha)					Population (no.)			Density	
	Irrigated	Rainfed	Dryland	Home garden	Total	Male	Female	Total	Persons (no.)/ha wetland	Wetland area (ha)/household[b]
A	600	0	0	20	620	3225	3312	6537	0.092	0.39
B	1244	25	0	68	1337	4751	4863	9614	0.129	0.51

[a] Source: village records. [b] For both villages, the average household size was 3.9 persons. We assume 90% of the households are farming families.

Table 2. Land access characteristics[a] in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Village	Family heads (no.)	Owner non-cultivators (no.)	Owner cultivators (no.)	Farming, (renting/sharing) (no.)	Landless (no.)	Total farm households (no.)	Farm households (%)	
							Owners	Landless
A	1690	119	575	407	361	1468	47	25[b]
B	2100	----------	1441	----------	1600[c]	3041	–	41-53[d]

[a] Source: village records and key informants. [b] Estimated by key informants. [c] Assuming one owner, farmer, or landless person per family unit. [d] The total number of farmers plus estimated number of landless farmers is greater than estimated number of family heads in village B, where some owners live outside the village. Yet, if the landless and total-farm household estimate is correct, 53% of the farm families are landless. On the other hand, if we assume that all owners live in the village, the estimated number of family heads is correct — that 90% of the households are farmers — then there are 989 landless families or 41% of the farm households.

Table 3. Social characteristics[a] of sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Village	Age (yr)	Education (yr)	Farm experience (yr)	Residency in the village (yr)	Household members	
					15 years old or younger	15 years old or older
A	46	4.0	25	39	2.71	3.25
B	42	3.9	20	32	2.43	2.6

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village.

Table 4. Tenure characteristics[a] of sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979 wet season.[b]

Village	Land type	Owned (ha)				Not owned (ha)			Total (ha)	
		Operated	Leased	Shared	Mortgaged	Rented	Shared	Mortgaged	Owned	Operated
A	Garden	0.07 (28)	0	0	0	0	0	0	0.07	0.07
	Dryland	0.03 (2)	0	0	0	0	0	0	0.03	0.03
	Rainfed	0	0	0	0	0	0	0	0	0
	Irrigated	1.07 (28)	0	0.05 (1)	0.14 (2)	0.08 (2)	0.33 (11)	0	1.26	1.48
	Total	1.17	0	0.05	0.14	0.08	0.33	0	1.36	1.58
B	Garden	0.22 (17)	0	0	0	0	0	0	0.22	0.22
	Dryland	0	0	0	0	0	0	0	0	0
	Rainfed	0.03 (1)	0	0.02 (1)	0	0	0	0	0.05	0.3
	Irrigated	2.17 (22)	0.05 (1)	0.29 (6)	0.22 (2)	0	0.41 (8)	0.14 (3)	2.73	2.72
	Total	2.42	0.05	0.31	0.22	0	0.41	0.14	3.00	3.26

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b]Because agronomic cooperators were purposefully selected and economic cooperators were randomly selected, this sample may be slightly overrepresented by farmers with above-average holdings. Figures in parentheses indicate number of farmers with each land and ownership type.

ents in village B was about 2.2 times as great as in village A; this was consistent with our estimate of the relative frequency of landlessness, as shown in Table 2.

Cropping pattern

Rice monoculture was common. The predominant pattern was rice - rice - rice in village A and rice - rice in village B (Table 5). In both villages, few farmers grew dryland crops after rice.

Technology adoption

Both study villages are located in the main rice-producing area of Java. Consequently, the level of modern rice technology adoption was high. In village A, 90% had used fertilizer by 1968, although only 48% had adopted IRRI modern varieties (Table 6). But by 1978, all had adopted modern varieties. Tractor use was not significant until 1977 (31%), but rose to 55% by 1978. Interestingly, although 76% had planted modern varieties by 1972, adoption of the sickle was not widespread until 1976 (66%).

In village B, adoption progressed more slowly. Farmers trying modern varieties did not approach 50% until 1971, and fertilizer use did not reach 90% until 1977. In contrast, sickle adoption appeared to follow the same pattern as IR variety adoption. Tractors were used earlier in village B rising to 24% in 1976, 34 in 1977, and 66% in 1978.

The data indicate that yield-increasing technologies (fertilizer, modern varieties, insecticides) were adopted more rapidly in village A where the owned and operated farm size averaged 1.07 ha but labor-substituting technologies (sickle, tractor) were adopted more rapidly in village B where owned and operated lowland averaged 2.17 ha.

CHANGES IN LABOR SUPPLY

A shift in the supply of labor curve for land preparation may be due to several factors including changes in population, seasonal migration, off-farm and non-farm employment, and draft power.

The most important component in population change is natural growth. As the data suggest, neither *permanent* in-migration nor out-migration is significant in either village (Table 7). Yet, the data show that population has been increasing in recent years.

Table 5. Cropping patterns[a] followed by sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1978.[b]

Village	Farmers (%)			
	Rice - fallow	Rice - rice	Rice - rice - rice	Others[c]
A	2	32	59	7
B	2	94	0	4

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b]Wetland parcels only, 1977-78 wet season and 1978 dry season. [c]Mostly rice - rice - secondary.

Table 6. Cumulative adoption pattern[a] of sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Practice	Adoption[b] (%)													
	Before 1966	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
						Village A								
Bimas[c] program	0	0	7	38	41	69	72	79	79	79	79	86	93	97
IR variety	0	0	0	48	66	72	72	76	76	76	76	86	96	100
Fertilizer	13	24	34	90	93	93	93	97	97	97	97	97	97	100
Insecticide	14	28	34	97	97	97	97	97	97	97	91	97	97	100
Rodenticide	21	34	41	93	93	93	93	93	93	93	97	97	97	100
Tractor	0	0	0	0	0	0	0	0	0	3	7	14	31	55
Thresher	3	3	3	3	3	14	14	21	21	24	28	28	28	31
Rice mill	10	10	10	10	10	27	27	41	76	79	90	90	93	97
Sickle	0	0	0	0	0	0	0	0	0	0	10	66	93	100
						Village B								
Bimas[c] program	7	7	10	17	17	40	47	57	60	67	67	70	73	17
IR variety	10	10	10	30	33	43	47	60	60	73	77	80	97	97
Fertilizer	24	24	24	45	52	59	66	79	79	79	83	83	100	100
Insecticide	11	11	11	29	36	46	54	68	68	77	82	82	100	100
Rodenticide	28	28	31	45	48	62	69	83	83	83	83	83	100	100
Tractor	3	7	10	10	10	10	10	14	14	14	21	24	34	66
Thresher	0	0	0	0	0	0	3	3	3	3	3	3	3	3
Rice mill	10	10	14	28	28	45	62	66	83	83	86	90	100	100
Sickle	7	7	7	31	31	48	52	66	69	72	79	79	100	100

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b]Indicates only the percentage of farmers who had adopted the technology in the respective years. This does not mean that the farmers continued to use the technology after the initial adoption. [c]Bimbingan massal (mass guidance).

Table 7. Population changes in 2 lowland villages, Karawang, West Java, Indonesia, 1974-75 to 1978-79.

Village	Natural growth (%/yr)	Persons who inmigrated (no./year)	Persons who out-migrated (no./year)
A	2.5[a]	1-2[b]	10[b]
B	1.5-2[c]	36[d]	0-10[e]

[a]Estimated from village records, 1968 to 1979. [b]Recent years, key informant. [c]Estimated by key informants for past 10 years. [d]For 1978, but key informants reported that the number was much smaller in the 5 years before 1978. [e]Reported by key informants as 0 in 1978, but 10 in 1974.

Seasonal out-migration

In village A in previous years (1974 as a reference point), about 500 men went to Jakarta during the off-season. In 1979, key informants reported that seasonal out-migration occurred after the second rice harvest, but only about 200 men, many of whom were landless, were involved. The decline in seasonal out-migration was attributed to the substitution of *becaks* (peddle cabs) for motorized transportation in Jakarta and the increase in farm work due to the introduction of triple-cropping of rice,

In village B, key informants reported that seasonal out-migration occurred between the period after land preparation and before harvest. Hence, the respondents did not feel these activities affected available labor for land preparation. They estimated that 5% of the males out-migrated for seasonal work in Sumatra (plantation labor) and Jakarta (*becak,* construction). The rate of seasonal migration is now much less than in previous years.

Seasonal in-migration

The amount of labor absorbed by rice production is dependent on both the cultural practices used and the degree to which various operations are mechanized. Previous studies indicated a labor need of 150 to 200 days/ha for transplanted wetland rice (Hidajat et al 1979, Sudana, this volume). In wetland rice production in Java, little family labor is employed although the average farm size is extremely small (Table 8). Because a large percentage of the families are landless the size of operated holdings is greater than the area that could be done by family labor alone.

In village A, 30% of the sample farmers operated more than 2.0 ha of lowland, the average unit being 1.58 ha (Table 9). In village B 54% farmed more than 2.0 ha lowland, the average holding being 2.56 ha (Table 4, 9). This distribution may be slightly skewed upward because the agronomic cooperators were purposely chosen, whereas the economic cooperators were randomly selected.

In village A, key informants estimated that in 1979 in-migration of seasonal labor constituted about 10, 10, and 20% of the total labor used for land preparation, transplanting, and harvesting. For land preparation and transplanting, the owner contacted the laborers and hired them individually. Key informants estimated that in the wet season, 10 tractors from outside the village came and plowed 300 ha in 1978-79 and 16 plowed about 75% of the land in 1979-80 (Table 10). Plowing

Table 8. Type of labor[a] used by sample farmers in 2 lowland villages in Karawang, West Java, Indonesia, 1977-78 wet season.[b]

Village	Labor use[c] (%)														
	Land preparation														
	Man		Animal		Tractor		Planting		Weeding			Harvesting			
	F	H	F	H	F	H	F	H	F	C	H	F	C	H
A	8	92	45	65	0	100	5	95	8	28	66	7	28	65
	(30)		(17)		(16)		(30)		(30)			(30)		
B	17	83	1	99	6	94	7	93	21	0	79	8	0	92
	(21)		(29)		(17)		(29)		(29)			(29)		

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b] Many farmers used a combination of types of labor for land preparation. [c] Figures in parentheses indicate the number of farmers responding to each question. F = family, H = hired, C = *ceblokan* (weeding gives the right to harvest).

Table 9. Percentage of distribution of operated holding[a] of sample farmers in 2 lowland villages, by size class, Karawang, West Java, Indonesia, 1978-79 wet season.

Village	Wetland rice area operated (% in each size class)							
	0.01-0.50 ha	0.51-1.00 ha	1.01-2.00 ha	2.01-3.00 ha	3.01-4.00 ha	4.01-5.00 ha	5.01-6.00 ha	>6.01 ha
A	29	19	22	19	7	4	0	0
B	7	7	29	26	18	4	4	2

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village.

Table 10. History of hand tractor introduction[a] in 2 lowland villages, Karawang, West Java, Indonesia, 1972-79.

Village	Ownership	Units introduced (no.)							
		1972	1973	1974	1975	1976	1977	1978	1979
A	Owned[b]	0	0	0	0	0	0	0	0
	Outside[c]	0	0	0	0	0	0	10	16
	Government[d]	0	2	2	2	2	2	0	0
B	Owned[b]	3	3	2	2	2	0	2	12
	Outside[c]	0	0	0	0	0	0	50	60

[a]Source: key informants. [b]Owned by village resident. [c]Owned by outsider. [d]Demonstration unit provided by Government for rent.

contracts were arranged beforehand by an advance man who set a plowing schedule. The tractors were used from early in the morning to as late as midnight. For harvesting, the laborers contacted the owner or the laborers who held *ceblokan* rights to harvest the crop. Survey data for 1977-78 (Table 11) showed a somewhat different picture. Almost all the hired man and animal land preparation labor used by the sample came from within the village, but most of the tractor service (81%) was supplied by outsiders. Transplanting and weeding labor was supplied wholly by villagers, compared to only 56% of the harvest labor. Except in the case of tractors, the data indicate little use of labor from sources outside the subdistrict.

In village B key informants reported significant in-migration of seasonal labor. Land preparation had previously been done mainly by hand although a few tractors had been owned by residents since 1972. In the 1978-79 wet season, 50 tractors from outside the village provided land preparation services: the number increased to 60 in 1979-80 (Table 10). Almost all land preparation is now by tractors, with the contract arranged by an advance man who signs up owners of contiguous parcels. Key informants reported that about 200 persons came from outside the village to transplant in the 1978-79 wet season. About 30% of the harvest labor was also in-migrants. The number was less than in previous years, because of the trend toward greater synchronization of planting. The survey data are not entirely consistent with the key informants' reports. About 70% of the respondents hired locally owned tractors, and 100% reported hiring local labor only for transplanting, weeding, and harvesting (Table 11).

Decline in draft power

Animal labor as an alternative source of power for land preparation has declined in both villages. Key informants reported more than 100 work animals in 1970, but only 68 in 1978-79 in village A and only 8 in 1978-79 in village B. The reasons for the decline included reduction in the grazing area, difficulty in scheduling land preparation when depending on animal power, the threat of the irrigation authority to fine farmers who permit their animals to wallow in the irrigation canals, and the cheaper rates for tractor use. Animal power is used largely by farmers who own a cow or carabao.

Table 11. Source of hued labor[a] for principal rice operations of sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1977-78 wet season.

Village	Source of hired labor[b] (%)															
	Land preparation								Trans-planting	Weeding	Harvest			
	Man		Animal		Tractor									
	V	S	V	S	V	S	D	P	V	V	V	S	D	P
A	97	3	100	0	19	19	62	0	100	100	56	40	2	2
	(30)		(16)		(16)				(30)	(30)	(50)			
B	100	0	100	0	70	0	24	6	100	100	100	00		0
	(30)		(22)		(17)				(31)	(31)	(31)			

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b] Figures in parentheses indicate number of respondents using each type of hired labor. The total number of responses may be greater than the number of farmers because some farmers used labor from more than one source. V = same village; S = same subdistrict, different village; D = same district, other subdistrict; P = same province, other district.

Off-farm employment

Changes in off-farm employment opportunities may affect labor supply. Table 12 shows that few respondents did agricultural activities outside their own farm. That is consistent with the observation that the sample included large landowners who typically did not provide labor services to other farmers. The persons who sought work off their own farm were probably those with small farms.

The survey data show that a majority of the respondents in both villages felt there was no change in off-farm job opportunities in 1979 compared to the preceding 5 years (Table 13). In village A, those who felt there were more opportunities frequently gave as a reason the growing of a third crop. In village B, the respondents most frequently identified more input use (fertilizer, spraying) and a reduction in the animal population as factors that increased labor opportunities.

Nonfarm job opportunities

Changes in nonfarm job opportunities may affect labor supply. Almost half of the respondents in village A and one-third in village B held nonfarm jobs during the period (Table 14). The survey data indicate that a majority of the respondents saw no change in nonfarm job opportunities in 1979 compared to the preceding 5 years (Table 15). In village A 40% believed there were more jobs, particularly part-time activities (fishpond), dry-season jobs (irrigation repair), or service jobs (driver, teacher) which required special skills. The data suggest that recent changes in nonfarm employment are probably not a significant factor in any recent change in the labor supply for land preparation.

Perceptions of changes in labor availability

As noted earlier, the farmers interviewed relied heavily on hired labor for all rice production operations. In village A, about 7% felt it was more difficult to find labor to hire for all operations than in the preceding 5 years (Table 16). In village B, the only operation for which there was greater difficulty in hiring labor was land preparation by man. Respondents who perceived a labor shortage were the larger farmers in the sample, operating 3.5 ha and owners of 4.4 ha. Those who indicated “no change” or “easier” were farmers operating 2.45 ha and owners of 2.27 ha.

CHANGES IN THE DEMAND FOR LABOR

Changes in the demand for labor may arise as a consequence of changes in the area cultivated, cropping intensity, and/or type of technology used.

Area expansion

The villages studied are in an area originally settled hundreds of years ago. In village A, key informants reported there were about 400 ha of irrigated lowland as early as 1830. The 1967 lowland area of 611 ha was reduced to 600 ha by 1979 by the demand for living space. In village B, key informants reported that increasing population reduced the lowland area from 1,300 ha in 1974 to 1,244 ha by 1979. Recent changes in the cultivated area have not changed the demand for labor for rice production.

Table 12. Employment off their own farms of sample farmers[a] in 2 lowland villages, Karawang, West Java, Indonesia, 1977-78.

Village	Job holders (%)	Farmers (no.) doing each job					
		Land preparation	Trans-planting	Fertilizing	Spraying	Weeding	Harvesting
A	30	6[b]	1[c]	2[c]	2[c]	2[c]	6[b]
B	13	4[c]	4[c]	0	0	4[c]	2[b]

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b]Including work, outside the village. [c]Worked only in the village.

Table 13. Farmers' response regarding changes in job opportunity off their own farms and reasons for changes[a] in 2 lowland villages, Karawang, West Java, Indonesia, 1979.[b]

Village	Farmers (%)			Farmers (no.) citing reason for change[c]						
				Less opportunities	More opportunities					
	Fewer changes	No change	More changes	More tractors	Third crop	More inputs	Less animals	More land	People leave	No reason given
A	3	63	34	1	9	2	0	0	0	0
B	6	50	44	2	0	5	5	1	1	3

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b]Respondents were asked if there were fewer, more, or no changes in off-farm job opportunities in 1978-79 compared to 1974-75. [c]Some farmers gave more than one reason.

Table 14. Nonfarm work [a] of sample fanners in 2 lowland villages, Karawang, West Java, Indonesia, 1977-78.

Village	Job holders (%)	Farmers (no. in each job type)					
		Trader	Laborer	Factory	Govern-ment	Handi-craft	Live-stock
A	47	6 [b]	6 [b]	0	0	1 [c]	1 [b]
B	30	3 [b]	2 [c]	1 [c]	2 [c]	1 [c]	0

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b] Including work outside residents' village. Worked only in residents' village.

Table 15. Farmers [a] response regarding changes in nonfarm job opportunities and reasons for changes: 2 lowland villages, Karawang, West Java, Indonesia. 1979. [b]

Village	Farmers (%)			Farmers (no.) citing reason for change [c]					
				Less opportunities		More opportunities			
	Fewer changes	No change	More changes	More trade competition	No reason given	Fish-pond	Service	Construction/ irrigation repair	No reason given
A	3	57	40	1	0	4	3	7	1
B	10	83	7	1	2	0	1	1	0

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 respondents/village. [b] Respondents were asked if there were fewer, more, or no changes in nonfarm job opportunities in 1978-79 compared to 1974-75. [c] Some farmers gave more than one reason.

Table 16. Farmers' perceptions of changes in labor availability for selected rice operations[a], 2 lowland villages, Karawang, West Java, Indonesia, 1979.[b]

Village	Farmers (%) perceiving the changes											
	Land preparation by man			Transplanting			Weeding			Harvesting		
	More difficult	No change	Easier	More difficult	No change	Easier	More difficult	No change	Easier	More difficult	No change	Easier
A	7	80	13	3	90	7	3	90	7	7	83	10
B	26[c]	31	37	0	80	20	0	80	20	0	78	23

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village. [b]Respondents were asked if the difficulty in hiring labor was greater, less, or the same this year compared to that 5 years ago. [c]The most common cause (cited by 7 respondents) was a decline in animal power.

Cropping intensification and integrated pest control

The Government of Indonesia has sought to increase cropping intensity so as to increase food production. At the same time, an integrated pest control program built around the synchronized planting and harvesting of a large contiguous area and the implementation of a rice — rice secondary crop pattern (no third crop of rice) is being promoted to combat the brown planthopper (Oka 1979). The impact of these efforts on the demand for labor may be felt in several ways.

- First, in areas where a rice - fallow pattern is practiced, the land preparation for the second rice crop will coincide with the harvest of the first rice crop. The latter activity commands a very high wage rate.
- Second, where a third crop (secondary) is to be introduced in areas irrigated for less than 10 months, the first crop should be planted as early as possible to fully utilize available water. Hence, the demand for labor may be concentrated over a shorter period during land preparation for both the first and second crops.
- Third, a third crop will increase the demand for labor at a time when seasonal out-migration is normally greatest.
- Finally, the synchronization of planting required to facilitate integrated pest control will also concentrate land preparation over a shorter period of time.

The irrigation system in village A was built during the colonial period and is presently part of the Jatiluhur Authority. The system was upgraded to a technical standard in the 1960s. Key informants note that double-cropping of rice had been practiced before the mid-1960s, when the BIMAS (Bimbingan Massal) program was introduced into the area. Table 17 shows that 80 of the respondents had planted the same pattern, basically rice - rice - rice, for at least the past 5 years. Many of those recently adopting a new pattern added a third rice crop as a result of the government's production program.

The irrigation system servicing village B was constructed in 1925 and was included in the Jatiluhur Authority in 1958. Double-cropping of rice has been widely practiced since the early 1960s when a more reliable supply of water became available. Table 17 shows that all the respondents have planted a rice – rice pattern for at least the past 5 years, mainly because of "custom." Consequently, there has been no change in rice cropping intensity that would affect the total demand for land preparation labor.

Before evaluating the constraints to moving the cropping season forward, it is useful to evaluate the existing cropping calendar. In village A, key informants reported land preparation begins in early October when irrigation water comes. All fields in the village are prepared in 25 days (1979-80). Transplanting occurs over a 10day period and harvesting over a 2-week period. The second crop is completely planted 3-4 weeks after the first harvest; delays are due to farmer-to-farmer variability, differences in variety maturity, and a shortage of labor for land preparation. In contrast, the data in Table 18 suggest that either the 1978-79 crop was established much quicker than in previous years or the key informants seriously underestimated the time required to complete the work. Analysis (Table 19) suggests that available manpower can complete land preparation in 25 days, without any in-migrating labor or assistance from the 86 carabao available in the village.

In village B, key informants reported that land preparation begins in November

Table 17. Recent changes in the cropping pattern[a] of sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Village	Same[b] (%)	Farmers (no.) giving reason for				
		Changing		Not changing		
		Government/ extension	Price	No water	No labor	Custom
A	80	6	1	4[c]	2[c]	0
B	100	0	0	3	0	27

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village. [b]Same pattern during the past 5 years. [c]Only farmers not growing rice - rice - rice.

Table 18. Cumulative distribution by week[a] of completion of each activity, 2 lowland villages, Karawang, West Java, Indonesia.

Operation season[b]	Percent of farmers who had completed the operation by wk									
	1	2	3	4	5	6	7	8	9	10
Village A										
Harvesting, 1977-78 wet season (1 = 1-7 Feb)	4	18	21	29	39	61	64	64	64	64
Transplanting, 1978 dry season (1 = 1-7 Mar)	4	8	12	16	20	36	48	50	50	57
Harvesting, 1978 dry season (1 = 1-7 Jun)	4	8	14	14	25	39	46	50	57	68
Transplanting, 1978-79 wet season (1 = 1-7 Nov)	4	15	15	26	41	59	70	85	93	93
Village B										
Harvesting, 1977-78 wet season (1 = 1-7 Apr)	11	59	67	74	78	89	93	93	100	100
Transplanting, 1978 dry Season (1 = 1-7 May)	15	23	54	74	93	93	93	93	93	93
Harvesting, 1978 dry season (1 = 1-7 Aug)	4	4	8	27	46	73	88	92	96	96
Transplanting, 1978-79 wet season[c]	10	10	17	55	86	86	93	97	100	100

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village. Week 1 is the first week a respondent completed each operation. [b]For each activity the beginning week is noted in parentheses. [c]Village records show hectares planted by month as November (200), December (700), and January (347).

and is completed in 1 month. Transplanting also extends over a 1-month period. Village records showed that in 1978-79, the area planted per month was 200 ha in November, 700 ha in December, and 344 ha in January. These figures are generally consistent with the survey results reported in Table 18, where 17% of the farmers completed land preparation in November and 76% in December. (Seventeen percent of the total lowland area is 211 ha and 76% of the area is 945 ha.) The data in Table 19 suggest that if only local manpower were used, it would take 40 days to complete land preparation for the lowland area.

In village A survey data showed that the farmers' decision on when to prepare the land was based on water availability and the need to synchronize their activities with

Table 19. Human labor requirement for land preparation[a] in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Village	Irrigated area (ha)	Male population[b] (15-50 yr)	Technical coefficient for land preparation[c] (work days/ha)	Total human labor needed to prepare lowland (work days)	Days (no.) to complete land preparation with village labor
A	600	1,480	63	37,800	26
B	1,244	2,180	63	78,372	40

[a] Source: key informants and secondary data. [b] For village A, a complete population profile by age category was available. About 51% of the male population was between 15-49 years old (1979). We assumed 90% of this population to be farmers. The same assumptions were used for village B. [c] Record keeping data in Subang for 1976-77 (Hidayat 1979) and in Indramayu for 1977-78 (Sudana 1981) estimate the land preparation human labor input as 64 and 61 six-hour workdays. An average of 63 is used here.

those of others to avoid rat damage from too early planting or bird damage from too late planting (Table 20). About two-thirds of the farmers felt they could not do the first land preparation earlier. Key informants cited shortage of cash to hire labor and shortage of labor as the major constraints, but the farmers cited "no water" and "waiting for instructions from the government" (Table 21).

Reducing turnaround time also permits crop intensification. On the average, 10 days elapsed between the harvest of the first and the beginning of land preparation for the second crop (Table 22). A more rapid turnaround between the first and second rice crops was not feasible because the farmers either were "busy harvesting" or must wait for others to synchronize planting.

In village B, farmers waited for water and instructions from the village leadership before beginning land preparation for the first crop (Table 20). Constraints to earlier land preparation identified by key informants were availability of inputs (fertilizer), labor shortage, and water. Farmers in the survey identified the main constraints to earlier land preparation as "no water" and "need to wait for others to minimize rat damage" (Table 21). On the average, farmers reported waiting 14 days after harvest to begin land preparation for the next crop (Table 22). Constraints to reducing turnaround time were water shortage and farmers' harvesting activities (Table 22).

Table 20. Factors considered by sample farmers in deciding when to begin land preparation for the first crop in 2 lowland villages, Karawang, West Java, Indonesia. 1979.[a]

Village	Farmers (%) considering the factor			
	Water availability	Instructions from village leader	Need to synchronize with others	Others
A	50	0	40	10
B	53	40	0	7

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village.

Table 21. Constraints to earlier wet-season land preparation[a] identified by sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Village	Could you not do land preparation earlier? (% answering no)	Farmers (%) citing the constraint						
		No water	No labor	Wait for instruction	Must wait for others	Secondary crops in field	Others	No response
A	73	42	4	34	0	8	4	8
B	53	44	0	0	44	0	6	6

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village.

Table 22. Constraints to reduced turnaround time between first and second rice crop[a] identified by sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979.

Village	Turnaround time[b] (days)	Farmers (%) citing the constraint					
		Busy harvesting	Labor not available	Water not available	Must wait for others	Soil fertility	Wait seedlings
A	10	51	15	0	29	5	0
B	14	38	8	38	0	12	4

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village. [b] Days from harvest of first crop to start of land preparation for the second rice crop.

New technology

The introduction of the hand tractor in both villages has greatly reduced the demand for labor. In village A, key informants estimated that the 10 tractors did 300 ha in 1978-79 and 75% of the area in 1979-80. This is consistent with the adoption data that show 31 and 55% of the respondents had used tractors by 1977 and 1978. In village B, the arrival of 50 hand tractors in 1978-79 and 60 in 1979-80 had an equally dramatic impact on the demand for land preparation labor.

INTERACTION OF SUPPLY AND DEMAND FACTORS: WAGE RATE CHANGES

We expect to observe the impact of changes in the supply and demand for labor reflected in the wage rate paid for various agricultural tasks. Cash wages paid rose steadily in both villages from 1974-75 through 1978-79 for all operations except harvesting, which is paid as a crop share (Table 23). In 1974-75 the wage rate for man plowing, transplanting, and weeding were about 133,152, and 174% higher in village B than in village A, but harvesting cost was higher in village A (18%). This difference may be due to the fact that village B is 1-hour drive from the main road whereas village A is on the main highway. By 1978-79 the relative difference in wage rates had remained relatively constant, except that wages for transplanting were 27% higher in village B and those for harvesting were 24% higher in village A. The absolute fall in the harvesting wage in village B may be associated with the higher concentration of landholding, with the owners attempting to reduce labor costs to increase net returns. In Table 24, cash wages are indexed to show percent of change relative to the base period. A steady rate of increase was observed across all operations, except harvesting.

Table 23. Mean wage rates paid for major rice production operations during the past 5 wet seasons by sample farmers in 2 lowland villages in Karawang, West Java, Indonesia, 1979.[a]

Year	Mean wage rates paid[b]											
	Plowing						Transplanting (Rp/h)		Weeding (Rp/h)		Harvesting (Rp/h)	
	Man (RP/h)		Animal (Rp/h)		Tractor (Rp/ha)							
					Village A							
1974-75	29.6	(27)	133.9	(29)	[c]		26.2	(28)	23.9	(28)	18.3	(29)
1975-76	33.8	(27)	151.6	(29)	[c]		30.4	(28)	26.1	(28)	18.3	(29)
1976-77	35.0	(27)	182.0	(29)	12,000	(2)	36.1	(28)	30.2	(28)	18.3	(30)
1977-78	40.4	(28)	183.7	(24)	12,292	(12)	40.2	(30)	33.5	(30)	18.3	(30)
1978-79	43.3	(30)	196.2	(23)	12,907	(16)	40.2	(29)	34.2	(29)	18.3	(30)
					Village B							
1974-75	45.2	(27)	190.8	(10)	[c]		39.9	(27)	41.6	(27)	15.5	(24)
1975-76	45.2	(27)	190.8	(10)	[c]		40.7	(27)	43.1	(27)	15.3	(24)
1976-77	48.3	(28)	201.5	(10)	[c]		40.2	(29)	44.9	(29)	15.2	(24)
1977-78	52.9	(29)	290.0	(12)	[c]		48.1	(29)	49.0	(29)	15.1	(24)
1978-79	66.4	(29)	322.5	(15)	18,059	(17)	50.9	(29)	59.7	(29)	14.7	(24)

[a] Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village. [b] US$1 = 625 rupiahs (Rp). Figures in parentheses indicate number of farmers answering the question.
[c] No respondent knew tractor cost.

Table 24. Index of cash wages paid for major operations in rice production during the past 5 wet seasons by sample farmers in 2 lowland villages, Karawang, West Java, Indonesia, 1979.[a]

Year	Index of cash wages					
	Plowing			Transplanting	Weeding	Harvesting
	Man	Animal	Tractor			
			Village A			
1974-75	100	100	*b*	100	100	100
1975-76	114	114	*b*	116	109	110
1976-77	118	137	100	138	126	100
1977-78	136	138	102	153	140	100
1978-79	146	141	108	153	143	100
			Village B			
1974-75	100	100	*b*	100	100	100
1975-76	100	100	*b*	102	104	99
1976-77	107	106	*b*	101	108	98
1977-78	117	152	*b*	121	118	97
1978-79	147	169	100	128	144	95

[a]Source: Central Research Institute for Agriculture Farm Survey. Base year av is 100. [b]No respondent knew tractor cost.

Changes in cash wages can be meaningfully evaluated only if we consider the relative purchasing power of the wage in the year it is received. The data in Table 25 were calculated by deflating (dividing) the index of cash wages by the rural cost-of-living index (nine essential commodities) to determine the real wages (BPS 1979) prevailing each year. In village A real wage for all operations decreased from 100 in 1974–75 to approximately 90 in 1978-79, with the rate of decline about similar

Table 25. Index of real wages paid for major operations in rice production during the past 5 wet seasons, Jatiluhur Cropping Systems Project area, West Java, Indonesia, 1979.[a]

Year	Index of real wages				
	Plowing			Transplanting	Weeding
	Man	Animal	Tractor		
			Village A		
1974-75	100	100	*b*	100	100
1975-76	94	94	*b*	96	90
1976-77	85	99	100[c]	99	91
1917-78	91	93	95	103	94
1978-79	89	90	92	93	89
			Village B		
1974-75	100	100	*b*	100	100
1975-76	83	83	*b*	84	86
1976-77	77	76	*b*	73	78
1977-78	79	102	*b*	81	79
1978-79	90	103	100[b]	78	88

[a]Source: Central Research Institute for Agriculture Farm Survey, 30 farmers/village. Money wages deflated by rural index of 9 essential commodities. 1971 av = 100, Dec 1974 = 210, Dec 1975 = 254, Dec 1976 = 292, Dec 1977 = 312, Dec 1978 = 344. [b]No price reported. [c]Base year is 1976-77 because no price was reported for previous years.

between operations. For village B the real wage rate for all human operations also declined from 100 to about 90. The real cost of animal plowing appeared to increase over the period, but because there were only eight draft animals in village B in 1978-79, there was no active market for their services.

SUMMARY AND CONCLUSION

This analysis sought to evaluate constraints to increasing cropping intensity by first evaluating changes in factors that affect the supply of and demand for labor (Table 26).

In village A on the supply side, the population increased steadily during the past 5 years without any significant relief from permanent out-migration. Seasonal out-migration occurred during the off-season, but has been declining in recent years. Seasonal in-migration of labor was not significant, except for tractors which were introduced in 1978-79. While the draft animal supply has fallen steadily, neither off-farm nor nonfarm employment opportunities changed significantly. In fact, 93% of the farmer sample felt there was either no change or relatively more available labor. On the demand side, there has been no expansion in area during the same period and cropping intensity has not changed significantly. The interaction among supply and demand factors is reflected in the falling real wage rate, which supports the general impression that the supply of human labor has increased more rapidly than the demand.

Several interesting observations should be pointed out.

- First, 80% of the farmers had not changed their pattern during the past 5 years. Hence, a large proportion of the 90% doublecropped parcels and 60% triple-cropped in 1978-79 were already using these intensive patterns before the tractor was widely adopted.
- Second, farmers who were not triple-cropping in 1978-79 cited water as the main constraint.

Table 26. Changes in supply of and demand for labor during the past 5 years in villages A and B in Karawang, West Java, Indonesia, 1974-79.

Parameter	Much less	Marginally less	No change	Marginally greater	Much greater
Supply					
Natural increase				A, B	
Permanent out-migration			A, B		
Permanent in-migration			A, B		
Seasonal out-migration	B	A			
Seasonal in-migration		A,[b] B[b]			A,[a] B[a]
Draft power	A	B			
Off-farm employment			A, B		
Nonfarm employment			A, B		
Labor availability			A, B		
Demand					
Area expansion			A, B		
Crop intensification			A, B		
New technology	A,[a] B[a]				

[a] Tractor. [b] Human labor.

- Third, even with the widespread adoption of the tractor, the main transplanting period (70% planted) was extended more than 6 weeks in 1978–79, when available labor could do the work in less than 25 days.

In village B on the supply side, population increased steadily during the past 5 years, without major out-migration. Seasonal out-migration occurred during the low labor demand periods and decreased in recent years. In-migration is minimal and possibly declining. Draft power was almost nonexistent, and has been declining. Off-farm and nonfarm job opportunities have not changed significantly, and 75% of the farmers saw either no difference or more labor available for land preparation compared to 5 years ago. On the demand side, there was neither expansion in area nor change in cropping intensity. The interaction between supply and demand factors was reflected in real wage rates, which fell during the period. That supports the general impression that supply of labor has increased relative to demand.

Several interesting observations can be drawn.

- First, although extensive mechanization occurred in 1978-79, cropping intensity did not increase.
- Second, about 50 tractors were used for land preparation in 1978-79, but it still took 2-3 months to plant the fields in the village. Available human labor could complete land preparation in 6 weeks.

The data suggest no significant labor constraint to increasing cropping intensity in the two villages. The introduction of tractors neither was a prerequisite for cropping intensification nor did it greatly shorten the period required to establish the first rice crop. The main factor that seemed to be associated with crop intensification was water availability.

If we accept the above conclusion, we must ask why mechanization has experienced such a rapid rate of adoption in the past 2 years. The answer is found by comparing the cost of land preparation with manpower and with a tractor. The cost by tractor was estimated at Rp19,361 in village A and Rp27,089 in village B. The cost with human labor was Rp32,784 in village A and Rp46,872 in village B. The computation assumed manpower requirements of 60 days/ ha and cash wage rates (1978-79) for man and tractor as shown in Table 23. A food cost of Rp200/day in village A and Rp250/day in village B were added to the wage rate. The tractor rate shown was for one plowing. Key informants reported that the second plowing cost two-thirds as much as the first plowing. Hence, we see a significant cost-reducing incentive in replacing human labor with a tractor for land preparation where little or no family labor is used for this operation. The rate of tractor adoption appeared more rapid in village B where average farm size was greater.

In some villages power shortage may be a binding constraint. But this analysis suggests that researchers should carefully examine the existing situation before assuming that power is the limiting factor. Even if power is a probable constraint, we must consider nonmechanical alternatives for overcoming that constraint. For example, CRIA research has shown that dry seeding (*gogo rancah*) of rice can reduce the manpower requirements for land preparation and shorten the crop establishment time by several weeks. At the same time, turnaround time can be reduced by using no tillage (*walik jerami*) practices. Where new seedlings are sown

after harvesting the rice crop, turnaround time may be reduced by sowing earlier nurseries.

The government is encouraging farmers to synchronize planting to avoid pest damage. More information is needed to determine how much larger the area of synchronized planting must be to control brown planthopper. Where labor shortages are identified, the government can inform the landless laborers of the water rotation schedule so they will know where labor demand is high.

In reflecting on the meaning of the term *shortage,* we must keep in mind that the only measure of labor shortage is a real wage increase.

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Parcel-, farm- and community-level variables influencing cropping intensity in Pumdi Bhumdi, Nepal

Marlin Van Der Veen

Pumdi Bhumdi is one of five cropping systems sites in Nepal. It lies 208 km east of Kathmandu along the Pokhara-Bhairawa road. Cropping systems trials are on the south slope of a hill, at altitudes ranging from 750 to 1,270 m. An average 4,000 mm rain falls each year and 6 consecutive months receive more than 300 mm. The soils of the area are silty loam with low pH — generally 5.0 to 6.0. Total nitrogen, P_2O_5, K_2O, and organic matter vary from low to high.

Previous studies (Mathema and Van Der Veen 1978) of the area indicate that the farms are small ($\overline{X}$= .8 ha), subsistence oriented, mixed — both crops and livestock are raised — and traditional. Except for wheat, few improved varieties of crops are grown and very little inorganic fertilizer or pesticide is used. Crop yields are consequently low and a significant proportion of the farms apparently are unable to meet basic household food needs.

Although a number of cropping patterns exist, a large part of the lowland — more than 50% — is devoted to a rice monocrop.

The low cropping intensity on the lowlands and the generally low yields suggest that considerable scope exists for increasing crop production. Cropping systems trials have already shown how yields of individual crops can be raised substantially (Cropping Systems Staff 1979); however, the cropping systems program has paid less attention to identifying means for increasing the number of crops grown per parcel per year. This is partially explained by the fact that there is not a complete understanding of the farming systems followed by the Nepalese farmers. Little is known about the constraints to increasing cropping intensity and where leverage can be gained to improve the productivity of the farming systems. This paper seeks a better understanding of the farming systems in Pumdi Bhumdi and, from this understanding, explain why much land is monocropped and suggest some requirements for more intensive cropping. It was hypothesized that factors explaining monocropping include:

- micro-agroclimatic variations;
- pests and animals that a farmer cannot control without the cooperation of others and which make multicropping unprofitable or risky; and

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- resources other than land, which are in short supply and which are allocated to more profitable uses. In a subsistence rural area such as Pumdi Bhumdi where little or no cash inputs are used in crop production, the resources likely to be of concern are labor, bullock power, and compost.

METHODOLOGY

Most data in this study came from a cropping systems survey of 15% of the households in each cropping systems site in Nepal. The sample in Pumdi Bhumdi was 83 randomly selected farm households. The survey covered household characteristics, off-farm employment and income, livestock owned, and information about each parcel farmed by the household. Data on each parcel included the farmer's classification of the parcel, cropping pattern during 1977-78, yields, amount of inputs used, constraints to more intensive cropping and higher yields, and cropping pattern planned for 1978-79.

In framing the questions to obtain the farmers'classification of their parcels, land type (upland, lowland), fertility, water source, timing of irrigation, and residual moisture were considered.

The amount of labor and bullock power for land preparation were estimated by direct observation and timing by clock as well as by biweekly or weekly interviews with the farmers or their wives.

GENERAL FARM AND HOUSEHOLD CHARACTERISTICS

Farm types

Sixty-three percent of the sample farms are *mixed land type,* i.e. farms with significant amounts (more than 20%) of both upland and lowland (Table 1). The rest are *mainly lowland* or farms with less than 20% of the cultivated area in upland.

Farm size

Although the farms in Pumdi Bhumdi are generally small, variations in size exist. Forty-one percent of the households cultivate less than .61 ha, and 33% cultivate more than 1 ha. The mean cultivated area for the sample is .87 ha, and the mixed land type farms are slightly more predominant among the smaller size categories.

The mean value of the crops produced on a farm increased with farm size—about Rs 690 (US$l.00 = 11.90 Nepalese rupees) for farms less than .41 ha, and Rs 6500 for farms larger than 1 ha during 1977-78.

Household size was not strongly correlated with farm size. The mean number of household members in the sample was 5.8 persons.

Farm size and cropping intensity

There was very little relation between farm size and cropping intensity (Table 2). Although the upland was generally more intensively cultivated, the proportion between the upland and lowland areas was about the same between land size categories, except with the farms less than .41 ha in size. In most cases the proportion of each land type monocropped, double-cropped or triple-cropped was about the

Table 1. Farm and household characteristics by farm category, Pumdi Bhumdi, Nepal, 1979.[a]

Farm size (ha)	Farm type	Households (no.)	Av farm size (ha)	Av no. of parcels	Av household size	Av no. of household members with off-farm employment	Av off-farm income (Rs)	Av gross value of crop production (Rs)	Av value of livestock owned (Rs)
.40 or less	Mixed	19	0.15 (0.10)	2.79 (2.07)	5.26 (3.35)	1.05 (1.03)	2203 (3131)	609 (480)	1432 (1372)
	Mainly lowland	5	0.20 (0.08)	2.60 (1.67)	4.40 (1.14)	0.60 (0.55)	816 (1276)	168 (586)	2181 (682)
More than .40 but not more than .60	Mixed	6	0.50 (0.05)	6.00 (1.26	5.17 (2.32)	0.83 (0.75)	1457 (25 13)	1931 (580)	2991 (2181)
	Mainly lowland	4	0.51 (0.10)	7.50 (3.11)	4.75 (1.50)	0.50 (0.58)	1365 (1599)	2096 (582)	3646 (1650)
More than .40 but not more than 1.0	Mixed	13	0.80 (0.10)	8.77 (3.54)	5.38 (1.45)	0.69 (0.75)	1873 (2587)	3739 (1352)	4058 (1604)
	Mainly lowland	8	0.71 (0.07)	7.50 (2.14)	5.63 (2.13)	0.63 (0.92)	3168 (3875)	2400 (792)	4788 (2164)
More than 1.0	Mixed	14	1.65 (0.48)	9.14 (3.16)	7.00 (2.57)	0.43 (0.65)	1834 (3998)	6479 (2462)	5929 (4843)
	Mainly lowland	13	1.79 (1.03)	9.23 (3.11)	6.92 (2.50)	1.00 (0.82)	3019 (3206)	6585 (4663)	5683 (2131)
All farms		82	0.87 (0.78)	6.76 (3.79)	5.79 (2.53)	0.77 (0.82)	2131 (3090)	3409 (3240)	3885 (3006)

[a]Figures in parentheses are standard deviation. US$1 = Rs 11.90.

Table 2. Multiple cropping index (MCI) by farm size, Pumdi Bhumdi, Nepal, 1977-78.

Farm size (ha)	Land type	MCI 1.00-1.99		MCI 2.00-2.49		MCI 2.50 +		Total	
		Proportion of parcels	Percent of area	Proportion of parcels	Percent of area	Proportion of parcels	Percent of area	Proportion of parcels	Percent of area
.40 or less	Lowland	90	73	34	19	18	8	56	100
	Upland	10	10	66	46	82	44	44	100
	Total	100	45	100	31	100	24	100	100
More than .40 but not more than .60	Lowland	96	66	96	15	36	19	73	100
	Upland	4	8	4	1	64	91	27	100
	Total	100	51	100	11	100	38	100	100
More than .40 but not more than 1.0	Lowland	98	87	60	10	12	3	76	100
	Upland	2	2	40	21	88	87	24	100
	Total	100	67	100	12	100	20	100	100
More than 1.0	Lowland	98	84	55	7	34	9	81	100
	Upland	2	6	45	25	66	69	19	100
	Total	100	69	100	11	100	20	100	100
All farms	Lowland	97	83	56	9	29	8	78	100
	Upland	3	6	44	24	71	70	22	100
	Total	100	66	100	12	100	22	100	100

same between farm size categories. The proportion of the triple-cropped upland on farms less than .41 ha, however, was smaller than that of larger farm size categories.

Cropping systems

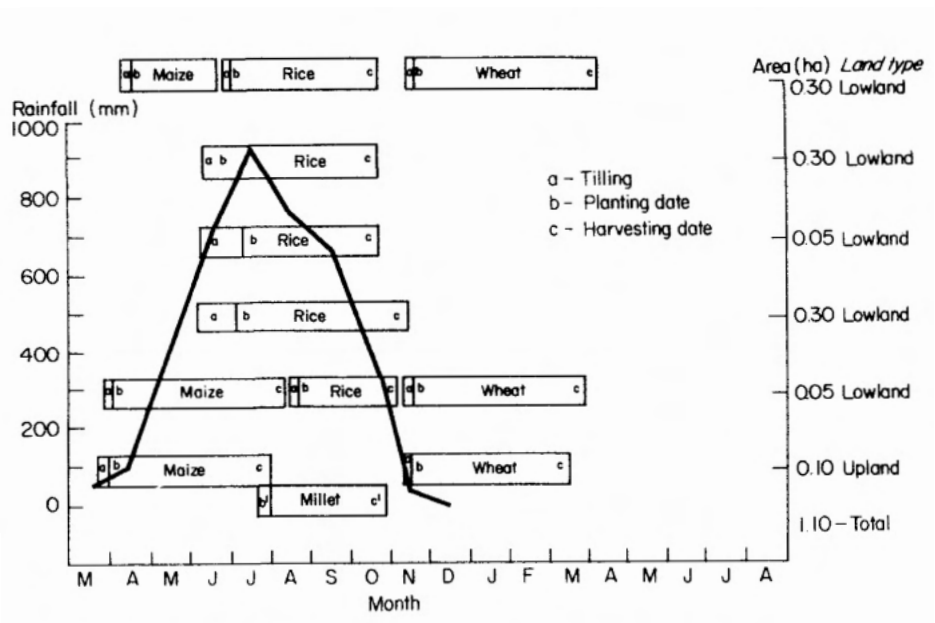
Monocropping, double-cropping, and triple-cropping patterns were followed on many of the farms (Fig. 1, 2). Rice-based cropping patterns predominated on the mainly-lowland farms resulting in peak labor and bullock demands during June and July when land is to be prepared for the rice crop. The combination of maize-based and rice-based cropping patterns on the mixed-land farms allowed a longer time for land preparation during the spring and greater flexibility in the choice of cropping patterns to be followed.

Grain requirements

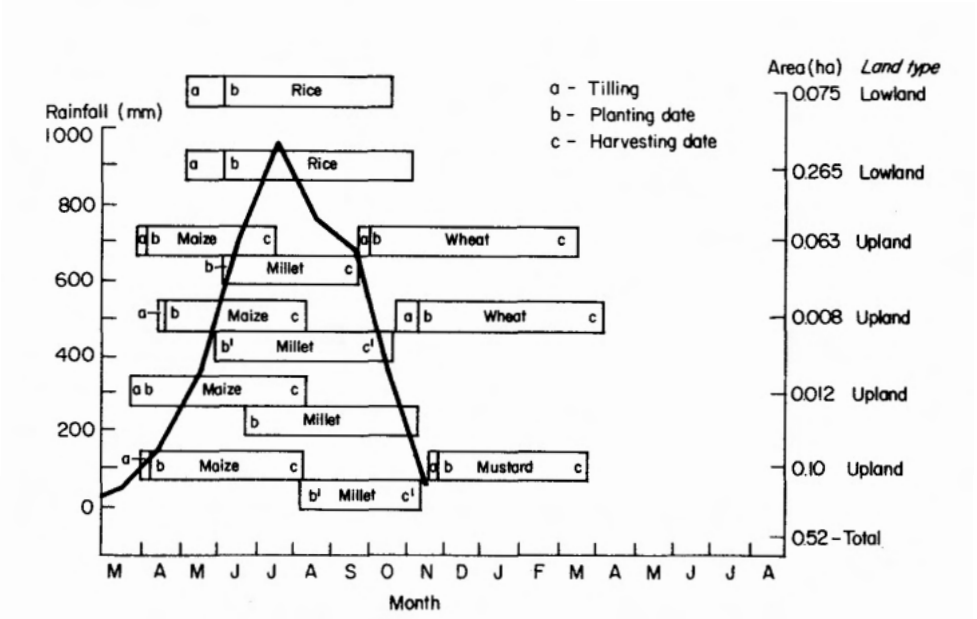
As a whole, the farmers in Pumdi Bhumdi produce more grain per year than the estimated minimum grain requirement for their household if it is assumed that a normal amount of nongrain foods are also consumed (Table 3). However, 39% of the farms — mainly less than 0.6 ha in size — did not produce their household grain requirements in 1977-78. A few larger farms with particularly large households were also deficit producers.

Off-farm income

Off-farm income was an important supplemental source of income for many households in the sample (Table 1). The mean yearly off-farm income was 33% less than the mean value of crops produced in 1 year. Not counted were earning of many



1. Cropping systems on mainly lowland type farm, Pumdi Bhumdi, Nepal, 1978-79.



2. Cropping systems on a mixed land type farm, Pumdi Bhumdi, Nepal, 1978-79.

household members with small farms who worked on others' farms. Off-farm employment, which generally occurred the year-around, included working in government offices as clerks or peons, teaching, army service, blacksmithing, and carpentry.

Livestock in the farming systems

Livestock contributed substantially to the well-being of the households. Livestock provide cash income; meat, milk, eggs, and animal by-products for household

Table 3. Percentage of households producing household grain requirements and percentage of household grain requirements produced, by farm size, Pumdi Bhumdi, Nepal, 1977-78 [a]

Farm size (ha)	Farming households (%)	Households (%) producing household grain requirements[b]	Household grain requirements produced (%)
0.40 or less	29	17	37
More than 0.40 but not more than 0.60	12	50	113
More than 0.60 but not more than 1.00	26	76	211
More than 1.00	33	93	262
All farms	100	61	174

[a] Source: Nepal, His Majesty's Government 1977. [b] The amount of edible food grains required per head per annum was assumed to be 160 kg. Of the total food grain production, either 40% will be lost in the husking of rice or 3% will be lost in milling of other food grains. Also, 10% will be lost in storage or from nonfood use.

consumption; dung for compost; power for land preparation; and savings for possible future cash or food needs. The buffalo are especially valued for milk that can be sold fresh. Eighty-two percent of the farmers own at least one female buffalo. Only 50% of the farmers own bullocks that are used for land cultivation. About 87% of the farmers own at least 1 cow, bullock, or buffalo.

It was hypothesized that the number and value of livestock owned per household would be positively related to both land size and to household size. Larger farms would provide more plant residue for livestock feed and would require more bullock power for land preparation. Larger households have more members to tend the livestock. However, the following regression shows that the value of livestock owned was related not to household size but to farm size.

$$L = 12.76 + 21.69\ x_1^{**}, + 1.38\ x_2^{n.s.}$$

$$R^2 = 0.40^{**}$$

where

L = value of livestock (Rs × l00),

x_1 = farm size (ha) and

x_2 = household size (people).

**Significant at the 1 % level.

n.s. = not significant at the 5% level.

FARMERS LAND CLASSIFICATION AND CROPPING INTENSITY

The farmers in the sample were asked to describe each parcel they farmed by land type, level of fertility, water source, timing of irrigation, and residual moisture. Ninety-four percent of the lowland parcels were irrigated, but none received irrigation during the dry periods of the year. The lowland parcels generally have good water supply during the monsoon, because of the abundant rain during that time of the year. None of the upland parcels received irrigation.

Level of soil fertility and land type, as assessed by the farmers, were used to categorize the parcels as:

Category 1	relatively fertile lowland	16%
Category 2	lowland of intermediate fertility	34%
Category 3	relatively infertile lowland	27%
Category 4	relatively fertile upland	9%
Category 5	upland of intermediate fertility	10%
Category 6	relatively infertile upland	4%
		100%

The parcels were also categorized into early drying or late drying according to moisture retained after the supply from rain or irrigation.

Three main cropping patterns predominated in the lowlands during 1977-78 (Table 4).

Parcel types 1 and 2 were significantly more intensively cultivated than parcel type

Table 4. Common cropping patterns on the lowlands, by parcel type, Pumdi Bhumdi, Nepal, 1977-78.

Parcel type	Cropping pattern	Percent[a] of area	Percent[a] of parcels	Area (ha)
Relatively fertile	Rice - fallow	73	61	11.8
	Rice - fallow - maize	19	20	
	Rice - winter crops[b] - maize	8	19	
Intermediate fertility	Rice - fallow	64	79	24.6
	Rice - fallow - maize	33	10	
	Rice - winter crops - maize	3	11	
Relatively infertile	Rice - fallow	82	87	19.6
	Rice - fallow - maize	10	10	
	Rice - winter crops - maize	5	3	

[a]Chi-square with 4 degrees of freedom = 19.9**. Percentage figures do not add up to 100 because minor crops have been omitted. [b]Mainly wheat.

three (chi-square significant at the 1% level). The differences in cropping intensity were, however, not large. Seventy-three percent of parcel type 1, 64% of parcel type. 2, and 82% of parcel type 3 were monocropped in 1978-79. Eight percent of type 1, 3% of type 2, and 5% of type 3 were triple-cropped. Although cropping intensity on the lowlands was not independent of parcel type, farmers' classification of the fertility of parcels does not explain the differences in cropping intensity.

Moisture situation of the lowland parcels and cropping intensity showed no significant relation (Table 5).

Although upland cropping patterns and parcel type were not independent (chi-square significant at the 1% level), parcel types 4 and 5 were only slightly more intensively cultivated than parcel type 6 (Table 6). Eighty-one percent of parcel type 4 area, 78% of type 5, and 6% of type 6 were triplecropped to maize - soybean/millet - wheat in 1977-78. The only other major cropping pattern was maize/millet. Monocropping was rare.

Cropping pattern was not independent of the moisture situation of the uplands (Table 7). Triple-cropping was practiced in 29% of the parcels with low residual moisture and in 57% of those with high residual moisture. There was no difference between low- and high-moisture parcels and the percentage of monocropping.

It is clear that microagroclimatic variations, as distinguished by farmers, affect cropping intensity. Multicropping was more prevalent on the uplands and on the

Table 5. Lowland cropping intensity, by moisture-holding capacity, Pumdi Bhumdi, Nepal, 1977-78.

Multiple cropping index	Parcels[a] (no.)	
	Early drying	Late drying
1	235 (80)	14 (74)
2	32 (11)	3 (16)
3	28 (9)	2 (11)
Total	295 (100)	19 (101)

[a]Figures in parentheses are percentages.

Table 6. Common cropping patterns on the uplands, by parcel type, Pumdi Bhumdi, Nepal, 1977-78.[a]

Parcel type	Cropping pattern	Percent of area	Percent of parcels	Area (ha)
Relatively fertile	Maize[b] - fallow	5	4	5.2
	Maize/millet - winter crop[c]	81	77	
	Maize/millet - fallow	13	20	
Intermediate	Maize - fallow	3	3	6.9
	Maize/millet - winter crop	78	63	
	Maize/millet - fallow	19	31	
Relatively infertile	Maize - fallow	2	19	3.9
	Maize/millet - winter crop	66	46	
	Maize/millet - fallow	32	23	

[a]Chi-square with 4 degrees of freedom = 94.2**. Percentage figures do not add up to 100 because minor crops have been omitted. [b]Mix-cropped with soybean and/or vegetables. [c]Mainly wheat but also mustard and potato.

Table 7. Upland cropping intensity, by moisture situation, Pumdi Bhumdi, Nepal, 1977-78.[a]

Multiple cropping index	Parcels (no.)	
	Early drying	Late drying
1	16 (14)	4 (14)
2	64 (57)	8 (29)
3	33 (29)	16 (57)
Total	113 (100)	28 (100)

[a]Chi-square with 3 degrees of freedom = 9.86*. Percentages are in parentheses.

parcels classified as relatively more fertile. Residual moisture influenced cropping intensity on uplands where crops are also grown during the driest times of the year.

However, the small differences in the available water within land types and the small difference in the percentages of areas devoted to different cropping patterns between fertility levels within a land type suggest that other variables influence cropping intensity in Pumdi Bhumdi. These will be discussed further.

CONSTRAINTS TO MORE INTENSIVE CROPPING

Pests and animals

The farmers of the monocropped parcels reported pests and animals as constraints to intensive cropping on 10% of the parcels (Table 8). Monkeys were the primary problem, but rats and birds were also a concern. The severity of this problem may be lessened if more of the lowland is cropped during the winter and spring.

Residual moisture and shade

Lack of water and, in a few cases, shade was a constraint on 23% of the monocropped parcels. Six months of continuous rainfall of more than 200 mm and 7 of continuous rainfall of more than 100 mm in Pumdi Bhumdi suggest that enough

Table 8. Constraints to more intensive cropping on monocropped land by parcel type, Pumdi Bhumdi, Nepal, 1978-79. [a]

Parcel type (code no.)	Parcels (no.)	Pests and animals		Grazing cattle		Water shortage or shade		Lack of plant nutrients		Lask of and/or bullocks		Parcel is far from house		Miscell-aneous		No con-straint	
		Parcels (no.)	%	Parcels (no.)	%	Parcels (no.)	%	Parcels (no.)	%	Parcels (no.)	%	Parcels (no.)	%	Parcels (no.)	%	Parcels (no.)	%
1	44	4	9	14	32	8	18	6	14	5	11	9	20	3	7	12	27
2	92	9	10	10	11	14	15	26	28	7	8	10	11	9	10	21	23
3	111	8	7	16	14	39	35	61	55	5	5	13	12	2	2	9	8
4	4	1	25	–	0	–	0	2	50	2	50	–	0	–	0	–	0
5	2	1	50	–	0	–	0	–	0	–	0	–	0	–	0	1	50
6	14	4	29	17		–	0	5	36	–	0	–	0	1	7	1	7
Total	267	27	10	41	15	61	23	100	37	19	7	32	12	15	6	44	16

[a] The percentages are within parcel types across constraints. Their sums exceed 100 because more than one constraint was reported for some par eels.

moisture is available for 2 crops per year. However, the low rainfall during the 5 winter months limits crop growth at this time to those parcels with relatively high levels of residual moisture. Lack of moisture was more predominant among parcels classified as relatively infertile — coarse-textured with low organic matter and therefore have poor water-holding capacities and receive little runoff from other parcels.

Shading was a problem in parcels adjacent to forest areas.

Grazing livestock

Grazing livestock during winter and spring was reported as a problem on 15% of the monocropped parcels and on 32% of the monocropped relatively fertile lowland. The problem can be solved by either building a fence or guarding the parcel every day while the crop is in the field. An easier solution is for farmers to decide to crop their land in winter and spring, and to agree to keep cattle out of the area.

Distance of parcel from house

The distance of the parcel from the house was a constraint in 12% of the monocropped parcels.

The parcels lie relatively close to the house but there is some relation between cropping intensity and distance. Of the parcels of the sample farmers only 11% are more than one-half hour walking distance from the house, but 89% of that group are monocropped.

Most of the other constraints are not affected by distance (Table 9). All the parcels with power and labor constraints and about 80% of those affected by nutrient constraints, pests and/ or wild animals, and cattle grazing are less than 0.5 hour away from the farmers' house.

Plant nutrients

The lack of plant nutrients was reported to be a reason for monocropping in 37% of the monocropped parcels.

Sources. Organic fertilizer in the form of compost is the most important source of plant nutrients in Pumdi Bhumdi (Table 10). The farmers do not grow green-manure

Table 9. Relationship between monocropping constraints and parcel distance from the house, Pumdi Bhumdi, Nepal, 1978-79.

Constraint	Parcels				Total (no.)
	0.50 h walk or less from house		More than 0.50 h walk		
	No.	%	No.	%	
Land is far	16	57	12	43	28
Labor or bullock shortage, or both	20	100	0	0	20
Nutrient constraints	77	78	22	22	99
Pest or wild animals, or both	21	78	6	22	27
Cattle grazing	35	85	6	15	41
Total	169	79	46	21	215

Table 10. Farms and parcels receiving fertilizer, Pumdi Bhumdi, Nepal 1977-78.

Type of fertilizer	Farms (%)	Parcels (%)	
		Lowland	Upland
Organic fertilizer (compost)	100	66	99
Inorganic fertilizer	21	9	7
Organic and inorganic	21	6	7

crops and the only leguminous crop is soybean mix-cropped with maize. All plant residues, except roots, are removed from the field and are used as feed, composted along with farmyard manures, or are used as fuel.

Compost used per farm. It was hypothesized that the amount of compost used on each farm yearly was related to the number of livestock owned, to the amount of plant material available as feed for livestock or for mixing with dung, and to the number of women working on the farm. Women in Pumdi Bhumdi are frequently the ones involved in compost making, bringing fodder to the animals, and carrying the compost to the fields. Farm size was the proxy variable representing the amount of plant material available for fodder or for composting.

$$C = 2.14 + .83\ x_1^{**} + .07\ x_2^{n.s.} + .32\ x_3^{n.s.} + .42\ x_4^{n.s.}$$

$$R^2 = 0.48^{**}$$

Where:

C = amount in metric tons of compost applied to the farm in 1978-79,
x_1 = number of livestock owned (cow + bullock + buffalo and l/2 calf),
x_2 = interaction between land size and livestock number,
x_3 = number of women working on the farm, and
x_4 = interaction between number of women and land size.

The number of livestock owned explained a significant part of the variation, but farm size and number of women did not. The woman variable was probably insignificant because of low interfarm variation in the number of women.

Compost used per hectare. Farm size is important when one looks at the average amount of compost used per farm per hectare. The number and value of livestock owned per household generally increased with the amount of land cultivated, and even the smallest farms frequently had one or two head of livestock. The smaller farms with high livestock number-land area ratio applied the largest amount of compost per hectare to their farms (Table 11).

Allocation of compost. Compost in Pumdi Bhumdi is allocated according to land type and cropping intensity. The upland receives on the average more than 4.4 times the amount of compost applied per hectare on the lowland, partly because the upland is more intensively cultivated than the lowland. The average amount of compost used varied directly with cropping intensity.

Table 12 shows that although the amount of compost applied per hectare per year varied with land type and with cropping intensity, it did not vary with the farmers' classification of the fertility levels of their parcels.

Adequacy of the nutrients supplied through compost. The amount of plant nutrients to be replaced in a soil each year to maintain its present level of fertility depends on the amount of plant nutrients lost each year by crop removal, drainage

Table 11. Relationship between compost used per hectare per year and farm size, Pumdi Bhumdi, Nepal, 1977-78.

Compost used (t/ha)	Farm of .40 ha or less		Farm of .41-.60 ha		Farm of .61-1.0 ha		Farm of >1.0 ha	
	No.	'%	No.	%	No.	%	No.	%
Less than 4.5	2	8	4	40	7	33	16	59
4.5 to 9	7	29	4	40	10	78	9	33
More than 9	15	63	2	20	4	15	2	8
Total	24	100	10	100	21	100	27	100

Table 12. Average yearly compost input, by multiple cropping index and parcel type, Pumdi Bhumdi, Nepal, 1978-79.

Multiple cropping index	Av annual compost input[a] (t/ha)					
	Parcel type 1	Parcel type 2	Parcel type 3	Parcel type 4	Parcel type 5	Parcel type 6
1	1.9 (3.3)	3.0 (5.9)	2.6 (3.1)	6.3 (5.7)	21.6 (30.1)	17.6 (25.8)
2	9.1 (10.2)	5.1 (4.9)	8.2 (8.0)	22.1 (26.9)	17.8 (15.8)	14.3 (9.8)
3	12.3 (6.9 j	10.9 (8.5)	7.9 (9.0)	20.2 (19.7)	18.0 (21.3)	24.8 (18.8)

[a]Parcel type 1 = relatively fertile lowland (L), 2 = L of intermediate fertility, 3 = relatively infertile L, 4 = relatively fertile upland (U), 5 = U of intermediate fertility, 6 = relatively infertile U.

or leaching, erosion, decomposition processes, and through grazing animals. Pumdi Bhumdi lies on a hillside, 50% of the fields are left bare at least 6 months of the year, and annual rainfall is 4,000 mm. The nutrient losses through drainage or erosion could be serious. Some gaseous nitrogen losses from the decomposition of organic matter may be inevitable.

Crop yields, type of crop, and number of crops grown per year affect the amount of nutrients lost through crop removal. Table 13 gives average yields and estimates of the amount of nutrients removed by common crops in Pumdi Bhumdi.

Table 13. Major nutrients lost by crop removal by crop, Pumdi Bhumdi, Nepal.[a]

Crop	Yield (t/ha)	Nutrient lost (kg/ha)		
		N	P_2O_5	K_2O
		Lowland		
Rice	2.2	54	26	46
Wheat	1.3	21	7	11
Maize	2.1	32	13	32
		Upland		
Maize	3.0	45	18	45
Finger millet	1.1	55	34	84
Wheat	1.3	21	7	11

[a] Source: Mariakulandai and Manickam 1975.

With other factors held constant, nutrient requirements increase with the number of crops grown per year. Table 14 shows estimates of the average amount of plant nutrients removed by crops in each major cropping pattern and a rough estimate of the amount of plant nutrients replaced by compost.

Nitrogen and phosphorus differences between the amount of nutrients removed and the amount supplied occurred in all the major patterns, especially in the lowland. Monocropped lowland on the average received only 15% of the nitrogen and phosphorus removed by the rice crop from the compost applied. Triple-cropped lowland received 41% of the nitrogen and 48% of the phosphorus removed per year. Fifty to 60% of the N and the P_2O_5 removed on the upland was generally returned per year with compost.

Lack of plant nutrients appears to be a constraint to more intensive cultivation for virtually all farms in the area.

Strategy of compost use. The farmers allocate more compost to the uplands and apply compost to the lowland only when it is multicropped. The availability of compost for the lowland seems to be a factor in determining whether the lowland is multicropped or not.

Multicropping of lowland occurs only on the mixed land type farms that have compost for the lowlands or on farms composed entirely of lowland and which have compost. In either case, multicropping generally occurred in only some, not all, of the lowland parcels farmed by each household, partly because of lack of compost. Monocropping of all of the lowland parcels occurred on 27% of the farms with lowland. Double-cropping of all the lowland parcels occurred only on 15% of the farms (Table 15); 58% of the farms had monocropping combined with double- and/or triple-cropping on their lowland parcels.

This variation in cropping intensity on farms and between farms in the lowlands partly explains why the farmers' classification of the fertility of their parcels is only slightly related to cropping intensity. Farmers with a larger share of relatively fertile parcels practice monocropping on some parcels because of lack of compost. All categories of parcels are monocropped on farms without compost for the lowland.

Efficiency in the allocation of compost. Five multiple regressions were run to test if the farmers were following the proper strategy in giving the upland priority in receiving compost. These regressed the gross value of annual crop production per hectare with the amount of compost applied annually per hectare for double-cropped and triple-cropped upland, and monocropped, double-cropped, and triple-cropped lowland.

The regressions showed that the amount of compost applied is significantly related to the gross value of crop production.

(1) Upland MCI = 2

$$Y = 1.93 + 0.21\,x^{**} - 0.0011\,x^{2\ \text{n.s.}} \qquad R^2 = 0.37^{**} \quad n = 70$$

(2) Upland MCI = 3

$$Y = 5.16 + 0.09\,x^{**} + 0.0013\,x^{2**} \qquad R^2 = 0.40^{**} \quad n = 150$$

(3) Lowland MCI = 1

$$Y = 2.76 + 0.19\,x^{**} \qquad R^2 = 0.15^{**} \quad n = 245$$

(4) Lowland MCI = 2

$$Y = 2.41 + .39\,x^{**} - 0.011\,x^{2\ \text{n.s.}} \qquad R^2 = 0.26^{**} \quad n = 38$$

Table 14. Major plant nutrients lost through crop removal and mean amount replaced[a] by compost, by cropping pattern, Pumdi Bhumdi, Nepal, 1977-78.

Cropping pattern	Nutrients lost (kg/ha)			Nutrients replaced (kg/ha)			% replaced		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
			Lowland						
Rice monocrop	54	26	46	8	4	25	15	15	54
Maize - rice - fallow	86	39	78	22	11	65	26	28	83
Maize - rice - wheat	107	46	89	44	22	133	41	48	149
			Upland						
Maize monocrop	45	18	45	28	14	84	62	78	187
Maize/finger millet	100	52	129	59	30	180	59	58	140
Maize/finger millet - wheat	121	59	140	63	32	192	52	54	73

[a]The nutrient contents of the compost used were an average of compost samples analyzed by the Soils Division, Department of Agriculture. These are ,92% N, .47% P_2O_5, and 2.8% K_2O on a dry-weight basis. Moisture content of the compost was assumed to be 50% of total weight.

Table 15. Lowland cropping patterns, Pumdi Bhumdi, Nepal, 1977-78.

Lowland cropping system	Farms	
	No.[a]	%
Monocropped only	20	21
Entirely double-cropped	11	15
Entirely triple-cropped	0	0
Some monocropped and some double-cropped	23	32
Some monocropped and some triple-cropped	12	16
Monocropped, double-cropped, and triple-cropped	7	10
Total	73	

[a] Nine households have no lowland.

(5) Lowland MCI = 3

$$Y = 4.16 + .248\ x^{\text{n.s.}} - 0.00156\ x^{2\ \text{n.s.}} \qquad R^2 = 0.32^{**} \qquad n = 31$$

Where

Y = gross value of crop production per hectare in thousand rupees

x = compost used per hectare in tons.

All double- and triple-cropped areas received compost in 1977-78 and have probably been receiving compost yearly. Consequently, the intercept figures for the double- and triple-cropped land cannot be interpreted as the value one might expect if no compost were applied.

It could be reasonably assumed that all land in Pumdi Bhumdi which receives no compost or inorganic fertilizer year after year would be monocropped. In this case the intercept value of Rs 2,760 for the monocropped rice could be accepted as the value to expect if no compost were applied to the lowland. A reasonable estimate of the yield of uplands that receives no fertilizer year after year might be 500 kg maize/ha or about Rs 940/year.

Table 16 shows the gross value of crops that can be expected with no compost, the mean amount of compost used, and the marginal product of compost using the preceding assumptions.

The relatively low marginal product of Rs 290 t compost on monocropped rice shows that if the farmers double- or triple-crop some of their land, they are probably right in not allocating compost to the monocropped lowland. The additional gross value of product harvested from the last ton of applied compost is much higher on the double- or triple-cropped upland or lowland.

The value of the marginal product is the same on the double- and triple-cropped upland, mainly because of diminishing marginal productivity of compost on the triple-cropped land.

Estimation of the value of the marginal product of compost on triple-cropped lowland is not possible because of the insignificance of the regression coefficient. The value of the marginal product of compost on the double-cropped lowland is slightly higher (but probably not significantly higher) than that on the double- or triple-cropped upland. But because the labor and bullock requirements for wheat and maize crops on the lowlands are more than twice that for wheat and a relay millet crop on the upland, the *net* marginal returns from the use of compost may be much higher on the upland.

Table 16. Gross value of crop production at zero and mean compost input, by land type and by multiple cropping index (MCI), Pumdi Bhumdi, Nepal, 1978-79. [a]

Land type	MCI	Gross value (thousand Rs)		
		With zero compost input	With mean compost input	Marginal product
Upland	2	.94	4.60	.43
Upland	3	.94	6.43	.43
Lowland	1	2.16	2.19	.29
Lowland	2	2.16	4.26	.47
Lowland	3	2.16	n.a.	n.a.

[a] n.a. = not available.

From the limited information available it seems that the farmers in Pumdi Bhumdi were generally rational in how they used their compost. The highest net returns from compost used probably occur in the upland where most of the compost was applied. Little compost was applied to the monocropped lowland where the returns to compost are the lowest. Farmers who did not own upland or those who felt they had sufficient compost for their upland applied compost to the multi-cropped lowland where the gross return to compost use was relatively high.

Nutrient sources for more intensive lowland crop production

The number of additional livestock required in Pumdi Bhumdi would be substantial if the additional plant nutrients needed for more intensive cropping of the lowland were derived only from the present methods of composting. If all the lowlands in the sample were triple-cropped and if the lowland area received as much compost as the presently triple-cropped area, 249 additional tons compost would be required. Each additional animal along with grass, leaves, and crop residues presently contributes .82 additional tons of compost/year (from the above regression). At this rate, 303 additional livestock would be required — 3.7 additional animals per family and a 137% increase in the livestock population. The number would be 300% higher if the amount of nutrients removed by crops were returned by the present means of composting. This magnitude of livestock increase is probably impossible, and a nutrient deficit would continue especially if higher crop yields are obtained.

Clearly more and improved ways of supplying plant nutrients to the soil must be introduced.

Power and labor shortages

Power and labor shortages actually prevented 2% of the farmers from cultivating some of their land and were also constraints to growing more crops per year on 7% of the monocropped parcels.

Only 50% of the farmers own 1 bullock, and the rest avail themselves of the services of a bullock team through a system of labor exchange. The largest demand occurs during lowland preparation for the rice crop. If all the bullocks in the sample work 7 hours a day, 70 work days is required for the bullocks to cover the lowland farmed by the farmers sampled (Table 17). The farmers take about 100 calendar days to finish land preparation for the rice crop; this time is one factor that may explain

Table 17. Time available and time required for land preparation under present and potential cropping intensity and implication for bullock number, Pumdi Bhumdi, Nepal, 1978-79.

crop	Current cropping pattern		Triple-cropping			Required increase in bullocks [e]
	Number of days spent [a]	Number of days required [b]	Mean number of days spent per parcel	Number of days available [c]	Number of days required [d]	
Rice	109	70	3	50	70	40
Wheat	60	11	4	35	43	23
Maize	40	33	5	35	83	37

[a] The number of days between start of land preparation and planting or transplanting of the last parcels. [b] Assuming each bullock owned by the sample farmers works 7 hours a day, 7 days a week; present cropping patterns; and mean bullock requirements per hectare for each crop in each land type. [c] The number of days between start of land preparation and planting or transplanting of the last parcels on parcels which are already triple-cropped. [d] Assuming all upland is devoted to a maize/millet - winter crop and all lowland is devoted to a maize - rice - wheat cropping pattern. [e] Assuming the number of days available does not increase.

the relatively poor use of the 6 months of high rainfall during the year.

Because of the smaller area cropped and the lower labor needs per hectare, the bullock power requirements are much lower in the maize and wheat crops than in the rice. With the present cropping intensity, the bullocks require only 11 work days for the wheat crop and only 33 days for the maize crop. It seems possible to increase the area of maize and wheat cultivated in a year with the present bullock population.

Future shortages. A bullock shortage problem could arise as cropping intensity increases. Triple-cropping reduces the time available for land cultivation. Plants are in the field 340 days/year in a maize - rice - wheat pattern in the lowland and 330 days/ year in a maize/ millet - wheat pattern in the upland. The lack of time for land preparation is one reason why farmers with triple - cropping harvest their crops when the moisture content of the grain is still high.

More intensive cropping can also significantly increase the requirement of bullocks for land preparation.

The required increase in the bullock population to allow triple-cropping in the area depends on the number of days for land preparation for each crop. The farmers spend an average of only 3, 4, and 5 days on land preparation per parcel on rice, wheat, and maize crops, respectively, with triple-cropping, but the parcels do not become ready for land preparation all at the same time. The number of days between the start of land preparation and the planting or transplanting of the last parcels on triple-cropped land in Pumdi Bhumdi is 50 for rice, 35 for wheat, and 35 for maize. If these number of days are available when the entire area is triple-cropped, the bullock population would have to be increased by 40% for the rice crop, 23% for wheat, and 137% for maize.

A bullock shortage could become a serious problem as more and more land in the area becomes triple-cropped. Planting early-maturing varieties and staggering the planting and harvesting dates of individual crops could increase the time available for land preparation.

Bullocks compete with the buffalo for the limited amount of fodder in the area. The buffalo provide a stable source of cash income for the farmers whereas the bullocks are fully used only 2 months of the year. One would expect that the net benefit of owning bullocks would increase with increased multicropping and with the consequent increase in bullock use throughout the year. The farmers may be willing to increase the bullock population if more fodder is made available as a result of more intensive cropping and if farmers would be provided with credit.

A possible labor shortage problem in the community with more intensive cropping would be similar to bullock shortage but not as severe. Labor shortages could become a serious constraint, however, in households that own no bullock and have a low farm-worker-per-hectare ratio.

A high proportion of the household in Pumdi Bhumdi belong to Brahmin or high-caste Hindus who hire low-caste Hindus as plowmen. A shortage of low-caste plowmen may develop along with bullock shortage in more intensive cultivation.

Transplanting rice requires a large labor input from the women and may become a problem if less time is allowed between crops. With present transplanting methods it takes 18 work days for local women who work 7 hours a day to transplant the rice crop.

SUMMARY AND CONCLUSIONS

This paper explains why farmers in Pumdi Bhumdi practice monocropping in much of the lowland, and suggests some requirements for more intensive cropping. More than 60% of the farms have both upland and lowland and hence complex cropping systems. More than 90% of the farmers own livestock. Because of the need for compost and bullock power for crop production and the need for plant residue for livestock feed, important relationships between crops and livestock existed on all farms. Many households supplement their farm production with off-farm employment.

Seventy-two percent of the lowland in Pumdi Bhumdi was monocropped during 1977-78. This monocropping was not concentrated on one type of farm but occurred on 85% of the farms with lowland. Fiftyeight percent of the farms with lowland had lowland monocropped and lowland double- and/ or triple-cropped. Fifteen percent of the farms devoted their entire lowland area to double-cropping and 27% devoted their entire lowland area to monocropping.

Factors considered as constraints to intensive cropping on the monocropped lowland included water shortage, lack of plant nutrients, power and labor shortages, grazing animals, pests and animals, and distance of the parcel from the house.

Damage caused by grazing livestock, monkeys, rats, and others are a problem to farmers who may want to multicrop their lowland. These problems can be reduced with community cooperation as more farmers in the area express a desire to grow more crops per year.

Identifying better means of using rainfall and residual moisture can help increase the possibility of more multicropping on the lowlands.

In general, increasing cropping intensity in Pumdi Bhumdi may not be as simple a task as raising the yields of individual crops. Yields can be increased by changing varieties and by applying moderate doses of fertilizer with little effect on the other components of the farming system. On the other hand, that can increase the demand for scarce resources such as bullock power, fodder, labor, and compost and other sources of plant nutrients.

A study of the interrelationships within the farming systems may give a clearer understanding of the constraints to change in the farming system and the requirements for improvement. Almost all constraints mentioned are controllable by man: however, more research in the areas of fodder and plant nutrient supply and in power and labor requirements are needed.

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Economic evaluation of the introduced cropping patterns in Indramayu, West Java, 1977-78

Wayan Sudana, Asep Saefuddin, and Richard Bernsten

Population density in Indramayu district, West Java, averages more than 500 persons/ km^2. That puts intense pressure on the land, and presents an urgent need to increase land productivity. Although the modern seed-fertilizer technology is widely adopted in the area, most rainfed rice farms grow only one crop and most farms with irrigation only 2 rice crops/year. Hence, there is potential for raising output per hectare through increasing cropping intensity. One possibility is development of a management strategy that will enable rainfed and irrigated farms to grow a grain legume crop after the rice is harvested.

The historical rainfall pattern shows the area receives 1,765 mm rain/ year, with 7 months having 100 mm or more. December is the wettest month and October the driest. Hence, the rainfed areas have adequate rainfall for growing a rice and a legume crop.

The Jatiluhur Irrigation System provides water to western Indramayu; the Rentang System, to the eastern part of the district. Farmers' fields receive water for 5-6, 7-9, or 10 months depending on their location. Normally, the 10-month area first receives water in early October, the 7-9 month area in late October, and the 5-6 month area in late December. Hence, all the irrigated zones have adequate irrigation and rainfall for two rice crops and a grain legume crop.

The Indramayu research was designed to test the feasibility of growing one rice crop and a grain legume crop in the rainfed area, and two rice crops and a grain legume crop in the irrigated zones. A package of management practices for each environment was developed and tested in farmers' fields. This paper evaluates the economic feasibility of the introduced technology.

METHODOLOGY

The cropping systems research strategy included a 2-year design stage during which small plot (1,000 m^2) trials and component technology experiments were conducted. At the testing stage, the best patterns were evaluated on a larger scale (Table 1). For comprehensive analysis, both agronomic and economic data were collected.

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Table 1. Cropping pattern trials by year and water availability category, Indramayu, Indonesia, 1975-78.

Category of patterns	Patterns tested[a]			
	Rainfed	5-6 mo of irrigation	7-9 mo of irrigation	10 mo or more of irrigation
		1975-76		
Farmers'		WLR-NTR	WLR-NTR	WLR-WLR
Farmers', without constraints		WLR-NTRCP	WLR-NTRCP	WLR-NTR-SB
Introduced		WLR-NTRCP	WLR-NTR-CP	WLR-NTR-SB
		1976-77		
Farmers'		WLR-NTR	WLR-NTR	WLR-NTR
Farmers' without constraints		WLR-NTR	WLR-NTR	WLR-NTR
Introduced A		WLR-NTRCP	WLR-NTR-SB	WLR-NTRCP
Introduced B		DSR-NTRCP	WLR-NTRCP	WLR-NTR-NTRCP
		1977-78		
Introduced	DSR-SB	DSRCP	WLR-NTR-SB	WLR-NTR-SB

[a]No pattern trials in the rainfed environment for 1975-76 and 1976-77. WLR = wetland transplanted rice (*padi sawah*), NTR = no tillage rice (*walik jerami*), DSR = direct-seeded rice (*gogo rancah*), SB = soybean, CP = cowpea.

Design

Initially the agricultural environment was classified into zones with 5-6, 7-9, and 10 months of irrigation. In each environment 9 farmers cultivating at least 0.5 ha and willing to allocate 0.1 ha to one of the patterns were randomly selected. In 1975-76 three farmers in each category planted:

- the pattern typically grown by farmers in the area, using their own inputs and management;
- the farmers' pattern without constraints (researchers provided material inputs desired by the cooperators); and
- an introduced pattern that the researchers thought would be most profitable.

In 1976-77, the same design was used but a second pattern was introduced.

In 1975-76 record-keeping data were collected from 36 farmers planting the existing (30) patterns, farmers' patterns (3) without constraints, and introduced patterns (3). In 1976-77 the project economists collected data on 45 farmers planting the existing (15) patterns, farmers' patterns without constraints (15), and the introduced patterns (15). Initial results showed that the introduced patterns were ready for preproduction testing (CRIA 1977-78).

Testing

Considering experience in the first 2 years, the research design was modified. First, *rainfed* forms were added to determine if the technology was applicable to that environment. Second, for more rigorous tests of the technology, the number of cooperators was increased to 6 in the rainfed, 15 in the 5-6 month irrigated, 6 in the 7-9 month, and 8 in the 10-month area. The minimum test area in each category was 3 ha. Third, 2 years of research showed that the introduced pattern was superior to both the farmers' patterns and farmers' patterns without constraints; thus only the introduced pattern was tested in the third year. In this pattern the cooperators provided labor and all material inputs (seed, fertilizer, insecticide) were supplied by the researchers.

In the rainfed area, represented by Pangkalan village, six farmers grew the introduced pattern: direct-seeded rice (*gogo rancah*) followed by soybean (Fig. 1).

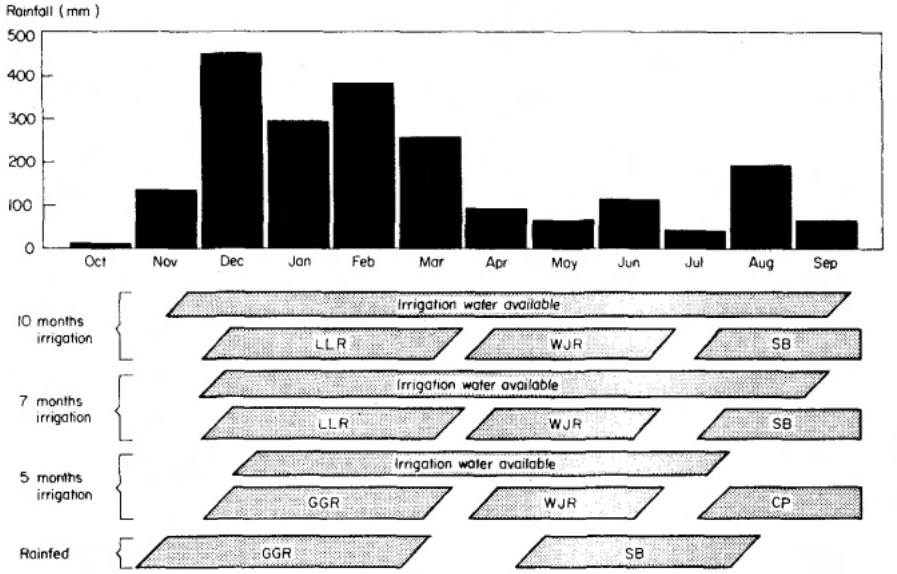
In areas with 5-6 months irrigation represented by Panyindangan Wetan village, 15 cooperators grew the introduced pattern of direct-seeded rice, followed by no-tillage transplanted rice (*walik jerami*), followed by cowpea (Fig. 1).

The area irrigated for 7-9 months was represented by Krusah village. With the increased availability of water, the introduced pattern was transplanted rice—no-tillage transplanted rice — soybean. Six cooperators planted the pattern (Fig. 1). The same pattern was grown by 8 farmers in areas with 10 months irrigation represented by Bangkalan village.

At all sites, farmers kept daily records of production, consumption, and marketing activities. Every 3 days, the village assistant visited each cooperator to check the data and enter the information in a record book.

AGRICULTURAL SETTING

The baseline survey in 1975 provides basic information about farmers in the area (CRIA 1977). Indramayu is an intensively cultivated, extensively irrigated wetland



1. Working calendar of preproduction cropping patterns, Indramayu, West Java, 1977-78. LLR = lowland rice, WJR = no-tillage transplanted rice, GGR = dry-seeded rice, SB = soybean, CP = cowpea.

rice zone. Although 2 rice crops were grown by more than 75% of the sample farmers with 7-10 months of irrigation, only about 30% of the farmers with 5-6 months irrigation planted a second rice crop. Only a small percentage of the respondents practiced direct seeding but more than 75% of those with 10 months and more than 50% of those with 7-9 months irrigation employed the no-tillage system to establish their second rice crop. Almost all respondents applied fertilizer, typically at 150-200 kg urea/ ha. Three-fourths used both pesticides and modern varieties. Rice yields were between 1 and 5 t/ha, but typical yields were 2-4 t/ha.

Weather during the 1977-78 cropping season was extremely unusual. Late rains delayed planting several weeks because irrigation water was supplied by a river diversion dam. When the water came, it was available longer than usual. Heavy rains fell in the normally dry months when the secondary crops were growing. These conditions reduced crop yield for the second rice crop and the secondary crops (Saefuddin and Herman 1979).

CROP MANAGEMENT AND LABOR USE

Areas with 10 months irrigation

In areas with 10 months irrigation, labor requirements (seedbed, land preparation, and transplanting) for establishing the transplanted rice crop were low (86 days/ha) because land preparation by hand (*changkul*) was done after the soil was softened by irrigation water (Table 2). Crop maintenance (weeding, fertilizing, pest control, and water management) also required a minimal amount of labor because good water control reduced weed growth. The relatively high yield (6.9 t/ha) of IR36 required a

Table 2. Total labor input by cropping pattern, crop, operation and source, Indramayu, West Java, Indonesia, 1977-78.

Environment, crop	Labor input[a] (days/ha)																	
	Seed-bed[b]		Land preparation straw cutting[c]		Planting[a]		Weeding		Fertilizing		Pest control[e]		Water management		Harvesting,[f] threshing, and drying		Total	
	F	H	F	H	F	H	F	H	F	H	F	H	F	H	F	H	F	H
Rainfed																		
Direct-seeded	0	0	16	84	22	78	103	91	7	4	0	0	7	0	9	38	164	285
5-6 mo irrigation																		
Direct-seeded	0	0	19	66	6	37	22	62	5	5	1	0	0	0	12	58	65	228
No-tillage transplanted	8	0	9	14	3	16	10	35	5	5	2	0	0	0	8	32	45	102
7-9 mo irrigation																		
Transplanted rice	7	0	20	22	8	33	5	8	1	1	2	0	3	0	6	33	52	97
No-tillage transplanted	6	0	0	21	1	35	0	16	1	4	0	1	3	0	17	34	28	111
10 mo irrigation																		
Transplanted rice	6	0	13	36	3	28	8	20	2	1	1	1	6	0	4	69	43	I55
No-tillage transplanted	5	2	7	20	3	23	11	32	2	3	4	1	0	0	9	54	41	135
Mean	4		50		42		60		7		2		3		54		222	

[a] One day equals 8 hours of work. All activities except seedbed, land preparation, pest control, and water management used also female labor. No exchange labor was used. F = family, H = hired. [b] Includes seedbed preparation and pulling. [c] Only one cooperator used tractor or animal. [d] Includes 30 days for replanting rainfed dry-seeded crop. [e] Insect and rat control. [f] Harvested with a sickle.

rather large harvest and postharvest labor input (73 days/ha).

The second rice crop was established by a no-tillage system. In this system, the stubble is cut near the base of each hill and is trampled into the saturated soil. The seedlings are transplanted between the rows formerly occupied by the first crop. This labor-efficient system uses only about 75% as much labor as that for the first crop (Table 2). Crop maintenance requirements were about 35% greater (53 days/ha) than for the first crop because of greater weed growth, and partly because irrigation water was cut off during the growth stage to combat a brown planthopper invasion. Harvesting by sickle and other postharvest activities required slightly less labor than for the first crop because of low yield (4.9 t/ha) due to extensive stem borer damage and water stress.

The third crop (soybean) was damaged by excessive rainfall on the low-lying field and yields averaged only 462 kg/ha.

Areas with 7-9 months irrigation

The labor requirement for establishing the transplanted crop in areas with 7-9 months irrigation was 90 days/ha (Table 2). Irrigation water softened the soil and made plowing with a hand hoe easy. Weed growth was minimal and crop maintenance required only 20 days/ha. Labor demand for harvesting by sickle and other postharvest activities was low, even though the yield was 7.2 t/ha. Some postharvest labor was probably not recorded.

The second rice crop, established with the no-tillage system, used about 30% less labor than the first crop. Crop maintenance requirements were also low. Sickle harvesting, threshing, and drying required 51 days/ ha, even though stem borer damage reduced the IR36 yield to only 4.6 t/ha.

The third crop of soybean suffered from rainfall and wet soil conditions and yielded only 610 kg/ha.

Areas with 5-6 months irrigation

The first rice crop in areas with 5-6 months irrigation was established by direct seeding. Labor requirements were high (128 days/ ha) (Table 2) because plowing was done before irrigation water had arrived. Rat damage before seed germination made replanting necessary. Crop maintenance requirements were high because weed growth was extensive. Rat and crab damage, low plant population, and flooding caused low yields (3.5 t/ha); nevertheless, labor requirements for sickle harvesting, threshing, and drying requirements were high (70 days/ha).

The second rice crop, planted using the no-tillage system, required only 50 days/ ha for crop establishment (Table 2). The crop maintenance labor input was less (57 days/ha) than for the direct-seeded crop because an adequate water supply suppressed weed growth. The crop yield was only 2.9 t/ha, and labor requirements for sickle harvesting, threshing, and drying were only 40 days/ha. Yield loss was due to severe stem borer and rat damage.

The third crop (cowpea) was completely lost because of excessive rainfall, flooding, and poor drainage.

Rainfed area

Crop establishment requirements for the direct-seeded crop in the rainfed environment were extremely high, averaging 200 days/ ha (Table 2). The soil was very dry when plowing was done, and poor seed germination required extensive resowing of seed. Crop maintenance labor requirements were also high (212 days; ha). Because the seed germinated slowly, weeds are very thick before it was possible to hoe the field. Sickle harvesting and postharvest requirements averaged 47 days/ ha for the 2.8 t/ha IR28 crop. Both flooding and excessive weed growth reduced yields.

The second crop (soybean) was completely lost to unusually heavy rainfall and poor drainage.

Hired labor

Hired labor for wetland rice production in Indramayu ranged from 64 to 80% of the total labor input for the sample farmers.

The data in Tables 3 and 4 support these hypotheses: 1) the greater the total labor input required to complete a field operation, the larger the percentage of hired labor; and 2) the greater the importance of timeliness, the larger the percentage of labor that will be hired.

Hired labor for weeding was generally in proportion to total labor requirements, with two exceptions. Although the rainfed direct-seeded crop absorbed 194 days of weeding labor/ ha, only 47% was hired. Because the farmers realized it would be extremely unprofitable to pay for such a large labor input, they probably mobilized their family labor reserve. On the other hand, even though the 7-9 months irrigated farms used only 16 days/ ha for weeding the no-tillage second crop, 100%, was hired. Because only a minimal total input was needed, the farmers could easily afford to hire all of their requirements. Fertilizing, pest control, and water management all needed only a small labor input, with the hired share averaging only 51, 24, and 0%. Finally, harvesting required a large absolute labor input over a short time interval. Consequently, an average of 73% of this labor was hired.

ECONOMIC EVALUATION

The feasibility of new cropping patterns is largely dependent on their profitability relative to the existing cropping patterns. In this analysis, each crop in each category is first evaluated in terms of gross returns. Cash costs (materials and hired labor) are subtracted from gross returns to determine the cash surplus, which is an estimate of the amount of money the farmer has to spend at the end of the cropping season if he sells his output at the price prevailing at harvest time. Material, hired labor, and total cash costs as a percentage of gross returns are estimated to evaluate the relative cash intensity of the crop. This cropping systems research is primarily directed at subsistence farmers. The subsistence minimum is defined as equal to 240 kg of cleaned rice/person per year. In Java the average farm size is about 0.5 ha/farm family. Hence, each cropping pattern is evaluated in terms of the number of days the pattern would provide a poverty level standard of living if it were planted on a parcel of 0.5 ha.

Table 3. Total human labor input by cropping pattern, crop, and operation. Indramayu, West Java, Indonesia, 1977-78. [a]

Environment	Crop	Total human labor input (%)							
		Seedbed	Land prepara-tion or straw cutting	Planting	Weeding	Fertilizing	Pest control	Warer manage-ment	Harvesting, threshing, drying
Rainfed	Direct-seeded rice	0	22	22	42	2	0	2	10
5-6 mo irrigation	Direct-seeded rice	0	29	15	29	3	0	0	24
	No-tillage transplanted	6	16	13	31	7	1	0	26
7-9 mo irrigation	Transplanted rice	0	23	34	8	1	0	0	34
	No-tillage transplanted	0	19	31	14	4	1	0	31
10 mo irrigation	Transplanted rice	3	25	16	14	2	1	3	36
	No-tillage transplanted	4	15	15	24	3	3	0	36

[a] Source: CRIA, Farm Record Keeping for 6 cooperators in rainfed areas, 15 in areas with 5 months irrigation, 6 in 7 months, and 8 in 10 months.

Table 4. Hired human labor as a percentage of total human labor input by cropping pattern, crop, and operation. Indramayu, West Java, Indonesia. 1977-78.[a]

Environment	Crop	Hired labor as percentage of total human labor input							
		Seedbed[b]	Land preparation or straw cutting	Planting	Weeding	Fertilizing	Pest control	Water management	Harvesting, threshing, drying
Rainfed	Direct-seeded rice	NA	84	78	47	36	0	0	81
5-6 mo irrigation	Direct-seeded rice	NA	78	86	74	50	0	0	83
	No-tillage transplanted	0	61	84	78	50	0	0	78
7-9 mo irrigation	Transplanted rice	0	52	80	62	50	0	0	85
	No-tillage transplanted	0	100	97	100	80	100	0	67
10-mo irrigation	Transplanted rice	0	73	90	71	33	50	0	95
	No-tillage transplanted	29	74	88	74	60	20	0	86
Total		7	75	86	72	51	24	0	82

[a] Source: CRIA, Farm Record Keeping. [b] NA = not applicable.

Finally, to evaluate the attractiveness of farming, compared to off-farm and nonfarm employment, the daily return to family labor, management, and land is estimated. This is a rough approximation of the imputed wage the farmer earns by growing the introduced patterns. Actually, it is an overestimate of returns to labor because the cost of land has not been deducted. Because land cost is difficult to determine, complete analysis is not attempted. Yet, this still provides a useful measure of the relative daily wage-generating capacity of each pattern.

Gross returns

As would be expected, gross returns were highest for the pattern with the highest combined yields, ranging from Rp 178,750 (rainfed) to Rp 817,725 (10 months irrigated) as shown in Table 5.

Material costs

The level of material inputs used in the introduced patterns was high — about Rp 30,000 to Rp 45,000/crop (Table 5). Yet, the rate of fertilizer applied in these patterns was not significantly different from the level typically used in the area. Farm records of 1976-77 for the randomly selected economic cooperators indicated that farmers typically use similar amounts of fertilizer. The same data showed that the cooperators applied substantially less insecticide than that used in the introduced cropping patterns (Table 6 and CRIA 1978).

Material costs must be evaluated in terms of the capacity of the pattern to repay these expenditures. Hence, in the farmers' patterns (Table 7) material costs as a percentage of gross returns averaged 13, 7, and 13% in the 10, 7-9, and 5-6 months irrigated patterns. These figures do not differ greatly from 9, 10, 14, and 17% required to cover material costs for the 1977-78 introduced patterns in the 10, 7-9 and 5-6 months irrigated and rainfed categories (Table 5). Hence, although material costs (fertilizer and insecticide) are greater, the increased yields and a slightly higher rice price make it possible for farmers growing the introduced patterns to easily cover the added costs.

Labor costs

In the introduced patterns, total hired labor costs ranged from Rp 132,472 (rainfed) to Rp 213,813 (10 months irrigated) as shown in Table 8. Among the different crop establishment systems, total labor costs were lowest for the no-tillage system followed by those for the transplanted and direct-seeded crops. Yet harvest costs constituted a significant proportion of total labor costs. Of the preharvest labor costs, expenses were lowest for the transplanted crop because although it used more hired labor than the no-tillage system, wage rates were 10-40% greater in the second season (Table 8).

In the farmers' patterns, total labor costs (Table 7) ranged from Rp 90,181 (7-9 months irrigated) to Rp 161,361 (10 months irrigated), somewhat less than the level used in the introduced patterns. The farmers used significantly less hired labor for their transplanted (Rp 70,048) and no-tillage crops (Rp 58,820) than did the cooperators growing the introduced patterns (Table 5). Part of this difference may be due to lower wages, lower yields, and a lower preharvest labor input during the 1976-77 season.

Table 5. Mean yields, costs, and returns per hectare by environment, cropping pattern, and crop. Indramayu, West Java, Indonesia, 1977-78.[a]

Parameter	Rainfed	5-6 mo irrigation			7-9 mo irrigation			10 mo irrigation		
	Direct-seeded rice	Direct-seeded rice	No-tillage trans-planted	Total	Trans-planted	No-tillage trans-planted	Total	Trans-planted	No-tillage trans-planted	Total
Yield (kg/ha)	2,750	3,451	2,901	6,442	7,195	4,550	11,745	6,915	4,910	11,825
Costs: (Rp/ha)										
Materials[b]	29,517	32,238	29,979	62,217	44,972	37,193	82,165	39,717	36,212	75,989
Hired labor	132,472	108,611	71,373	178,984	105,286	98,375	203,661	111,298	102,515	213,813
Total cash costs[c]	161,989	140,849	101,352	242,201	150,258	135,568	285,826	151,015	138,787	289,802
Returns: (Rp/ha)										
Gross	178,750	230,165	217,575	447,740	467,675	341,250	808,925	449,475	368,250	817,725
Cash surplus[e]	16,761	89,316	116,223	205,539	317,414	205,682	523,099	298,460	229,463	527,923
Gross return relative to[f]										
Material costs (%)	17	14	14	14	10	11	10	9	10	9
Hired labor costs (%)	74	47	33	40	23	29	25	25	28	26
Total cash costs (%)	91	61	47	54	32	40	35	34	38	35
Days of subsistence living[g] (0.5 ha)	24	142	161	303	505	284	789	475	317	792
Returns to family labor, management and land[h] (Rp/day)	102	1,374	2,583	1,869	6,104	7,346	6,539	6,940	5,597	6,285

[a]Source: CRIA, Farm Record Keeping for 6 cooperators in rainfed areas, 15 in areas with 5 months irrigation, 6 in 7 months, and 8 in 10 months. US$1 = Rp 625. [b]Fertilizer, insecticide, and rat poison. [c]Total cash cost = material costs + hired labor. [d] Gross returns = yield × price. The first rice crop was valued at Rp 65/kg and the second crop at Rp 75/kg. [e]Cash surplus = gross returns - total cash costs. [f]Percent = respective cost ÷ gross returns. [g]Sayogyo defines the poverty line in Indonesia to be equivalent to 240 kg of cleared rice (*gabah*)/person per year. Hence, a typical family of 5 persons requires 4.83 kg of paddy (*beras*)/day, assuming a 68% recovery rate. [h]Returns to family labor, management and land = cash surplus ÷ total family labor input.

Table 6. Input use and material costs by cropping pattern and crop. Indramayu, West Java, Indonesia, 1977-78. [a]

Environment	Crop	Seed [b]		Fertilizer [c]				Total cost of insecticide (Rp/ha)	Rat poison (Rp/ha)	Total cost (Rp/ha)
		Quantity (kg/ha)	Total cost (Rp/ha)	Urea (kg/ha)	TSP (kg/ha)	ZK (kg/ha)	Total cost (Rp/ha)			
Rainfed	Direct-seeded rice	70	4,900	133	52	0	12,950	11,667	0	29,517
5-6 mo irrigated	Direct-seeded rice	70	4,900	174	46	0	15,400	11,938	0	32,238
	No-tillage transplanted	30	2,100	245	48	0	21,140	4,641	2,098	29,979
7-9 mo irrigated	Transplanted rice	70	4,900	287	50	50	30,840	9,187	0	44,972
	No-tillage transplanted	30	2,100	279	66	0	24,150	10,943	0	37,193
10 mo irrigated	Transplanted rice	70	4,900	255	52	50	28,740	6,077	0	39,717
	No-tillage transplanted	30	2,100	262	56	0	22,260	11,912	0	36,272

[a] Source: CRIA, Farm Record Keeping for 6 cooperators at rainfed sites, 15 in areas with 5 mo irrigation, 6 with 7 mo, and 8 with 10 mo cooperators. US$1 = Rp 625. [b] IR36 was used for all crops except rainfed direct-seeded rice (IR32). [c] Price of fertilizer is Rp 70/kg for urea and TSP (triple superphosphate) and Rp 145 for ZK (potassium sulfate).

Table 7. Mean yields, costs, and returns per hectare by environment, cropping pattern and crop, Indramayu, West Java, Indonesia, 1976-77 sample of farmers using existing cropping patterns. [a]

Parameter	5-6 mo irrigated			7-9 mo irrigated			10 mo irrigated		
	Trans-planted	No-tillage trans-planted	Total	Trans-planted	No-tillage trans-planted	Total	Trans-planted	No-tillage trans-planted	Total
Yield (kg/ha)	2,260	3,750	6,010	4,850	3,940	8,790	4,850	5,280	10,130
Costs (Rp/ha									
Materials [b]	21,030	17,750	38,780	22,500	10,960	33,460	37,100	36,200	73,300
Hired labor	72,932	62,130	135,062	54,996	35,185	90,181	82,215	76,146	161,361
Total cash costs [c]	93,962	79,880	173,842	77,496	46,145	123,641	119,315	115,346	294,661
Returns (Rp/ha)									
Gross [d]	117,520	251,250	368,770	252,200	263,980	516,180	252,200	353,760	605,960
Cash surplus [e]	23,558	171,370	194,938	174,704	217,835	392,539	132,885	238,414	37 1,299
Gross returns relative to: [f]									
Material costs (%)	18	7	11	9	4	6	15	10	13
Hired labor costs (%)	62	25	37	22	13	17	33	22	21
Total cash costs (%)	80	32	47	31	17	24	48	32	39
Days of subsistence living (0.5 ha)	47	265	312	348	337	685	265	369	634

[a] Source: CRIA, Farm Record Keeping for economic cooperators, 1976-77. US$l = Rp 625. [b] Fertilizer, insecticide, and rat poison. [c] Total cash cost = material costs + hired labor. [d] Gross returns = yield × price. The first rice crop was valued at Rp 52 and the second crop at Rp 67/kg. [e] Cash surplus = gross returns – total cash costs. [f] % = respective cost + gross returns. [g] Sayogyo defines the poverty line in Indonesia to be equivalent to 240 kg of cleared rice (*gabah*)/person per year. Hence, a typical family of 5 persons requires 4.83 kg of paddy (*beras*)/day, assuming a 68% recovery rate.

Table 8. Hired labor costs (Rp/ha) by cropping pattern, crop and operation, Indramayu, West Java, Indonesia, 1977-78.[a]

Operation	Wage rate[b] (Rp/day)	Rainfed		5-6 mo irrigated				7-9 mo irrigated				10 mo irrigated			
		Direct-seeded rice		Direct-seeded rice		No-tillage transplanted		Transplanted rice		No-tillage transplanted		Transplanted rice		No-tillage transplanted	
		MD	TC[c]	MD	TC[c]	MD	TC[c]	MD	TC[c]	MD	TC[c]	MD	TC[c]	MD	TC
Seedbed	465	0	0	0	0	0	0	0	0	0	0	0	0	2	930
Land preparation															
Harrowing	390	0	0	15	5,850	0	0	6	2,340	0	0	11	4,290	0	0
Plowing	480	84	40,320	51	24,480	0	0	16	7,680	0	0	25	12,000	0	0
Straw cutting	560	0	0	0	0	14	7,840	0	0	21	11,760	0	0	20	11,200
Planting	410/560	48	19,680	37	15,170	16	8,960	33	13,530	35	19,600	28	I1,480	23	12,880
Replanting	280	30	8.400	0	0	0	0	0	0	0	0	0	0	0	0
Weeding	360/400	91	32.760	62	22.320	35	14.000	8	2,880	16	6.400	20	7,200	32	12,800
Fertilizing	380/490	4	1.520	5	1,900	5	2.450	1	380	4	1.960	1	380	3	1,470
Pest control	505/540	0	0	0	0	0	0	0	0	1	540	1	505	1	540
Harvesting and threshing	1/6 crop	38	29.792	57	38,361	29	36,263	32	77,946	32	56,875	68	74.9I3	52	61,375
Drying	530/620	0	0	1	530	3	1,860	1	530	2	I,240	1	530	2	1,300
Total		295	132,472	228	108,611	102	71,373	97	105.286	111	98,375	155	I11,298	135	102,515

[a]Source: CRIA, Farm Record Keeping for 6 cooperators in rainfed area, 15 in the 5-mo area, 6 in the 7-mo, and 8 in the 10 mo: MD = man-days (including female labor) and TC= total cost. [b]Average wage paid per 8 hours of work. The wage rate to the left and right of the slanting line are for the first and second crops. US$1 = Rp 625.

Labor costs should also be evaluated in terms of the capacity of the pattern to generate income to cover the hired labor expenses. In the farmers' patterns, hired labor costs as a percent of gross returns averaged 40, 24, 56% in the 10, 7-9, and 5-6 months irrigated categories (Table 7). In contrast, the introduced patterns averaged 26, 40, and 74% in the 10, 7-9, 5-6 months irrigated, and rainfed categories (Table 5). Only the pattern in the rainfed system used relatively more hired labor than the farmers' existing patterns, and the introduced patterns in the 10 and 5-6 months irrigated categories spent relatively less on hired labor.

Cash surplus

The introduced patterns generated the greatest cash surpluses (more than Rp 500,000/ ha) in the 10 and 7-9 months irrigated categories (Table 5). The surplus was only Rp 205,539 in the 5-6 months category, and only Rp 16,761 in the rainfed area. Although the introduced patterns exceeded the 1976-77 farmers' patterns by more than Rp 100,000 in the 10 and 7-9 months irrigated categories, the introduced pattern in the 5-6 months category gave only about Rp 10,000 greater cash surplus (Table 7).

Days of subsistence living

The typical farmer in Java is a subsistence cultivator with about 0.5 ha of land. The introduced patterns in the 10 and 7-9 months irrigated areas generated on 0.5 ha a cash surplus that was equivalent to 26 months of family subsistence income. The patterns in the 5-6 months and rainfed area gave 10 and 1 month of subsistence income (Table 5). In comparison, the farmers' patterns (Table 7) generated an equivalent of 21, 23, and 10 months of subsistence family income in the 10, 7-9, and 5-6 months irrigated areas.

Returns to family labor

Although a large amount of labor is hired, the family still provides 25% of the labor input (Table 2). By farming, the family generates labor income for itself. The value of this imputed wage rate in the 10, 7-9, and 5-6 months categories averaged Rp 6,285, Rp 6,539, and Rp 1,869/day (Table 5), far in excess of the existing wage rates (Table 8). In contrast, the rainfed pattern provided only a return of Rp 102/day to family labor. Because labor input in days was not available for the farmers' 1976-77 patterns, no comparison was made between the introduced and farmers' patterns.

CONCLUSION

The original objective of the Indramayu research was to evaluate the economic feasibility of four introduced cropping patterns, which included management practices that enabled farmers to grow a grain legume crop after rice.

The trial was subjected to intensive climatic and pest pressure. Late rains and a delay in the delivery of irrigation water set back planting from 3 to 8 weeks, depending on the category. The first crop in the 5-6 months irrigated area was damaged by rats, crabs, drought, and flooding. Heavy weed infestation and flooding plagued the rainfed plots. At all sites the second rice crop was severely attacked by

stem borer. Excessive rain in the dry season severely damaged the grain legume crops.

Against this background, the introduced pattern of two rice crops in the 10 months irrigated category performed better than the 1976–77 farmers' pattern in that environment. Although the soybean crop yielded only 0.5 t/ha, the 1976–77 trials indicated that a yield of 460 kg/ ha would cover cash costs. Hence, the grain legume crop was a partial success.

The introduced pattern in the 7-9 months irrigated category also performed better than the farmers' 1976–77 pattern. A small profit was earned from the soybean crop, which averaged 610 kg/ha.

The introduced pattern (2 rice crops) in the 5-6 months irrigated category performed about the same as the farmers' 1976-77 patterns. But all of the investment in materials and hired labor for the cowpea crop were lost. Hence, the pattern cash surplus was reduced from Rp 206,000 to about Rp 125,000.

The rainfed pattern performed poorly. If the cost invested in the soybean crop that failed were considered, the financial loss to the farmers probably reached Rp 60,000.

These results suggest that the 3-crop pattern is appropriate for the 10 and 7-9 months irrigated areas for 3 reasons.

1. It outperformed the farmers' patterns, even under severely adverse conditions.
2. Under more favorable weather conditions, a soybean yield up to 1.5 t/ ha could be achieved, as was obtained in the 1976-77 component technology soybean trial (CRIA 1978).
3. Under drier weather conditions, it would be possible to achieve more effective stem borer control, thereby increasing the yield of the no-tillage rice crop.

In the 5-7 months irrigated area, the 3-crop pattern appears more risky. Researchers observed that because the fields were left fallow during the previous dry season, the soil was especially hard and densely covered with weeds. Once a three-crop system is established, the profitability of the direct-seeded crop will increase because labor costs for land preparation and weed control will fall and yields will increase. Normal weather also will permit better control of stem borers in the second rice crop. Finally, 5 cowpea varieties yielded 0.8 t/ha or more in the 1976-77 component technology trials; it should therefore be possible to produce a profitable cowpea crop under average weather conditions. Yet, these factors taken together suggest that farmers — typically averse to risk — will probably be unwilling to adopt the patterns until it is demonstrated that the three-crop pattern is superior to the farmers' existing pattern.

In the rainfed area, the problems are similar to those in the 5-7 months irrigated sites. Before farmers can be expected to adopt the two-crop pattern, it must be demonstrated that labor requirement for land preparation and weed control can be reduced by double-cropping or some other cultural practice. The viability of a grain legume crop after rice depends on sufficient soil moisture to sustain the crop — but not too much rain — and adequate drainage. Farmers in rainfed areas are generally poorer than cultivators with irrigation and are least able to bear the weight of crop loss. Hence, they will avoid risk and cannot be expected to adopt the two-crop pattern until the technology's superiority is clearly demonstrated.

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Survey of a pilot rice production project in the Philippines

Jose Nicolas, Edwin C. Price, Rizalino T. Dilag, Jr., and L. D. Haws

The main task of the IRRI cropping systems program is to intensify crop production. In the Philippines, IRRI collaborates with government agencies in areas where cropping intensity can possibly be increased. Of the country's 3.5 million ha of rice land, about 47% is rainfed wetland. Yields from these areas average 1.34 t/ha.

In crop year 1974-75, the pilot rice production project KABSAKA (from *Kabusugan sa kaumahan,* meaning abundance on the farm) was launched in Iloilo, a province that has 70% nonirrigable areas. The rice production technology used in KABSAKA, which had been developed in applied research trials in Bulacan Province during the early 1960s, proved that two wetland rice crops and one dryland crop are feasible. The technology involved the direct-seeding of the first rice crop in April or early May, transplanting or wet-seeding of rice in August or September, and planting of an upland crop (UC) in December or January.

The Philippine Council for Agriculture and Resources Research (PCARR), International Rice Research Institute (IRRI), Bureau of Agricultural Extension (BAEx), National Grains Authority (NGA), Area Marketing Corporation (AMC), Bureau of Plant Industry (BPI), Bureau of Soils (BS), Ministry of Agrarian Reform (MAR), Philippine National Bank (PNB), and the local Rural Bank signed a memorandum of agreement November 1976 to work cooperatively on KABSAKA. The growth of the project is seen in Figure 1.

The study reported here focused on assessing the impact of the adoption of a rice - rice cropping pattern in KABSAKA. Specifically, the study aimed to determine:

- the cost and returns of crop production before and after the program;
- the level and extent of component technologies being used by farmers;
- the accrued socioeconomic, infrastructural, and institutional benefits after the program; and
- the constraints presently encountered by farmers in their farming activities.

PROCEDURE AND METHODOLOGY

Nine barangays of Santa Barbara, Iloilo, were evaluated (Fig. 2). KABSAKA-financed farmers were chosen randomly from a list of cooperators. Out of 108

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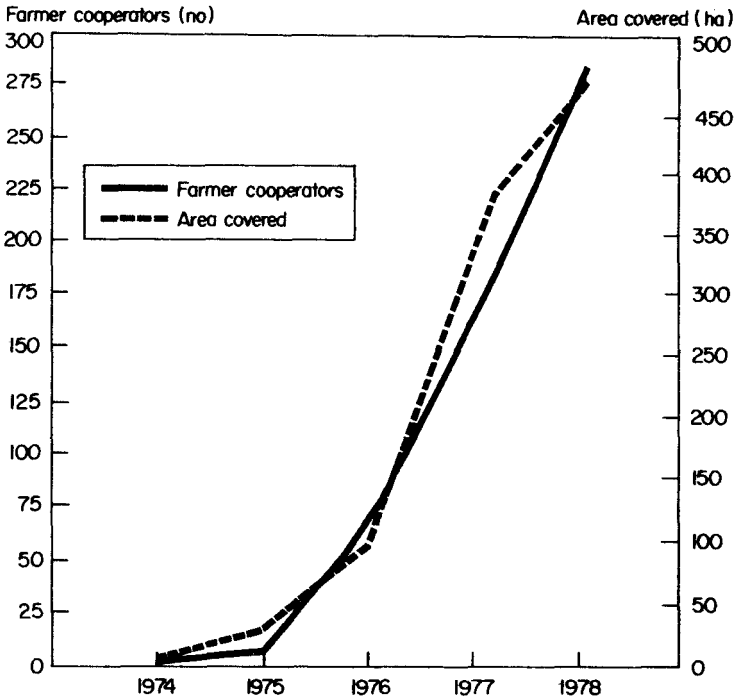
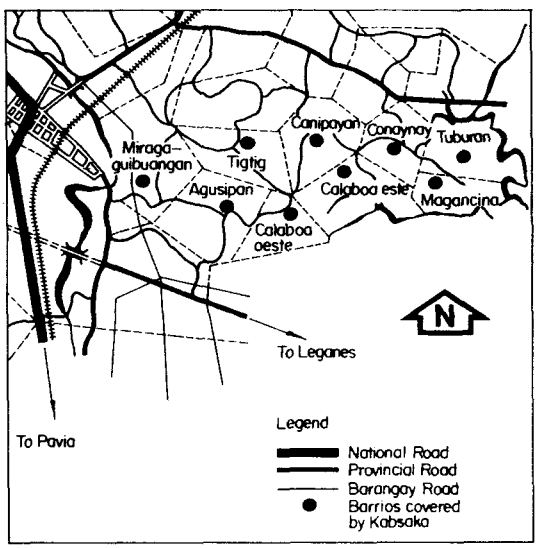


1. Annual increase in number of fanners adopting the new technology and the corresponding increase in area covered, 9 KABSAKA pilot villages, Santa Barbara, Iloilo, Philippines, 1974-78.



2. Location of 9 villages covered by KABSAKA, Santa Barbara, Iloilo, Philippines.

Table 1. Distribution of 30 farmer respondents in 9 villages, Santa Barbara, Iloilo, Philippines, 1978-79.

Village	Farmers (no.)		
	Financed	Self-financed	Total
Agusipan	2	1	3
Miraga-Guibuangan	4	1	5
Tigtig	2	1	3
Calaboa Este	2	1	3
Calaboa Oeste	2[a]	1	3
Tuburan	2	1	3
Conaynay	4	–	4
Canipayan	3[a]	–	3
Mangacina	2	1	3
Total	23	7	30

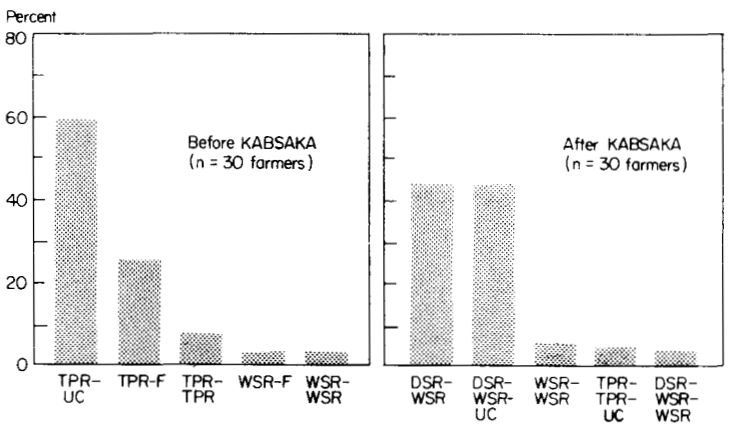
[a]One farmer was financed by a FACOMA (farmers' cooperative), the rest by the Philippine National Bank.

financed farmers, 23 were interviewed. Seven self-financed farmers, purposely selected at one farmer per barrio, were also interviewed. The interviews took place in August 1979. Table 1 shows the sample size distribution in each barangay. In barrios with few financed farmers, a minimum of two financed farmers were taken for statistical purposes.

INDICES OF CHANGE AND ADOPTION OF COMPONENT TECHNOLOGIES

The major farmers' cropping patterns before KABSAKA were transplanted rice (TPR) - UC and TPR - fallow (Fig. 3). A TPR - TPR pattern was practiced by a few farmers whose farms bordered a creek.

Of the 30 farmers interviewed in 1979, 47% completed 2 rice crops and an UC the previous crop year. Because 50% were delayed in polishing the first crop, the



3. Cropping pattern adoption, by type of rice establishment, before and after the start of KABSAKA, Santa Barbara, Iloilo, Philippines, crop year, 1978-79. TPR = transplanted rice, UC = upland crop, F = fallow, WSR = wet-seeded rice.

planting of the second crop was affected. The delay plus insufficient rainfall in October-November allowed completion of only two rice crops.

A TPR - UC pattern, with mostly mungbean as UC, was widely planted before KABSAKA. With KABSAKA, dry-seeded rice (DSR) - wet-seeded rice (WSR) and DSR - WSR - UC became the major patterns (Fig. 4).

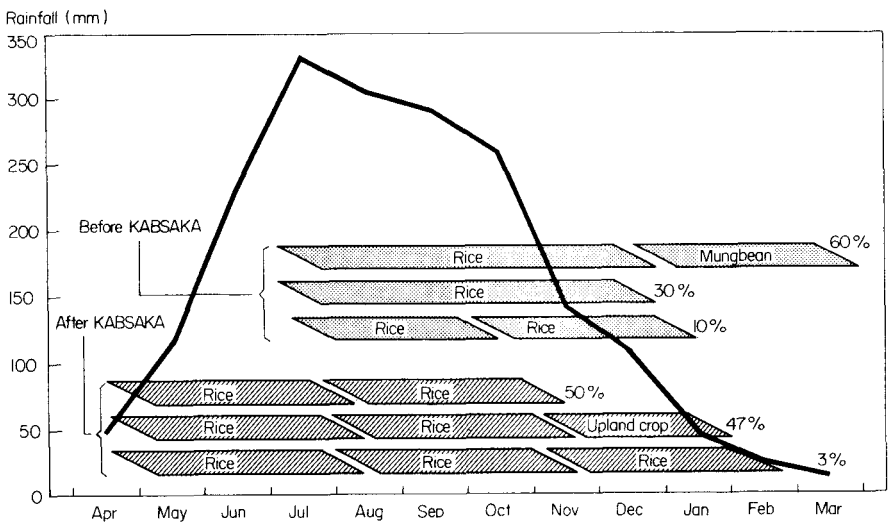
Figure 5 shows the planting and harvest dates of three crops in 1978-79 and the 10-year average monthly rainfall distribution (1969-79). The main third crop was mungbean, which was broadcast-relayed (zero tillage) from early December until the third week of January. Other upland crops planted were cowpea, sweet potato, maize, soybean, peanut, watermelon, sorghum, squash, and eggplant.

Cropping intensity

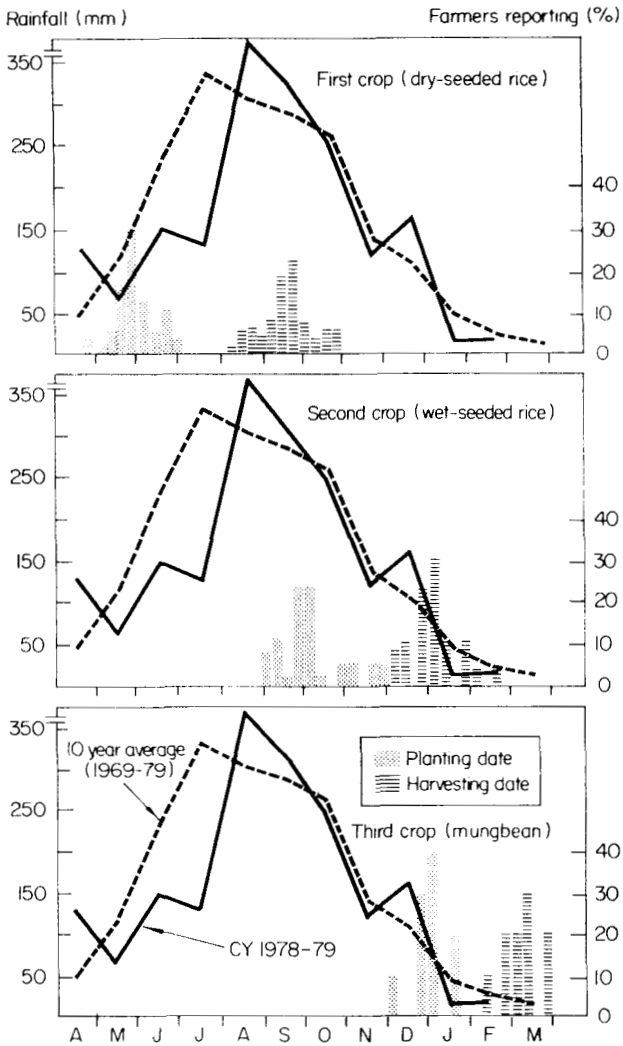
Before KABSAKA, about 30% of the total area cultivated was double-cropped. Upon the implementation of KABSAKA, the cropping index rose to more than 200%. The rate of increase in cropping intensity for all farmers was roughly 60% (Fig. 6).

Varieties used

Before KABSAKA, only 13% of the farmers used modern varieties and the rest used traditional varieties such as BE_3 and Binato. With KABSAKA 100% and 97% of the farmers used modern varieties (IR36) for the first and second crop.



4. Cropping pattern adoption of 30 farmers before and after KABSAKA as plotted against a 10-year (1969-79) average annual rainfall distribution, Santa Barbara, Iloilo, Philippines. The percentages indicate the farmers using the patterns.



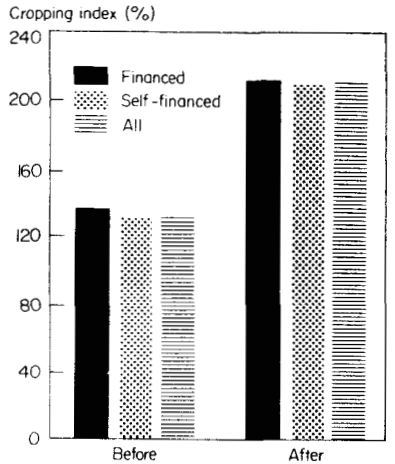
5. Planting and harvesting dates of first and second crops of rice and an upland crop (mungbean) in crop year (CY) 1978-79, and the 10-year average monthly rainfall (1969-79) distribution, Santa Barbara, Iloilo, Philippines.

Seeding rate

The KABSAKA recommended seeding rate for DSR and WSR was between 88 and 110 kg/ ha. Farmers in the study area used 144 kg/ ha for DSR and 138 kg/ ha for WSR. The reason for using more seed was allowance for dead seedlings, birds, insects, and plants uprooted during weeding.

Fertilizer use

The 30 KABSAKA farmers applied fertilizer on the first crop. This is about a 25% increase in the number using fertilizer before KABSAKA. The second rice crop also registered a high percentage of users (90%). The frequency of treatments and amount



6. Cropping intensity for 30 farmers before and after the start of KABSAKA, Santa Barbara, Iloilo, Philippines, 1978-79.

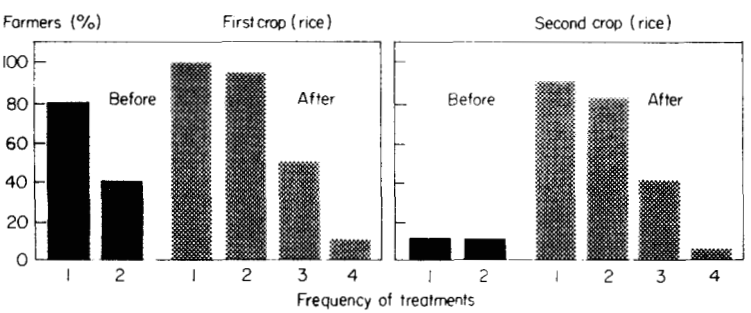
of fertilizer applied on the first and second crops are shown in Figures 7 and 8.

Some deviation from the recommended rate and time of fertilizer application was due mostly to lack of fertilizer to buy; delay in fertilizer delivery, which caused omission of the basal application; and insufficient rainfall during the period when fertilizer should be applied.

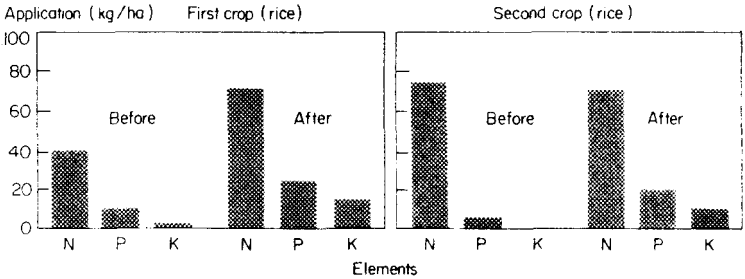
Insecticide use

All KABSAKA farmers used insecticide on the first rice crop — a 30% increase in the number of users — perhaps because they associated good variety and higher yield with a need for proper crop management. On the second crop, 97% applied insecticide.

For UC, more farmers used insecticide on mungbean. All farmers used almost the same amount of insecticide for the first and second rice crops (0.44 and 0.45 kg a.i. /ha), indicating a high degree of insect pest protection. The farmers observed more insect pests on WSR than on DSR.



7. Percentage of farmers applying fertilizer by number of treatments on first and second crops before and after the start of KABSAKA, Santa Barbara, Iloilo, Philippines, 1978-79.



8. Amount of fertilizer elements applied on first and second crops before and after the start of KABSAKA, Santa Barbara, Iloilo, Philippines, 1978-79.

Herbicide use

A high percentage (93%) of KABSAKA farmers applied herbicide on the first rice crop but only 50% did so on the second rice crop. The rest of the farmers saw no need to apply herbicide because of thorough puddling of fields. Financed farmers applied a heavier concentration of preemergence herbicide (1.30 kg a.i. ha) than did the self-financed farmers (0.75 kga.i./ha). Application was 1-5 days after sufficient rain to allow germination of the rice seeds. Five farmers (3 financed and 2 self-financed) used postemergence herbicide at a low rate (0.05 kg a.i./ha). Table 2 gives herbicide use by crop.

Herbicide concentration on the second rice crop was generally low because less weeds were observed in the field. Some farmers reported herbicide burns on seedling leaves. One farmer, who had to choose between insecticide and herbicide, chose insecticide.

Table 2. Amount of herbicide applied on first and second rice crop by KABSAKA farmers, Santa Barbara, Iloilo, Philippines, 1978-79. [a]

Classification of farmers and type of herbicide	Amount (kg a.i./ha)		
	DSR	WSR	TPR
	First crop		
Financed			
Preemergence	1.30 (16)	0.28 (1)	[b]
Postemergence	0.05 (3)	0.59 (1)	–
Self-financed	0.55 (6)	–	
Preemergence	0.75 (4)	–	–
Postemergence	0.05 (2)	–	–
	Second crop		
Financed			
Preemergence		0.80 (3)	–
Postemergence		0.20 (8)	–
Self-financed			
Postemergence		0.11 (4)	–

[a] DSR = dry-seeded rice, WSR = wet-seeded rice, TPR = transplanted rice. Figures in parentheses indicate number of farmers. [b] Applied in seedbed only.

YIELD

For all KABSAKA farmers, average yields were 3.8 t ha for DSR first crop and 2.9 t/ha for the WSR second crop. Four farmers had no yield because of drought in October-November. The yields were compared with those before KABSAKA.

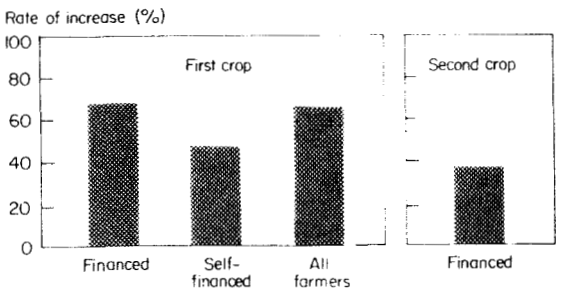
For the first rice crop, and regardless of method of establishment, yields were 67% higher for the financed farmers and 48% for the self-financed, or 65% for all farmers. For the second rice crop, the yield increase was 38% (Fig. 9).

Mungbean yields averaged 0.4 t/ha (Fig. 10). Other upland crops were cowpea, peanut, sweet potato, field maize, sorghum, eggplant, squash, and watermelon.

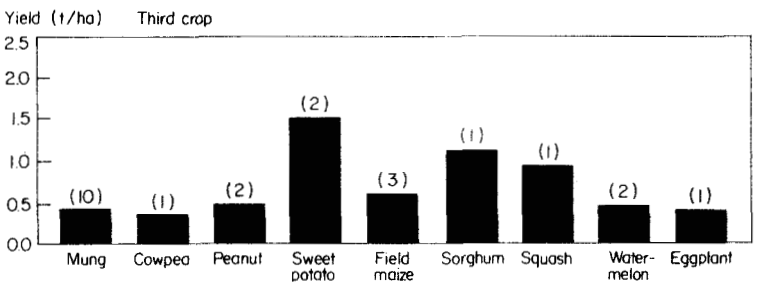
COSTS AND RETURNS

Table 3 shows the costs and returns analysis for 30 KABSAKA farmers. Computation for gross returns and cash material items was based on constant prices for crop year 1978-79. The highest returns over cash materials (₱6,311/ha) were obtained by bank-financed farmers. The self-financed farmers had returns amounting to ₱4,880/ha.

Among financed farmers, the increase in gross returns was 138% higher than that before KABSAKA; that in cash inputs was 115%. The self-financed farmers registered 112 and 84% increase on gross returns and returns on cash inputs. For all



9. Increase in rice yield over previous year (pre-KABSAKA), 30 farmers, Santa Barbara, Iloilo, Philippines, 1978-79.



10. Mean yield of upland crops under KABSAKA, Santa Barbara, Iloilo, Philippines, 1978-79. Numbers in parentheses indicate farmers who planted the crop.

Table 3. Costs and returns[a] analysis of rice and upland crops for 30 KABSAKA farmers, Santa Barbara, Iloilo, Philippines, 1978-79.

Item	Before KABSAKA			KABSAKA			
	First crop[b]	Second crop[c]	Total	First crop[b]	Second crop[c]	Third crop[d]	Total
Gross returns (P/ha)	2,354	931	3,285	3,702	3,039	907	7,648
Material costs (P/ha)	291	125	416	784	612	215	1,671
Seeds	122	113	235	278	263	185	726
Fertilizer	147	9	156	368	326	27	721
Insecticide	20	3	23	66	69	3	138
Weedicide	2	–	2	72	14	–	86
Returns over material costs (P/ha)	2,063	806	2,869	2,918	2,367	692	5,977

[a]₱7.35 = US$1.00. [b]Rice. [c]Rice or mungbean. [d]Upland crops.

farmers, the increase amounted to 133% on gross returns and 108% on net returns over material costs.

The major source of financing was the Philippine National Bank (PNB). A KABSAKA farmer financed by the PNB was entitled to a minimum loan of ₱1,200/ha allocated as follows:

- land preparation ..... ₱280 (cash)
- seeds and fertilizer ..... 534 (in kind)
- herbicide and insecticides ..... 350 (in kind)
- Samahang Nayon (precooperative association) ..... 35 (in kind)

Twenty-one respondents obtained PNB loans amounting to ₱43,800 or ₱2,086/farmer. Two respondents acquired commodity loans totaling ₱14,000. Interest on PNB loans was 12%. As of August 1979, 74% of 23 financed farmers had fully paid, 17% partially paid, and the rest (9%) had not paid.

MARKETING

The number of farmers selling rice increased after the implementation of KABSAKA. The change was more evident for the second crop, which was mostly rice. The rice was either delivered to or picked up by the buyer. An equal percentage of farmers before and after the start of KABSAKA delivered the first crop to the buyers in Santa Barbara and nearby towns (33% each) or had it picked up by the buyers (40 and 47%).

For the second rice crop (KABSAKA), 50% of the farmers delivered rice to Santa Barbara or a nearby town. Only 17% had the rice picked up by the buyers.

In 1978-79, the combined first-crop and second-crop rice marketed by both groups of KABSAKA farmers amounted to 177 t, compared to only 41 t before KABSAKA. Of that quantity, 155 t was supplied by the financed farmers and 22 t by the self-financed. The rice was marketed to private buyers (30%), FACOMA (29%), NGA (26%), and AMC (15%).

Most farmers considered payment of marketing transportation cost a burden. Costs ranged from ₱1.00 to ₱2.50/sack (46 kg).

SOCIOECONOMIC BENEFITS OF KABSAKA

The impact of KABSAKA can be measured from the socioeconomic, institutional, and financial benefits derived from it. Table 4 lists some gains by 23 financed KABSAKA farmers. Socioeconomic benefits derived included increases in farm and household assets, house improvement, and education of children.

Institutional benefits consisted primarily of the technical assistance extended by the BAEx specialist on the use of modern farm technology. Motivation for increased production was attributed largely to the financial assistance extended by PNB and other financing institutions.

Table 5 shows increase in household assets obtained by the financed farmers.

An interesting result of KABSAKA was the farmers' acquisition of farm implements — hand tractors, water pumps, rice mills, threshers, sprayers, plows, harrows, and work animals. The implements noted during the survey excluded those bought before KABSAKA. Eleven farmers (10 financed and 1 self-financed) improved their houses (Table 6).

Another index of change was the pursuit of higher education by farmers' children. Eight financed farmers and six self-financed farmers gained sufficient income to send their children either to college, vocational school, or high school.

A survey of the existing farm power and machinery showed an increasing trend or

Table 4. Socioeconomic changes among households joining KABSAKA as reported by 23 financed farmers, Santa Barbara, Iloilo, Philippines, as of August 1979.

Change	Farmers reporting	
	No.	%
Increased farm assets	17	74
Increased household assets	11	48
House improvement	10	43
Improved education of children	7	30
Payment of debts	4	17
No change	1	4

Table 5. Household assets acquired by financed KABSAKA farmers, Santa Barbara, Iloilo, Philippines, as of August 1979.[a]

Asset	Farmers reporting (no.)	Quantity of item (no.)	Total value (₱)	Av value (₱/farmer)
Television	3	3	7,100	2,367
Stereo	3	3	3.800	1,267
Gas stove	1	1	50	50
Oven	1	1	2,500	2,500
Refrigerator	3	3	6,800	2,267
Motorcycle	1	1	9,300	9,200
Living room set	3	3	1,300	433

[a] ₱7.35 = US$1.00.

Table 6. Farm capital assets and other improvements acquired by financed and self-financed KABSAKA farmers, Santa Barbara, Iloilo, Philippines, as of August 1979.[a]

Capital asset	Farmers reporting (no.)	Quantity of item (no.)	Total value (₱)	Av value (₱/farmer)
Hand tractor[b]	5	5	82,200	16,440
Pump irrigation[c]	4	4	11,200	2,800
Rice mill[a]	1	2	56,000	56,000
Thresher[e]	5	7	35,600	7,120
Sprayer[f]	16	16	4,760	298
Work animal	3	7	12,400	4,133
Plow/harrow	9	14	2,205	245
Livestock for market	2	7	1,700	850
House improvement	11	11	29,740	2,704
Artesian well	2	2	600	300

[a]₱7.35 = US$l.00. [b]4 10-hp tractors, 1 12-hp tractor; excluding 2 farmers who had hand tractors even before KABSAKA. [c]1 10-hp pump, 2 8-hp pumps, 1 4-hp pump; excluding 2 farmers who had pumps even before KABSAKA. [d]The farmer owned 2 rice (cono) mills. [e]2 farmers had 2 threshers each. [f]Excluding 1 farmer who had a sprayer even before KABSAKA.

demand for power tillers and threshers. About 30 hand tractors and 25 threshers provided services to the farmers in the study area. Villages traversed by creeks or a river foresaw the need for water pumps for supplemental irrigation for rice and other crops during drought (Table 7).

ADVANTAGES AND CONSTRAINTS ENCOUNTERED BY FARMERS

Five years after the launching of KABSAKA, farmers using its technology could enjoy things they could not acquire before. The adoption of improved technology (e.g. high-yielding variety, new cropping patterns, fertilizer, insecticide, and herbicide) resulted in a great increase in crop yield and income. Improvement in the levels of farm family living was shown largely by investments in farm and household assets, house improvements, and higher education for children.

Table 7. Farm machinery and power equipment in 9 villages covered by KABSAKA project, Santa Barbara, Iloilo, Philippines, as of August 1979.

Village	Hand tractor, 4.5-15 hp (no.)	Thresher, 7-16 hp (no.)	Water pump, 4–12 hp (no.)
Tigtig	6	5	–
Calaboa Oeste	3	1	1
Calaboa Este	3	3	2
Mangacina	4	6	6
Tuburan	–	–	2
Miraga-Guibuangan	3	2	–
Conaynay	3	–	–
Canipayan	4	4	–
Agusipan	4	4	3

Table 8. Marketing problems encountered by 30 farmer respondents in Santa Barbara, Iloilo, Philippines, 1978-79.

Problem	Financed farmers (%)	Self-financed farmers (%)	Total (%)
Marketing			
Low price for palay	48	71	53
Bad marketing arrangement and red tape	8	–	6
High transport costs	9	–	7
Lack of grain dryer	17	–	13
Lack of transport facilities	17	–	13
Bad roads	8	–	7

Farmers' constraints were mainly economic and infrastructural (Table 8). The farmers commented on the problem of low price (53%), high transport costs (7%), and bad arrangement with buyers (6%) in rice marketing. The low price of rice was primarily due to its poor quality (because of the lack of a dryer), especially during the wet months when farmers had to dispose of wet or fermented rice. A rice dryer large enough to provide services to the farmers especially during the wet months must be considered. The second major problem (33%) was the lack of infrastructural and transport facilities, and the roads that are impassable during the rainy season. There is a need to extend credit to encourage widespread adoption of the modern technology accompanying the program.

ADOPTION OF TECHNOLOGY

Evaluating cropping patterns in a whole-farm framework

J. C. Flinn, S. K. Jayasuriya, and E. Labadan

A characteristic of cropping systems research in the Asian Cropping Systems Network is the design of cropping patterns, then their evaluation in farm environments where the technology is expected to be adopted (Zandstra 1979). Researchers recognize that this procedure is demanding on personnel (both farmers and researchers) and resources (particularly farmland and finances), and also is time-consuming. Experimental practices are therefore continuously scrutinized to increase the likelihood that the ones advanced to subsequent phases of field trials are among the alternatives with the best chance of being used by target groups of farmers. This screening, which becomes more rigorous as data become increasingly available from field trials, may lead to:

- the rejection of a particular cropping pattern or set of management practices;
- technical adjustments (e.g., in varieties, planting dates, or input use) in proposed patterns; or
- the acceptance of a particular pattern and its advancement to the next stage of the process from research to farmer recommendations.

Farmers normally judge new cropping patterns in the context of their total farm household operation. Thus, the agronomic and economic attractiveness of a practice to a particular farmer will be conditioned by his needs, means, and circumstances. Researchers, on the other hand, frequently choose the farmer's field as the unit of analysis because suitable methodologies — both in the conduct of on-farm agronomic trials and in the subsequent economic evaluation and interpretation of the findings — are better developed and more readily available to field workers. Examples of simplified methods of whole-farm analysis developed in the Asian Cropping Systems Network are provided by Banta (1980) and by Price (1980). By those approaches, a limited range of proposed experimental patterns and farmers' patterns can be evaluated with data from field trials and observations of farmer performance and market factors. But analytical procedures to screen a wider range of technologies in a whole-farm context are more complex and usually require computer support. If circumstances permit, prospective technologies should be examined both before and during field trials.

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This paper provides an analysis, within a whole-farm context, of a number of alternatives that may be considered for a new cropping systems site. In part, the potential of crop sequences and associated management practices designed during the initial phase of the research process, before data from field trials become available, are examined. In addition to examining possible innovations in biological technology, two other options are considered: the alternatives of institutional change (in this case, the provision of institutional credit) and infrastructural development (in this case, irrigation).

Zandstra et a1 (1981) have discussed in some detail the evaluation of new cropping patterns from three major viewpoints: agronomic feasibility, economic feasibility (i.e., their fit to farm and community resources), and economic viability or profitability. For our purposes, we expand these dimensions to four and argue that innovations should be judged in relation to their:

- agronomic feasibility,
- level and dependability of profits,
- compatibility with the farming system (i.e., the farm household's needs, means and resources), and
- compatibility with the community's economic and social infrastructure.

A technology that is judged positive on all four criteria has a good chance of being adopted by farmers and should be carried forward in the subset of alternatives being evaluated in the field phase of the research.

The agronomic feasibility of a cropping pattern is bounded by natural-environment factors (e.g., weather, soil type, pest and disease complexes), and judgment during the initial design stage is based largely on the agronomist's knowledge of crops and his interpretation of the environment. But more formal analysis of weather data (e.g., Morris 1980, Virmani 1980) do provide researchers with a more rigorous quantitative base to use when screening cropping patterns.

The levels of profits of proposed cropping patterns are normally evaluated by comparing profitability based on costs and returns analysis, but attempts to evaluate the dependability of profits have been few. The importance of uncertainty (in relation to both yield variability, input, and product market performance) in influencing farmer's decisions to adopt innovations has long been recognized (e.g., Rogers. 1962, Wharton 1969), but often inadequately incorporated in the evaluation process. Indeed, when a new cropping systems site is being established, participants in the research often have limited impressions of the yield or profit distributions of existing practices, let alone of proposed ones. [1] For this reason, the stability of the proposed practices in this paper is judged by sensitivity analysis as opposed to incorporation of risk parameters in the model.

Budgeting out a large number of possible cropping pattern alternatives then screening them within a whole farm framework is tedious unless a formalized approach is available. Budgeting also suffers from the limitation that the real (i.e.,

[1] The authors have derived farmer estimates of the yield variability of existing cropping patterns using triangular distributions as suggested by Anderson et al (1977). If yield as opposed to price variability is regarded as the main cause of profit variability, then the agronomists' analysis of weather and soil data provides a basis for approximating production variability by landscape position.

opportunity) cost of resources to a given farmer may deviate from market prices (Barlow et al 1979). Whole-farm analysis via linear programming circumvents this valuation problem, and also allows assessment in a whole-farm framework of the relevance of a cropping pattern innovation or other changes in the farmer's environment.[2] This approach, of course, is not without its shortcomings, which in particular relate to the model usually being based on assumed certainty, the single valued nature of the objective function being maximized (or in some cases minimized), and the fact that at the margin, resource supplies and input use are somewhat flexible as opposed to fixed (Palmer-Jones 1977, Stent 1977).

Although the issue of evaluating the applicability of innovations as determined by socioeconomic infrastructure (e.g., markets, input supplies, credit, extension services, government policies, social norms) is beyond the scope of this paper, programming models of representative farms provide the analyst the opportunity to examine how sensitive farm plans (including the proposed technology) are to these exogenous socioeconomic variables.

THE RESEARCH SITE

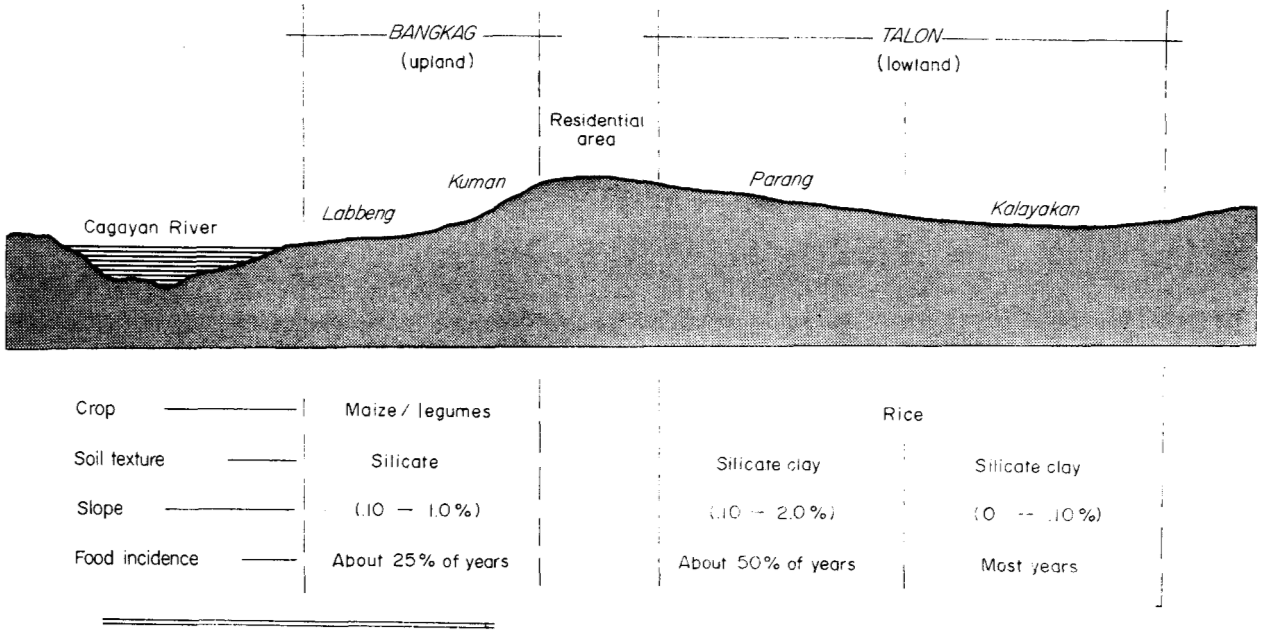
The Cagayan Integrated Agricultural Development Project (CIADP)/IRRI outreach site is north of Solana on the floodplain and terraces of the Cagayan River in northeastern Luzon (Gines et al 1980). Farmers recognize three major landscape typologies, which are distinguished largely by hydrological differences (Fig, 1). Farmers refer to the rice lands as the *talon.* The lowest portion of the talon (and as a result the most flood prone) is the *kalayakan,* and the slightly higher elevations are the *parang.* Farmers identify the upper and lower elevations of the maize-dominated upland as the *bangkag kuman* and *bangkag labbeng.* The lowest terrace of the landscape bordering the Cagayan River is referred to as *labbeng* and *kimoy.* This extremely flood-prone area occurs only to a limited extent in the cropping systems site.

The site has a short dry season (December to April) and is wet the rest of the year. Floods, which generally occur between September and November, together with the interaction of soil type, landscape position, and rainfall, influence cropping patterns feasible from an agronomic viewpoint (Fig. 2).

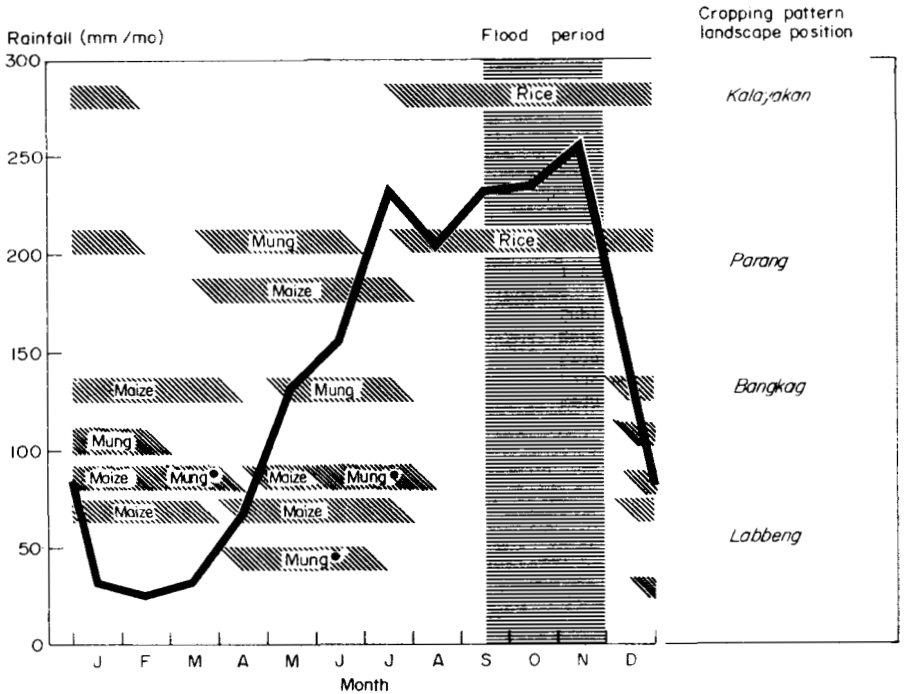
Farmers at the site have adopted few modern innovations. The dominant rice varieties — *wagwag pino* and *wagwag tawataw* — are local low-yielding, long-strawed, photoperiod-sensitive varieties with two particularly valuable characteristics, ability to withstand drought in the seedling stage (particularly *tawataw*) and floods in the vegetative stage (particularly *pino*). Maize and mungbean varieties grown are likewise local. Tillage and transport are by carabao (water buffalo); minimal quantities of agrochemicals are used.

The data for the farm planning model reported were collected during four visits to the site. In addition to data reported by Gonzaga and Price (1980) using the

[2] Hardaker (1979) reviews quantitative techniques for small-farm analysis. Young and Rickards (1978) provide an excellent summary of linear programming and its application to the analysis of small farms.



1. Schematic representation of landscape at the cropping systems site, Cagayan Valley, Philippines.



2. Rainfall distribution (Tuguegarao) and dominant cropping patterns (including land preparation and harvest times) at Cagayan Valley cropping systems site, Philippines. ● = mung or peanut.

Cropping Systems "Survey for Design" (IRRI 1977), information on farmer's means and circumstances that may influence cropping patterns' particular relevance to him was collected (CIMMYT 1980). The initial visit was for reconnaissance purposes, the second focused on data collection, and the last two were to check specific information and to discuss proposed cropping patterns with farmers and IRRI site researchers.

Some characteristics of farm households at the site are summarized in Table 1. Although family size was in the order of 6 persons, the effective family labor supply was generally 2.0 to 2.5 persons. Hired labor normally transplanted the rice crop (cash payment) and harvested all crops (payment was normally based on harvesters' shares). Animal power was not regarded as a major constraint because the farms were generally small and because most farmers owned two working carabaos (one may be young, without full working capacity). Thus, while hired labor may be used to assist in land preparation, carabaos were less frequently hired. The exceptions were the poorer farmers who had none or only one animal, and the richer farmers whose farms required considerable quantities of hired labor and power.

Exchange of labor (farmer plus carabao) was practiced to a limited extent to complete land preparation in a short period of time. Farmers believed that if substantial increases in the demand for animal power occurred, there would be an increased shift toward hired labor and animal power and a reduction in traditional exchange relationships.

Table 1. Characteristics of farm households, Cagayan Valley Cropping Systems site, Philippines. [a]

	Unit	Typical value
Family size	persons	6
Full-time farming	persons	2.5
Age of operator	yr	43
Schooling of operator	yr	3
Farm size	ha	3
Talon-kalayakan	ha	0.5
Talon-parang	ha	1
Bangkag - upper	ha	1
lower	ha	0.5
Working animals (carabao)		2
Net crop yields [b]	t/ ha	
Talon rice		0.4-0.7
mung		0.1-0.2
Bangkag maize		0.5-0.8
mung		0.1-0.2
peanut		0.3-0.5
Labbeng maize		0.4-0.8
mung		0.1-0.2

[a] Source: Gonzaga and Price (1980) and survey by authors. [b] The yield ranges represent yields at different times of the year, and are net after harvesters' and owners' shares are deducted.

Average farm size was 3 ha, and most farmers were share-tenants or part owners of their land. The dominant characteristics of the site were low crop yields, low levels of purchased inputs, and low cash-flow situations. Most farmers lamented that after they had met their basic household expenses, they had little cash surplus and had to borrow money at high interest rates to finance their farm operations.

THE FARM PLANNING MODEL

The linear programming model in the present analysis has three components:

1. an objective function, that is, the goal which the farmer seeks to attain;
2. a set of alternative activities, e.g., crop and livestock production; and
3. a set of restraints, e.g., land, labor, and power availability.

Although it is recognized that farm households have a multiplicity of goals, the linear programming formulation of the farm requires that a single objective function be specified. [3] The objective function specified in the model was to maximize cash income from the farm after subsistence food and cash required for the family had been met. Minimum levels of food consumption and cash for family needs were built into the constraint set as activities that had to be met by the farm business before the desire to earn as much money as possible becomes the operational objective.

The activities and constraints included in the programming model are gleaned from Figure 3. Production activities included livestock (that is, the farmer's cara-

[3] Multiple objectives can be approximated in linear programming using the chance-constraint formulation proposed by Charnes and Cooper (1961). Multiple-objective models (linear goal programming provides an example) have also been applied with limited success to resource allocation problems of small farmers (Flinn et al 1980).

RESTRAINTS OR RESOURCES	ACTIVITIES								
	Livestock	Crop activities		Hired resources		Sales	Cash flows /loans	Food/feed transfers	Consumption
		Existing	Proposed	Labor	Power				
Kalayakan Parang Bangkag – Upper – Lower		(+)	(+)						
Labor (15-day periods)		(+)	(+)	(–)					
Power/carabao (15-day periods)	(–)	(+)	(+)		(–)				
Crop Pools		(–)	(–)			(+)		(+/–)	(+)
Feed pools	(+)	(–)	(–)					(+/–)	
Cash flows	(+)	(+/–)	(+/–)	(+)	(+)	(–)	(+/–)		
Food Consumption									(+)
Irrigation (proposed)			(+)						

3. Characteristics of LP model of small farm. (+) indicates the activity uses a resource, (–) Indicates the activity contributes to level of resource.

bao), the farmer's existing cropping alternatives, and vectors of proposed cropping activities (the new crop or institutional technology being evaluated). Important intermediate activities included the hiring of labor and power, crop sales, credit transaction, consumption, and activities which enabled cash, food and feed to be transferred between periods within the year's planning horizon. The important restraints were land (4 classes), the farmer's labor and power bases, his cash flow and household cash requirements, and minimum levels of food consumption.

The cash requirements for subsistence (over and above farm-produced food) was set at ₱1,000 a year. The family's dietary needs (assuming 6 persons) was based on 2,000 calories/ head daily, 60% of which was met from farm-produced maize, rice, or mung (NEDA 1979, FAO 1972). A maximum food intake constraint (0.75 kg/person daily for farm-produced food) was included to prevent the possibility of the solution selecting large quantities of low-protein and low-energy foods which, if consumed in sufficiently large quantities, would satisfy the basic food requirements. In addition to food for humans, crop stubble (maize and rice) was required to provide half the feed requirements for the carabao.[4] The feed value of the stover and the animal feed requirements were those proposed for use by FAO (Young and Rickards 1978).

CURRENT FARM PLAN

The farm plan for a tenant using existing technology and the resource base as specified in Table 1 is in Table 2. The interest charged on borrowed cash was 100%, which reflects the cost of borrowing money in the area. Solutions were also obtained for 50% and 150% interest. Farm plans did not change materially at the lower interest rate, but at the higher interest rate, maize - mung replaced maize - peanut as the early crop in the upper *bangkag.*

The calculated plan identified, not surprisingly, an optimal cropping pattern similar to what is now practiced (Fig. 2). Rice was grown on the *talon* land; maize, mung, and maize intercropped with peanut were on the upland *bangkag* soils. The farm family met its basic calorific requirements with rice, maize, and mungbean.[5] The important difference between the calculated farm plan and actual practices is that few farmers plant all the *bangkag kuman* to maize-peanut intercrop. Farmers typically plant a portion of that land to maize-mung intercrop, and a portion to maize-peanut intercrop. In the model, peanut was the dominant legume (particularly for November-December planting) because it had a higher gross margin than mung. At that time, farmers were generally short of cash. Hence, the model failed to reflect actual practices because it did not capture the critical scarcity of cash that constrains farmers from buying peanut seed (which is also in limited supply) at that time of the year.

Cash inputs to the farming system (principally to hire transplanters and to buy peanut seed) were estimated to be ₱800, ₱730 of which was borrowed. Repayment

[4] This constraint was largely subjective, based on discussion with a few farmers, and in reality was not an effective constraint in the model. But if crop intensification did occur in the area and grazing lands were reduced, feed supply for carabao may become an important management factor.

[5] The diet also provided 55 kg protein/year, roughly 50% of the family requirements.

Table 2. Farm plan estimated as optimal from the linear programming model of a tenant-farmer using current technology, Cagayan Cropping Systems site, Philippines.

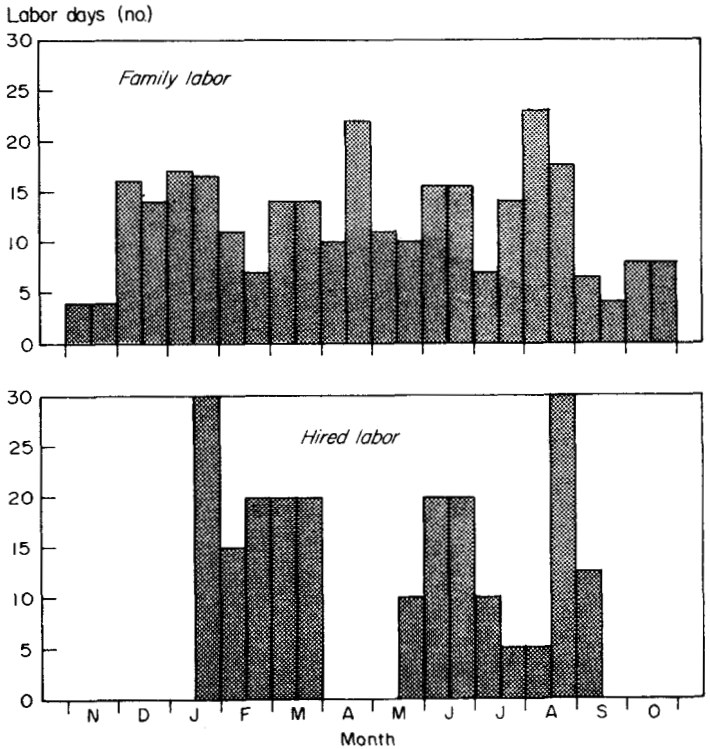
Land use	*Crop*	*Area (ha)*	*Growing season*
Kalayakan	Rice	0.50	Aug-Jan
Parang	Rice	1.0	Aug-Jan
	Mung	1.0	Apr-Jul
Bangkag kuman	Maize/peanut	1.0	Nov-Feb
	Maize/peanut	1.0	Apr-Aug
Bangkag labbeng	Mung	0.5	Jan-Mar
	Maize	0.5	May-Aug
Other reserve flows	*Requirement*		
Hire transplanters	42.5 days		
Food supply: energy	3300 K cal/yr		
Food supply: protein	55 kg/yr		
Cash flows	*₱/yr*		
Family living expenses	1000		
Family investment in farm	70		
Cash borrowed	730		
Cash repayment	1460		
Carabao (annual cost × 2)	334		
Cash surplus	348		
Scarce resources	*Unit*	*MVP* [a]	
Kalayakan	1 ha	201	
Parang	1 ha	1003	
Bangkag kuman	1 ha	2066	
Bangkag labbeng	1 ha	1533	

[a] The marginal value product (MVP) represents the value for 1 yr for a farmer with access to an extra hectare of the given landscape position.

was at 100% interest. There was also a cash cost of ₱167 a year, to reflect the cost of owning a carabao. The calculated cash "surplus" available to the farm family was ₱1,348, of which ₱1,000 (i.e. $40/ head per year) was allocated to subsistence cash requirements. Thus, the estimated surplus over and above assumed subsistence needs was ₱348. The effective constraint identified by the model was the farmer's land base as opposed to labor, draft power, or animal feed. The shadow prices of land generated by the linear programming solution show that the *bangkag* and *parang* were more valuable to the farmer than the *kalayakan;* the land the farmer could double-crop was more productive than the single-cropped land.

The implied distribution of family labor use over the year is shown in Figure 4. A peak demand for labor for land preparation and transplanting the upland crops occurs from late November through early February; a second peak occurs in April when the second-season upland crops are planted; a third peak in late July through August indicates preparation of rice lands and harvest of the second season upland crops. Hired labor follows a somewhat similar pattern. A first peak occurs in late January through early February at harvest of the rice crop; by February-March the early planted crops on the *bangkag* are ready to harvest. Through late May to early July the mung crop is harvested. The peak in labor use in late August and early September is to transplant the rice crop.

The contributions of the various crops to gross cash income of the estimated farm plan are listed in Table 3. The most important source of cash income is the sale of



4. Family and hired labor use for existing farm plan, Cagayan outreach site, Philippines.

peanut and mungbean. Because all the peanut crop is sold — as is most of the mungbean — cash income is very sensitive to the yields assumed for this crop in the farm planning model.

EVALUATING TECHNOLOGICAL ALTERNATIVES

The analysis considered three classes of innovations as options for the site:

- alternative cropping patterns and technology,
- institutional credit, and
- irrigation deliveries to the *parang.*

The innovations represent rather different options for increasing agricultural productivity and farmer incomes. The first involves the design of agricultural technology specifically suited to the farmers' resource base and the rainfed conditions at the site. The second represents a change in the institutional structure in the area. In the third, a modern rice technology now used by farmers elsewhere in the valley could be adopted at the site after substantial public investment in irrigation.

In incorporation of proposed technology vectors in farm models, two points are critical:

- What are reasonable levels of inputs and yields in simulating the "new" technology?

Table 3. Contributions of crops to gross farm income, Cagayan Cropping Systems site, Philippines.

Crop[a]	Landscape position	Production		Area (ha)	Net farm production (kg/ha)	Consumption[c] (kg)	Sales (kg)	Value (₱/kg)	Gross value	
		Gross (kg/ha)	Net[b] (kg/ha)						₱	%
Rice	*Parang*	1320	684	1.0	685	271	499	0.90	449	14
	Kalayakan	1100	551	0.5	275					
Maize	*Bangkag labbeng*	1400	801	0.5	400	632	603	0.85	513	16
Maize (peanut)	*Bangkag kuman*	700	387	1.0	387					
Maize (peanut)	*Bangkag kuman*	910	511	1.0	511					
Mung	*Parang*	275	139	1.0	139	30	180	5.00	900	28
Mung	*Bangkag labbeng*	300	141	0.5	70					
Peanut (maize)	*Bangkag kuman*	405	216	1.0	216	0	541I	2.50	1353	42
Peanut (maize)	*Bangkag kuman*	610	325	1.0	325					
Gross farm production									3215	

[a]The crop in parentheses is an intercrop. [b]Net yield to the farm operator is less than gross yield because harvester' and landlords' shares are deducted. [c]Because of milling losses, seed retention for planting, storage losses, etc., net farm production of rice and maize exceeds consumption plus sales. In the model, seed was retained from the previous harvest, except for peanut.

- What portion of the farm family's added income from the new technology may be used to help finance the cost of additional inputs?

The assumed resource requirements and yields of the proposed technologies were those identified during the Cropping Systems Programs design meetings (Gines and Torres 1980). In general, the researcher's expected yields are substantially higher than what farmers are achieving locally or elsewhere under comparable conditions. These yield expectations are obviously tentative and provide the researchers with estimates *before* the crops are planted. Clearly, as more information about the site (which will include the yields realized from the test patterns and the farmers' patterns) is collected, the structure and data included in the model should be updated.

Farmers generally use lower levels of inputs than are typically recommended (IRRI 1979). For this reason, the researcher's technology was defined as the high-input technology, and a lower-input technology between the researcher's and the farmer's levels of cash inputs was specified (Fig. 5). The associated yields for this intermediate technology were arrived at after discussions with researchers and farmers at the site. Each crop or planting date option was thus described by a production function with three levels of cash intensity. The proposed technology vectors were so constructed that a cash input and resulting output between adjacent comer points was feasible and incorporated in the optimal solution as a linear combination of the two comer points.

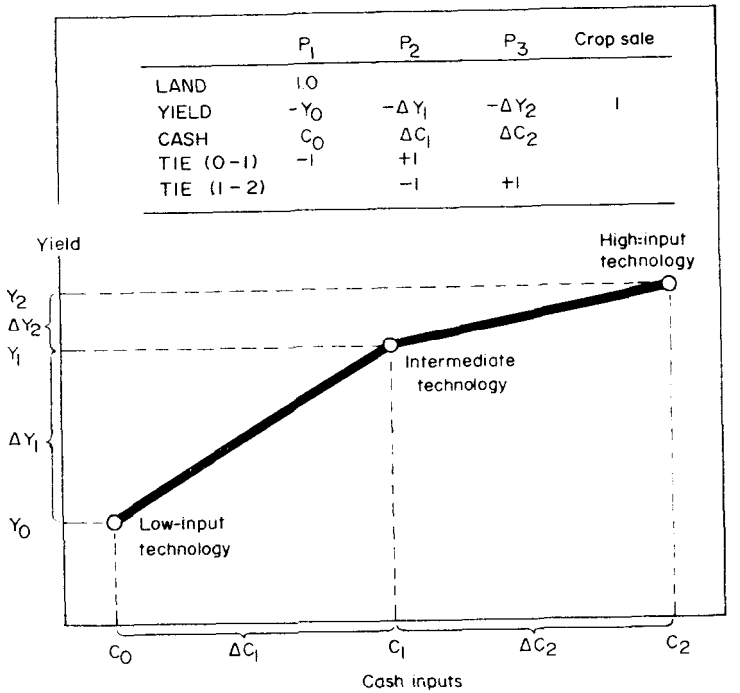
Tenant-farmers claim that after meeting priority household expenses, their cash surpluses to invest in farming are minimal. As a result, they are obliged to use the high-cost "informal" money market to finance their farming operations. But as incomes increase, the issue is what proportion of this added income will be reinvested in the farm. Many studies (for a review, see Clark and Haswell 1970) show that often, less than 20% of incremental income of the poorest farm households is reinvested in the farm. In a study of the somewhat more prosperous farmers at IRRI cropping systems sites at Batangas, Iloilo, and Pangasinan, Agcaoili (1980) found the proportion to be in the order of 25-30%. Because of the low cash surplus situation of the Solana farmers, 20% was used.

PROFITABILITY OF PROPOSED CROPPING PATTERNS

Farm plans using researchers' yield expectation

The proposed cropping patterns for the intermediate and high-cash input situations were incorporated in the linear programming model together with the existing technology. An initial solution was obtained with a limit on borrowed cash of ₱730 to provide a comparison with the current farm plan. The calculated farm plans for a farmer with the choice of existing and proposed technology are in Table 4.

The farm plan incorporating the proposed technology, but with borrowed cash restricted to current levels, suggests that a somewhat different farm plan from what is now practiced would be profitable. In the plan, much of the *parang,* and all of the *kalayakan* are left idle during the flood-prone late wet season, and the multiple cropping index falls from a current 1.8 to 1.4. The reason for this unrealistic result is that with the new technology and limited cash supplies, cash is comparatively more



5. Assumed production function for crops included in farm planning model. Cagayan outreach site, Philippines.

limiting than land per se. Thus, the plan reported in Table 4 maximizes returns to borrowed cash as opposed to land, and the least productive (on a per-peso investment basis) aspects of the landscape are left idle.

If the proposed crop technology were indeed profitable, then it would likewise be attractive for the farmer to borrow more operating funds than is now the case. Thus, a set of related linear programming solutions were obtained to the point where cash (at 100% interest rate) was no longer an effective constraint (Fig. 6). As the supply of borrowed cash increases, profit increases at a decreasing rate to a maximum of about ₱4,500 when ₱1,520 is borrowed. As profits increase, family investment in the farm also increases — at the limit set by the 0.2 marginal propensity to invest. The early increments in income are derived from mungbean sales and, later, from expansion of modern rice (grown using intermediate technology) to the previously vacant *talon* in the period August to January.

The derived cropping patterns as the cash constraint was parameterized are listed in Table 5. If cash is limiting, the most attractive new technology appears to be mungbean and, to a lesser extent, dry-seeded rice grown in the early wet season. As the cash constraint becomes less restrictive, modern rice grown under the more adverse flood conditions enters the optimal plan, first in the *parang,* and lastly in the *kalayakan.* If the proposed technologies as characterized by the model were available to farmers, access to credit (in this case from noninstitutional sources) would

Table 4. Existing farm plan and plan with "new" technology for tenant-farmers at Cagayan outreach site, Philippines.

	Current technology			Proposed technology [a]			
Land use	*Crop*	*Area (ha)*	*Season*	*Crop*	*Type*	*Area (ha)*	*Season*
Kalayakan	Rice	0.5	Aug-Jan				
Parang	Rice	1.0	Aug-Jan	Rice	I	0.50	May-Aug
	Mung	1.0	Apr-Jul	Rice	C	0.08	Jul-Jan
				Rice	I	0.14	Aug-Jan
				Mung	I	1.00	Mar-May
Bangkag kuman	Maize-peanut intercrop	1.0	Nov-Feb	Maize		0.11	Nov-Feb
				Mung	H	0.89	Nov-Feb
					I		
	Maize-peanut intercrop	1.0	Apr-Aug	Mung	H	1.00	Apr-Jul
Bangkag labbeng	Mung	0.5	Jan-Mar	Mung	C	0.02	Jan-Mar
	Maize	0.5	May-Aug	Mung	H	0.05	Dec-Feb
				Maize	C	0.50	Apr-Jul
Cash flows							
Farm living expenses (₱/yr)		l000			l000		
Farm investment (₱/yr)		70			729		
Cash borrowed (₱/yr)		730			730		
Cash surplus (₱/yr)		348			3645		
Multiple cropping index		1.83			I.43		

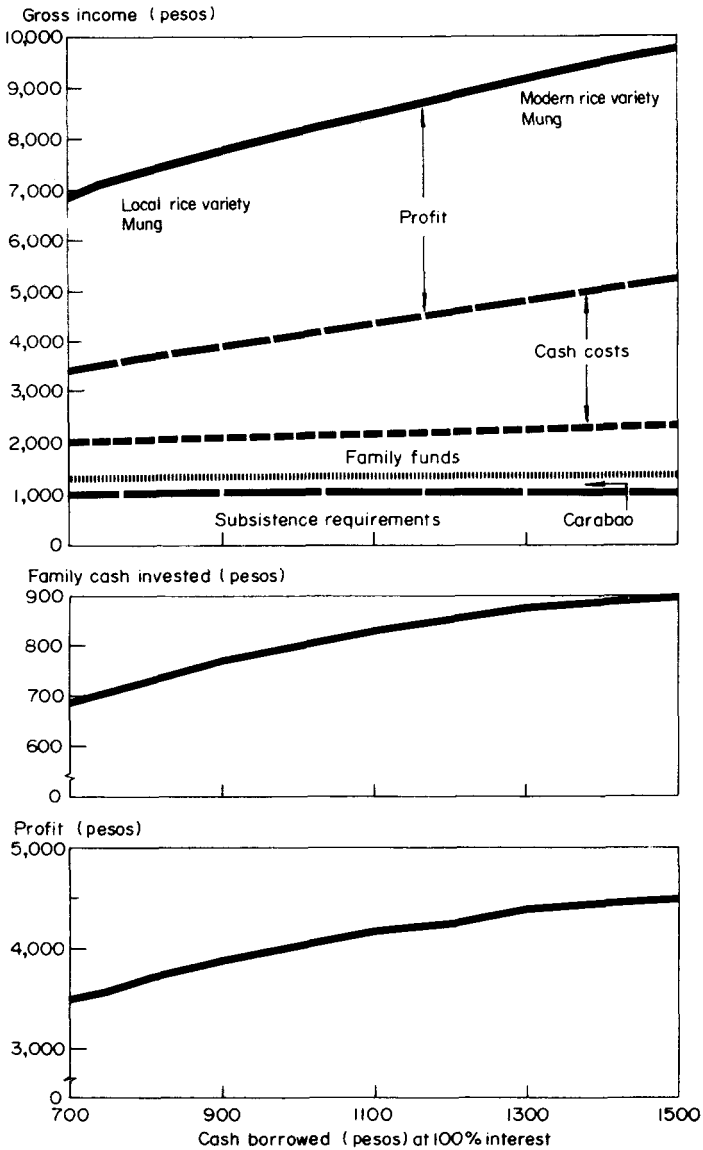
[a] Technology type may be current (C), intermediate (I), or high (H).

influence the ability of the farmer to financially benefit from the technology (the upper curve of Fig. 7). But although the return from extra credit is substantial in the range of ₱500-600 a year, the incremental benefit to the use of credit is small after ₱700-800. The increases in farm income were dramatic — in the order of ₱2,000 as borrowing increases in the range from ₱500 to ₱700 — because most of the credit is used to produce mungbean with the assumed high-level technology. Because this crop is sold (assumed gross yield of 0.9 t/ha at ₱5/kg), cash farm income is extremely responsive to the area planted. With existing technology, extra credit gives little scope to increase farm profits — provided a threshold of some ₱500-550 is available to the tenant-farmers.

Mungbean yields

As shown in Table 5, mungbean dominates cash income and approaches 1.6 t of total sales. Experience elsewhere suggests it would be unlikely for farmers to achieve the predicted yields under high technology (up to a gross of 0.9 t/ha); if these yields could be achieved, then the increased supply would probably depress the market price of mung. Thus, mungbean yields were reduced by 25% and 50% (input levels being held constant) to examine the sensitivity of the optimal plan to reduced productivity of this crop.

The optimal plans for new technology (with mungbean yields reduced by 25%) for a range of borrowed funds are in Table 6 and in Figure 7). At the lowest level of cash



6. Gross and net farm income as related to credit from informal sources.

constraint, reducing mung yields by 25% reduces the cash surplus from ₱3,437 to ₱704; when cash is not limiting (at 100% interest) calculated profits are reduced by about 75% from ₱8,025 to ₱2,029. Clearly, the farm plan and farm profits are extremely sensitive to the anticipated yields of mungbean.

At the lower levels of credit and with the reduced mung yields, the revised farm plan retains some mung grown under intermediate technology (in the *parang* and

Table 5. Optimal cropping patterns related to the availability of borrowed funds.[a] Cagayan outreach site, Philippines.

	Tech-nology[b]	Growing season		Level of borrowed funds							
		From	To	₱700	₱743	₱790	₱900	₱1,098	₱1,211	₱1,322	₱1,520
Landscape and crop				Area (ha)							
Kalayakan											
Rice (IR42)	I	Sep	Jan	–	–	–	–	–	–	–	0.50
Parang											
Rice (Tawataw)	C	Jul	Jan	0.08	0.08	0.08	0.86	–	–	–	–
Rice (IR42)	I	Aug	Jan	0.14	0.14	0.14	0.14	1.00	1.00	1.00	1.00
Mung	I	Mar	May	1.00	1.00	1.00	1.00	1.00	–	–	–
Mung	H	Mar	May	–	–	–	–	–	1.00	1.00	1.00
Rice (DSR, IR36)	I	May	Aug	0.50	0.50	0.50	0.50	0.50	0.50	0.50	–
Bangkag kuman											
Mung	I	Nov	Jan	0.89	0.89	0.89	0.89	0.89	0.89	–	–
Mung	H	Nov	Jan	–	–	–	–	–	–	0.89	0.89
Maize	H	Nov	Feb	0.11	0.11	0.11	0.11	0.11	0.11	0.1I	0.11
Mung	H	Apr	Jul	0.56	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bangkag labbeng											
Mung	C	Jan	Mar	0.02	0.02	0.02	–	–	–	–	–
Mung	I	Dec	Feb	0.48	0.48	–	–	–	–	–	–
Mung	H	Dec	Feb	–	–	0.48	0.50	0.50	0.50	0.50	0.50
Maize	C	Apr	Jul	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Multiple cropping index				1.43	1.57	1.57	1.83	1.83	1.83	1.83	1.83
Cropping intensity index[c]				0.42	0.47	0.47	0.65	0.63	0.63	0.63	0.6I
Profit (₱/yr)				3,437	3,545	3,652	3,875	4, I38	4.295	4,389	4,495
Family cash invested (₱/yr)				687	709	730	775	828	859	878	899
Sources of cash											
Rice sale (₱/yr)				52.26	52.26	52.26	527.76	–	–	–	–
Mung sale (₱/yr)				6,806.20	7,020.60	7,245.10	7,276.70	7,276.70	7,691.70	8,025.15	8,025.15
Modern rice sale (₱/yr)				–	–	–	–	1,218.75	1,218.75	1,218.75	1,743.15
Total (₱)				6,858.46	7,072.86	7,297.36	7,804.46	8,495.45	8,910.45	9,243.90	9,768.30
Marginal value product											
Kalayakan				144	111	79	69	72	88	107	131
Parang				2,050	2,020	1,992	1,993	2,003	2,093	2,201	2,320
Bangkag kuman				4,367	4,269	4,142	4,104	4,099	4,082	4,063	4,080
Bangkag labbeng				2,811	2,686	2,563	2,518	2,512	2,492	2,469	2,454

kuman), but reverts mostly to current technology (mung and maize in the *labbeng*, and maize-peanut intercrop as the early crop in the *bangkag*). Under the cash constraint situation, funds are initially allocated to upland crops whose return pet peso invested is higher than that from rice. As the cash constraint becomes less restrictive, modern rice and mung in the optimal plan expand to occupy the "unused" land. The multiple cropping index also increases largely because of the introduction of the mung - mung - IR42 pattern in the less flood-prone portion of the rice lands.

When the researcher's expected mung yields are reduced by 50% (i.e., an upper limit of 0.4 to 0.5 t/ha), local technology, mung, maize, and maize-peanut intercrop become more important components of the cropping pattern along with modern rice (Table 7). The feasibility of these patterns would depend on farmers' access to supplies of peanut seed, which is now in short supply in the area.

In summary, under capital-scarce conditions, improved legume technology may be more attractive to farmers than new rice technology. Under less capital-restrictive situations, the new rice technology would be adopted first in the upper stratum of the *talon* in the early wet season and subsequently in the lower, and more flood-prone aspects of the landscape. Thus, from the viewpoint of the whole farm, a stress on upgrading mungbean technology seems appropriate.

INSTITUTIONAL CREDIT

Tenant-farmers in the Solana area typically use informal sources of credit such as landlords, merchants, and moneylenders. They rarely have access to formal sources such as banks and government agricultural loan programs. Interest rates for the informal sources frequently exceed 100%; that for the latter (when available) is 14% a year. The sensitivity of the farm plan with experimental technology to a reduced cost of capital was evaluated by rerunning the farm planning model (using researcher's expectations of crop yields) with an option for the farmer to borrow from institutional sources. The results are summarized in Figure 8. The results did not predict any change in farm plan from those reported in the last column of Table 5.

IRRIGATION DEVELOPMENT

Irrigation facilities were constructed by the National Irrigation Authority near the Solana site in 1976. Water has been delivered to the headwork of the system, but not to the research site. The command area where water was delivered is mainly the *parang* land and some of the lower-lying *kalayakan.* Experience elsewhere in the valley shows that two crops of modern rice (IR36) could be grown in the period December to September — the first crop is transplanted after the flood recedes and the second crop is harvested before the high flood-prone time from early September onward.

Farmers now growing IR36 in Cagayan Valley (with irrigation and about 40 kg N/ha) report yields of 4 t/ha for the early crop (December-January plantings) and about 3 t/ha for the late crop (June planting). It was assumed that farmers at Solana could achieve these yields with similar levels of inputs. In the model, the cost of

Table 6. Optimal cropping pattern when mung yield is reduced by 25%, at varying levels of available credit.[a] Cagayan outreach site, Philippines.

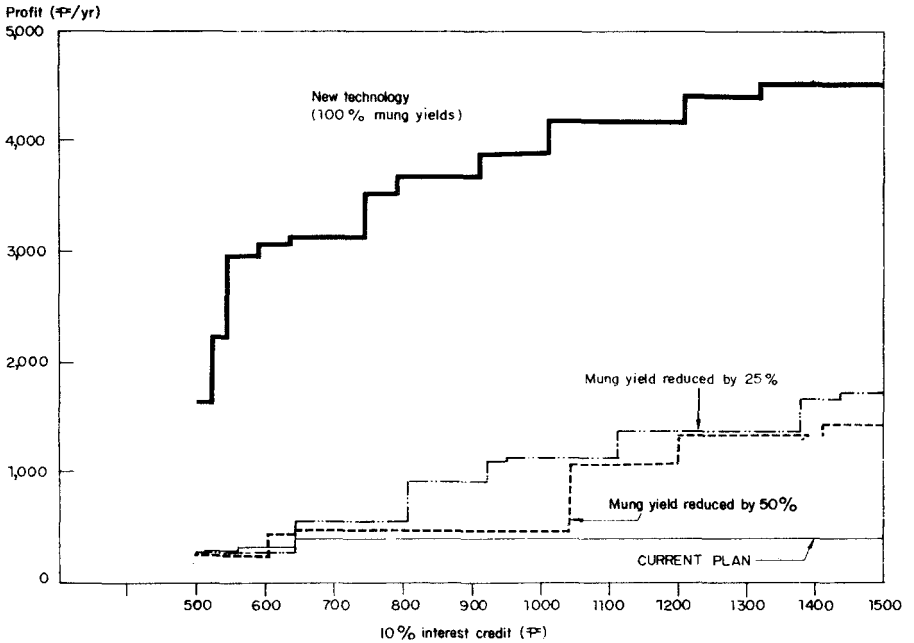
	Tech-nology[b]	Growing season		Level of borrowed funds									
		From	To	₱700	₱806	₱922	₱946	₱1,118	₱1,378	₱1,644	₱I343	₱2,016	₱2,071
Landscape and crop				Area (ha)									
Kalayakan													
Rice (IR42)	I	SeP	Jan	–	–	–	–	–	–	–	0.50	0.50	0.50
Parang													
Rice (IR42)	I	Aug	Jan	0.14	0.14	0.14	0.21	1.00	1.00	1.00	1.00	1.00	1.00
Rice (Tawataw)	C	Jul	Jan	–	–	0.79	0.79	–	–	–	–	–	–
Mung	I	Jan	Apr	–	–	–	–	–	–	0.60	0.60	0.60	0.60
Mung	I	Mar	May	0.34	1.00	1.oo	1.00	1.00	1.00	0.40	0.40	0.40	–
Mung	H	Mar	May	–	–	–	–	–	–	–	–	–	0.40
Mung	C	Apr	Jul	0.66	–	–	–	–	–	–	–	–	–
Mung	C	Apr	Jul	–	–	–	–	–	–	0.60	0.60	0.60	0.60
Rice (DSR, IR36)	I	May	Aug	0.50	0.50	0.50	0.50	0.50	0.50	0.50	–	–	–
Bangkag kuman													
Mung	I	Nov	Jan	1.00	1.00	1.00	1.00	1.00	–	–	–	–	–
Maize	H	Dec	Feb		–		–	–	1.00	1.00	1.00	1.00	1.00
Maize-peanut intercrop	C	Apr	Aug	1.00	1.00	1.oo	1.00	1.00	1.00	–	–	–	
Mung	H	Apr	Jul	–	–	–	–	–	–	1.00	1.00	1.00	1.00
Bangkag labbeng													
Mung	C	Jan	Mar	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	–	–
Mung	H	Dec	Feb	–	–	–	–	–	–	–	–	0.50	0.50
Maize	C	Apr	Jul	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

CONTINUED ON OPPOSITE PAGE

TABLE 6 CONTINUED

Tech-nology[b]	Growing season From	Growing season To	Level of borrowed funds ₱700	₱806	₱922	₱946	₱1,118	₱1,378	₱1,644	₱1,843	₱2,016	₱2,071
Sources of cash												
Rice sale (₱/ yr)			–	–	487.35	487.35	–	–	–	–	–	–
Maize sale (₱/yr)			183.73	183.73	183.73	183.73	183.73	2,445.58	2,011.23	2,011.23	2,011.23	2,011.23
Mung sale (₱/yr)			2,581.90	3,047.50	3,047.50	3,047.50	3,047.50	1,607.50	3,608.50	3,608.50	4,031.00	4,157.00
Modern rice sale (₱/yr)			–	–	93.32	93.32	1,218.75	1,218.75	1,218.75	1,743.I5	1,743.15	1,743.15
Peanut sale (₱/yr)			813.00	813.00	813.00	813.00	813.00	813.00	–	–	–	–
Total (₱)			3,578.63	4,044.23	4,531.58	4,624.90	5,262.98	6,084.83	6,838.48	7,362.88	7,785.38	7,911.38
Profit (₱/yr)			704	915	1,129	1,167	1,410	1,661	1,847	1,952	2.017	2,029
Family cash invested (₱/yr)			141	I83	226	233	282	332	369	390	403	406
Multiple cropping index			1.55	1.55	1.81	1.83	1.83	1.83	2.03	2.03	2.03	2.03
Marginal value product												
Kalayakan			65	62	10	26	72	109	125	202	270	292
Parang			1,084	1.087	1,094	1,112	1,175	1,393	1,484	1,563	1,621	1,645
Bangkag kuman			2,604	2,587	2,549	2,546	2,535	2,514	2,626	2,704	2,762	2,789
Bangkag labbeng			2,031	1,993	1,927	1,916	1,875	1,735	1,721	1,664	1,664	1,690

[a] US$1 = ₱7.50. [b] Technology may be current (C), intermediate (I), or high (H).



7. Relationship between farm profit and credit supply for a range of assumed yields of mungbean.

irrigation water was set at 18 cavans (about 900 kg) of rice per hectare of irrigated land per year, the irrigation fee the NIA would charge for water delivery to the area; other relationships were set at current farm practices.

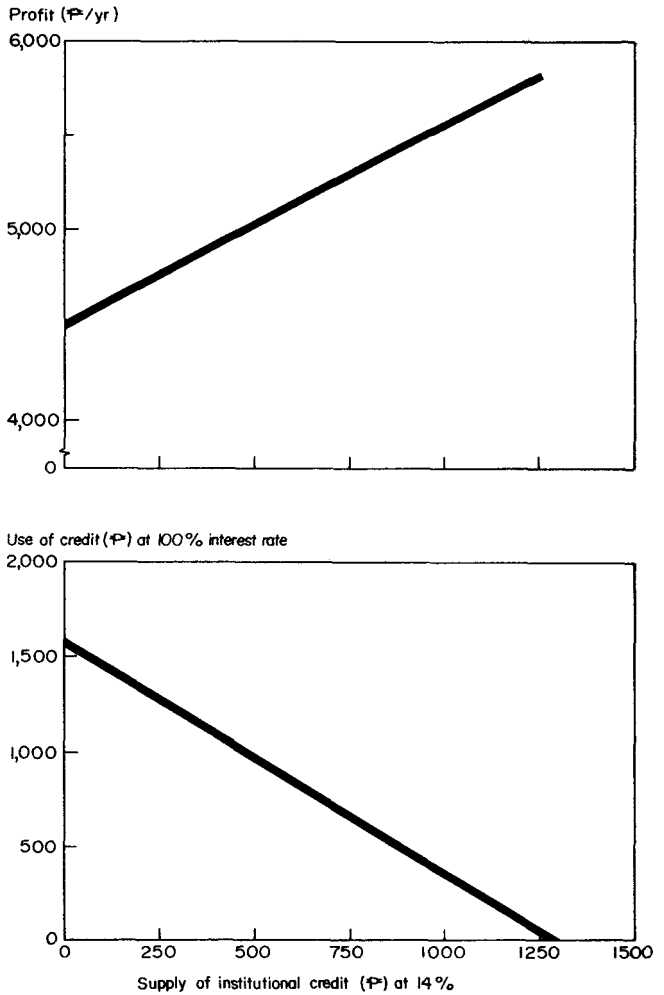
The optimal farm plan assuming an irrigated *parang* is listed in Table 8. Because of competition for carabao power in the period late November-December and in April-May between the upland crops on the *bangkag* and the rice on the talon, it is predicted that land preparation in part of the parang would commence in late November, and in the remainder, in December. Thus, there are two planting dates for both the first and second crops of irrigated rice. Cash expenses at ₱1,370 were estimated to be P570, or some 70% higher than in the current farm plan largely because of the purchase of fertilizer and labor to transplant the additional rice crop. In addition, the farmer pays the 18 cavans of rice in kind as the water levy.

The net result of the introduction of irrigation at these cost levels is probably negative — or at least very small — as the cash surplus generated (₱323) is ₱14 less than in the current farm plan without irrigation. This is probably an optimistic estimate — farmers speculate that if the *parang* were irrigated, the lack of drainage would result in inundation of low-lying areas. Farmers may therefore have to forego the production of *wagwag pino* on the *kalayakan* if irrigation water were delivered to the *parang.* But, if both irrigation and better drainage were introduced, the risk may be reduced and farmers may be able to operate more stable systems.

Table 7. Optimal cropping patternsand new cropping patterns with mung yields reduced by 50% credit availability.[a] Cagayan outreach site, Philippines.

	Technology[b]	Growing season		Level of borrowed funds			
		From	To	₱700	₱1,044	₱1,217	₱1,416
Landscape and crop				Area (ha)			
Kalayakan							
Rice (IR42)	I	Sep	Jan	–	–	–	0.50
Parang							
Rice (Tawataw)	C	Jul	Jan	0.79	0.79	–	–
Rice (IR42)	I	Aug	Jan	0.21	0.21	1.00	1.00
Mung	C	Apr	Jul	1.00	1.00	1.00	1.00
Rice (DSR, IR36)	I	May	Aug	0.50	0.50	0.50	–
Bangkag kuman							
Mung	C	Dec	Feb	0.83	–	–	–
Maize	H	Nov	Feb	0.17	1.00	1.00	1.00
Maize-peanut intercrop	C	Apr	Aug	1.00	1.00	1.00	1.00
Bangkag labbeng							
Mung	C	Jan	Mar	0.50	0.50	0.50	0.50
Maize	C	Apr	Jul	0.50	0.50	0.50	0.50
Sources of cash							
Rice sale (₱/yr)				487.35	487.33		
Maize sale (₱/yr)				571.66	2,445.58	2,445.58	2,445.48
Mung sale (₱/yr)				1,481.60	897.50	897.50	897.50
Modern rice sale (₱/yr)				93.32	93.32	1,218.75	1,743.15
Peanut sale (₱/yr)				813.00	813.00	813.00	813.00
Total				3,446.93	4,736.75	5,374.83	5,899.23
Profit (₱/yr)				594	1,095	1,339	1,444
Multiple cropping index				1.83	1.83	1.83	1.83
Family cash invested (₱/yr)				119	219	268	289
Marginal value product							
Kalayakan				53	53	110	295
Parang				1,055	1,055	1,203	1,347
Bangkag kuman				2,414	2,414	2,515	2,610
Bangkag labbeng				1,896	1,896	1,734	1,575

[a]US$1 = ₱7.50. [b]Technology may be current (C), intermediate (I), or high (H).



8. Relationship between supply of institutional credit, we of informal sources of credit (100% interest, unconstrained), and farm profit.

CONCLUSIONS

Whole-farm analysis by linear programming is a systematic way of examining enterprise budgets and so identifying a subset of activities and their levels which, if included in a farm plan, would maximize earnings for a farm with a specified resource base. The approach thus provides cropping system scientists the capacity to evaluate cropping patterns and other options within a synthesized whole-farm framework. The methodology offers considerable analytical power but is limited, in a field sense, because of reliance on computer capability. Thus, the Asian Cropping Systems Network must continue to seek simpler methods of whole-farm analysis suitable for use at cropping systems sites or for cases where researchers have limited

Table 8. Farm plan estimated as optimal, including irrigation deliveries to the *parang* land. Cagayan outreach site, Philippines.

Land use	*Crop*	*Area*	*Growing season*
Kalayakan	Rice	0.50	Jul-Feb
Parang	Rice	0.69	Nov-Mar
	Rice	0.31	Dec-Apr
	Rice	0.54	Apr-Aug
	Rice	0.46	May-Sep
Bangkag kuman	Maize-peanut intercrop	1.00	Nov-Feb
	Maize/peanut intercrop	1.00	Apr-Aug
Bangkag labbeng	Mung	0.50	Jan-Mar
	Mung	0.43	Apr-Jun
	Maize	0.07	Apr-Jul
Other reserve flows	Requirements		
Hire transplanters	72.5 days		
Food supply: energy	3300 K cal/year		
protein	55 kg/ year		
Cash flows	₱/yr		
Family living expenses	1000		
Family investment in farm	65		
Cash borrowed	1305		
Cash repayments	2610		
Carabao (annual cost × 2)	334		
Cash surplus	323		
Scarce resources	*Unit*	*MVP*[a]	
Kalayakan	1 ha	139	
Parang	1 ha	1746	
Bangkag kuman	1 ha	2011	
Bangkag labbeng	1 ha	1489	

[a] The marginal value product (MVP) represents the value for 1 yr for a farmer with access to an extra hectare of the given landscape position.

analytical facilities.

This particular analysis of the Solana cropping systems site demonstrates the higher potential of the upland (*bangkag*) than the lowland (*talon*) and in cash-scarce situations, the greater increments in farmer profits due to advances in legume technology than to improved rice technology per se.

If the new technology were feasible, the liquidity constraint becomes more binding than farm size. Therefore, access to credit was judged to be an important precondition for the widespread use of new technology. Finally, with existing technology, irrigation water for rice production at the site does not appear to be particularly attractive to farmers.

The inferences from the analysis are in the main consistent with expectations. In general, the approach was more useful in providing an integrative structure to examine farming systems at the site than in providing new information. Its analytical value would increase as the results from field trials permit more precise definition of the performance of the proposed cropping patterns.

The 1980 cropping year at Solana was marked by four important weather

occurrences: an early flood (late May) destroyed many farmers' mung crops; a flood (from rainfall higher in the catchment) in September destroyed maize crops in the *labbeng,* while a local drought destroyed rice seedbeds and delayed establishment of the rice crop; and recently, a typhoon in early November caused widespread damage. Such adverse weather conditions are the norm for Cagayan Valley. In response to them, farmers frequently reconsider and modify their short-run management tactics. Future farm planning models constructed to analyze cropping pattern options at this site should take account of these environmental realities and their impact on land use. A sequentially oriented decision model has appeal. Circumstances that will condition a farmer's response to hazards must also be better understood.

ACKNOWLEDGMENT

We acknowledge the contribution of C. Bantilan, E. C. Price, H. Gines, R. Gonzaga, and the staff of the Cropping Systems Program located at Solana to this activity.

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Factors contributing to increased rice production in Burma

Khin Win and Nyi Nyi

The diffusion of modern rice production technology among farmers in a developing country is a difficult process. Even though high yielding varieties have been developed, persuading the farmers to adopt those varieties and to follow the recommended practices is a formidable task. Farmers regard new technology with a measure of skepticism. This is especially true of the small farmers. The small farmer is aware of change, however; he sees much change during his travels to town and market. He is not unwilling to try the new. He is not averse to risk; he demands only that the risk be reasonable and within his limits.

Modern rice varieties were introduced in Burma in 1966 but their diffusion was slow. The modern varieties were short in stature and not really appropriate to the field conditions of much of the rice areas in Burma. Above all, the modern rices had poor eating quality compared to local strains. In addition, information about the modern varieties could not be diffused among the farmers because there was no strong agricultural extension organization.

Given that situation, an integrated action program was required if a new rice technology were to be widely diffused among farmers. It was clear from the scope of the problem and the size of the potential area of production that the approach would have to be one of selective application and exploitation.

RICE PRODUCTION

Rice is Burma's major crop. The major rice-growing areas have adequate rainfall and soil moisture during the main annual cropping season followed by a well-expressed 2-month dry season. The annual rainfall pattern is unimodal and the soil types are Fluvisol and Gleysol. The areas are along the coastal strips and on the Irrawaddy Delta. Most of the land is on a flat fertile plain and the annual rainfall ranges from 2,500 to 4,000 mm.

The system of rice cultivation in Burma may be broadly divided into five groups according to the water regime: rainfed wetland, irrigated wetland, dryland, winter, and deepwater. The rainfed wetland rice area is about 84% of the total.

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The growth rate of rice production in Burma over the past 30 years has been sluggish. Only during the past 5 years has it shown some acceleration (Table 1). Photoperiod-sensitive local rice varieties are widely grown. The increase in area of modern varieties is seen in Table 2.

CHOICE OF AN EXTENSION STRATEGY

The training and visit and package program tried by extension did not work under Burmese conditions. It was necessary to devise and formulate a program that would take maximum advantage of the prevailing conditions while minimizing the adverse effects of the constraints. The new strategy was designated *The Whole Township Rice Production Program.* In essence, it is a selective-concentrative strategy.

The selective-concentrative strategy

The components of the new selective-concentrative strategy are:

- a correct and proven new technology,
- political will and political guidance,
- selectivity and concentration,

Table 1. Rice sown area and production in Burma.

Years	Area sown (thousand ha)	Yield (kg/ha)	Production (thousand t)
1950-55	3,911	1,471	5,615
1956-60	4,161	1,566	6,115
1961-65	4,762	1,648	7,538
1966-70	4,982	1,639	7,710
1970-71	4,975	1,697	8,179
1971-72	4,978	1,716	8,192
1972-73	4,862	1,624	7,373
1973-74	5,089	1,762	8,620
1974-75	5,177	1,757	8,602
1975-76	5,203	1,830	9,227
1976-77	5,078	1,897	9,339
1977-78	5,136	1,945	9,481
1978-79	5,243	2,101	10,550

Table 2. The percentage of modern varieties grown on rice lands of Burma.

Years	Percentage of total sown area
1967-78	0.1
1968-69	3.5
1969-70	3.1
1970-71	4.0
1971-72	3.9
1972-73	4.4
1973-74	5.0
1974-75	6.8
1975-76	7.9
1976-77	8.9
1977-78	10.0
1978-79	14.8

- mass participation, and
- emulation and competition.

A correct andproven new technology. Much research work had been done over the years on modern rices — their yield components, their response to various types and applications of fertilizers, tillage operations, plant population densities, and water management. The results of that research had been made readily available but somehow things had never been widely accepted. Nevertheless, linkages between international research results, local research results, and extension were established and strengthened. The Agricultural Corporation and its extension workers were for the first time able to clearly, accurately, and meaningfully spell out for the farmers 10 impact points of the new rice production technology.

1. the use of high yielding varieties, both exotic and local,
2. proper tillage,
3. high plant population per unit area,
4. transplanting of seedlings of 25 to 30 days old,
5. application of recommended rates of chemical fertilizers,
6. basal application of farmyard manure,
7. proper weeding,
8. improved water management,
9. control of insects and diseases, and
10. minimization of losses at harvest.

Political will and political guidance. The State Council and state organs of power — the Burma Socialist Programme Party and the Peasants Asiayone — provided political will and political guidance at the national level. Lower-echelon organs down to the village level provided political leadership and political commitment. The administrative council members and Peasants Asiayone members were represented on four important committees at the township level:

1. Agricultural Management Committee
2. Cultivation Activities Committee
3. Procurement and Distribution of Inputs Committee
4. Disease and Pest Control Committee

Members of the Township Party Unit Committee and of the Township Peoples' Council exercised effective supervision of the program. The members were leaders elected by the people and were familiar with the physical, biological, social, and economic conditions of the townspeople. The leaders coordinated the activities of the various governmental agencies within the township and made decisions during the implementation of the program. Frequent visits were made by Ministers, Deputy Ministers, and members of the Divisional Committees.

Selectivity and concentration. Selectivity was in terms of locality, variety of rice, extension personnel, and management. During the first phase townships with suitable terrain, accessibility, and manageable size were selected. Selection of varieties meant the selection of appropriate modem variety, as well as of improved local varieties to suit soil and climate. It was fortunate that the Agricultural Corporation could provide modern varieties of better eating quality, taller plant height, and suitable growth period. They included locally improved rices, such as Shwe-ta soke, Seintalay, and Shwe-wah-htoon. The last was from gamma-ray irradiation

mutation.

Selection of extension personnel meant the selection of young people who were active, innovative, good team workers, and appreciative of the life of the farmer. Selection for management meant the selection of technically capable, imaginative, hardworking, problem-oriented managers.

Mass participation. If there was anything that the new technology demanded of the farmer, it was timeliness. Plowing, harrowing, and especially transplanting had to be done exactly on time. The density of plant population required more than the usual number of transplanters.

This was where mass participation activities contributed. Collective plowing, collective harrowing, and collective transplanting revived the age-old Burmese practice of helping each other through voluntary labor.

The township committees organized transplanting task forces from among non-farmers in the urban areas. Workers, students, police, and army personnel were organized to help. Because many of the workers had originally come from the rural areas, they were familiar with transplanting techniques, and quality and speed of the work did not suffer as one might have thought. A similar mass movement was mobilized during the harvesting period. Performers and writers also undertook to entertain the people.

Emulation and competition. Farmers in the village tracts, townships, and divisions were encouraged to emulate each other and to compete. The Agricultural Corporation provided some prizes, but often the people of the townships themselves were eager to provide prizes to the producers with the highest yields. In 1978-9 there were 1,599 farmers who produced more than 5 t/ha. Of these, 1,447 farmers produced between 5 t and 7 t/ ha. The remaining 152 farmers produced more than 7 t/ ha. In 1979-80, the number of farmers producing more than 5 t/ha is expected to increase more than tenfold.

ORAGANIZATION OF THE AGRICULTURAL, EXTENSION SERVICE

The Agricultural Extension Service is one of the responsibilities of the Agricultural Corporation. There is a Manager for each division, a Township Manager for each township, a Village Tract Manager for each village tract, and a Village Manager for each village. Village Managers and the Village Tract Managers are in constant touch with the village farmers. Each Village Manager looks after 1,500-2,500 ha.

Extension workers were previously allocated to a number of villages but under the new strategy, 10-12 Village Managers were grouped together at a technology diffusion center commonly called a production camp. Each production camp has a hall for training farmers. Educational posters and technical charts are hung on the walls as visual aids. The halls can be used as meeting places and alternately serve as places where village marriages or religious festivals are held.

There is a dormitory at each production camp for the Village Managers who live in the field. Thus living in close association with the farmers, they know each individual farmer intimately. Also, by living with their problems they pool their ideas and come up with valuable solutions.

National research workers and state farm workers, as subject matter specialists,

pay frequent visits to the production camps and train extension workers as well as farmers.

Pilot production program

The 10 impact points of the new technology were first tried on 162 ha in 1975-76. The project served as a training ground for 41 extension workers. It also served as a means for testing farmers' attitudes and as a guide to the sort of components that an integrated package of action would require. The results were encouraging. Rice yield rose from an average of 1.9 t/ha to 5.1 t/ha.

The success of the program (Phalon Village) led to its expansion to include five village tracts in 1976-77 — 1,886 ha with 506 farmers. This time the average yield rose from 2.1 t/ ha to 4.0 t/ha.

In 1977-78 the first Whole Township Rice Production Program was launched in two townships — Shwebo in Upper Burma and Taikkyi in Lower Burma. Again the results were encouraging; however, there was a diluting effect due to the large areas involved. The program covered 38,315 ha in Shwebo and 52,662 ha in Taikkyi. The diluting effect was due not only to the large areas involved but also to the shortage of subject matter specialists.

Full-scale program

By 1979 it was realized that the new technology as incorporated in the 10 impact points was correct and it was decided to extend the program to 23 townships and cover 850,000 ha.

Special high yielding modern varieties with a yield target of 3.6 t/ha were allotted to the best areas in the townships. The less favorable areas were also sown with modern varieties but were given second priority in terms of inputs and supervisory extension workers. The least favorable areas were sown with local varieties, but methods of cultivation were improved. The increase of area under modern varieties demanded a much larger input of fertilizer and insecticides. However, the energy crisis and the high rise of prices on the international market placed a restriction on the fertilizer and insecticide inputs that could be used. Extensive use of organic manure was encouraged.

The extended program

The components of the technology diffusion package operated beyond expectations. Most encouraging were the enthusiastic response of the farmers and their active acceptance of the new technology. These gave the authorities new confidence in moving into the next phase of the program: expansion to cover 43 townships in 1979-80.

Although the area of operation was greatly extended the selective-concentrative strategy remained valid. The areas were selected and the resources previously allotted to them were mobilized and concentrated on the task.

The program faces some difficulties. Any program gathering within it so large a proportion of the rural population and their agricultural productive work will meet various constraints in a developing country. A shortage of fertilizers and insecticides is one of the limits under which the program must operate. On the other hand, the

program has pointed to and brought into action one resource which can be said to spill over — the understanding, resourcefulness, and boundless enthusiasm of the people.

ECONOMIC RESULTS

The special program has contributed to national production an extra 500,000 t rice valued at US$28 million — a net benefit to Burma of US$11 million. This was equivalent to a 2.5:l rate of return on public and private investment. This ratio included a farm labor charge for the family, a land charge, supervisory costs, and capital investment for production camps, transport of supervisory staff, and other administrative items. If those costs are excluded the ratio would become 13:l.

The area under rice, yield, and productivity before and after the program are shown in Table 3. The multiplier effect of the extra money income generated by the farmers is not known, but to reduce its inflationary impact as well as to meet the domestic and production needs of the farmers, goods and instruments of production were sold to them directly at rice buying centers where the harvest was sold.

Because of the general rise in prosperity, there was a distinct decrease in the incidence of crime.

The Agricultural Corporation will study how farmers spend the extra income, with special emphasis on reinvestment for agricultural production.

THE PRODUCTION FUNCTION OF THE NEW TECHNOLOGY

A multiple regression analysis was made to account for the sources of yield changes due to the introduction of the 10 impact points of the new rice production technology. The production function could account for about 97% of the yield changes. The resulting regression equation is shown below.

$$y = 0.0816\,S + 0.0800\,RT + 0.1670\,N + 0.5313\,K - 0.675\,ID + 36.61;$$

where S = area (%) sown with 25- to 30-day-old seedlings
RT = row transplanted area (%)
N = urea fertilizer application (t/ha)
K = muriate of potash (t/ha)
ID = insect and disease infested area (%)

The percentages of contribution of the variables to the total yield changes were:

- urea fertilizer application 40
- recommended-seedling-age area 18
- insect-infested area 1
- row transplanted area 24
- muriate of potash 14
- residual 3

Table 3. Rice sown area, yield and production before and after the Whole Township Rice Production Program in 23 townships, Burma 1977-79.

Township	Sown area (thousand ha)		Change (%)	Yield rate (kg/ha)		Change (%)	Production (thousand t)		Change (%)
	1971-78	1978-19		1971-18	1918-19		1977-78	1978-79	
Oak Pho	33	32	–3	2576	3150	45	85	120	41
Kyauk taga	54	54	0	2407	2661	11	130	144	11
Taikkyi	51	50	–2	2823	2860	1	144	143	–1
Hmawbi	26	26	0	1731	2385	38	45	62	38
Hlegu	63	60	–5	1809	2450	35	114	147	29
Thongwa	59	58	–2	2068	2655	28	122	154	56
Henzada	56	56	0	2286	3339	46	128	187	46
Bassein (East)	65	66	2	2231	3136	41	145	207	43
Kyonpyaw	49	50	2	2204	3140	42	108	157	45
Kyaung gone	44	43	–2	2273	2930	29	100	126	26
Kyaik lat	55	54	–2	2 164	2722	26	119	147	24
Shwe Bo	41	42	2	3122	3190	2	128	134	5
Wet let	37	39	5	2432	2949	21	90	115	28
Khin U	29	30	3	2112	2667	23	63	80	27
Depeyin	30	34	13	2100	26 19	25	63	89	41
Ye U	24	28	17	2161	2643	22	52	74	42
Kyauk Se	19	20	5	2 105	3000	43	40	60	50
Pathin Gyi	14	16	14	2500	3313	33	35	53	112
Pwint Phu	22	23	5	259 1	2870	11	51	66	16
Sagu	12	12	0	2250	2500	11	27	30	11
Salin	12	16	33	2250	2632	17	21	43	59
Sandoway	14	15	7	1186	2467	38	25	37	48
Falam	2	2	0	1500	1523	2	3	3	0
Total	811	834	3	2281	285 1	25	1850	2370	29

ACCEPTANCE OF THE NEW RICE PRODUCTION TECHNOLOGY

The acceptance of the new rice production technology was tested by making a complete enumeration in Shwebo and in Taikkyi. The objectives of the survey were:

- to find which strata of farmers accepted the new rice technology and to indicate which farmers should be organized in future extension programs, and
- to determine how effectively the program had increased rice yields.

A set of nine hypotheses was tested. Factors significantly related to the acceptance of technology were:

- higher income farmers,
- moderately literate farmers,
- farmers from medium-size families (5-6 members),
- highly innovative farmers,
- urban-exposed farmers,
- party members, and
- decision made by both husband and wife.

Factors not significantly related to the acceptance of the technology were:

- age of farmers, and
- farm size.

DISCUSSION

Ganda: In Indonesia the training and visit (T & V) system was established as the main extension method. So the T & V system acts as a linkage between extension and the technology sources. Through the T & V, we can concentrate our extension effort, and maximize the extensionist mobility and communication with the farmers. We can also convey the appropriate technology to the farmer faster and solve production problems. I would like to know the basic constraints to the agriculture technology diffusion through T & V system in Burma.

Win: In Burma we do not have enough subject matter specialists and the mobility of the extension workers is also limiting. These are two constraints at the present which we are trying to remove. On the other hand, in the present program we take advantage of the tract and village organizations that are established. They effectively serve as additional extension workers in our present program.

Adoption of improved cropping patterns in Nambahdadi, Lampung

Inu G. Ismail, Imtiaz Basa, and Wayan Sudana

Once a new improved technology had been developed and is ready to try in a large-scale production program, the important questions are, "Can it be adapted by farmers?" and "Are farmers willing to adopt that technology?" Farmers' decisions play the major role in the production process and can determine the success of a program.

Cropping systems research is problem oriented. Target areas are selected for in-depth research. Activities in each target area include identificationand quantification of problems or possibilities, evaluation of new technology in farmers' fields, preproduction testing, and the transfer of technology to new target areas (Suryatna and McIntosh 1978).

Nambahdadi is a cropping systems research site in Lampung, Indonesia, that represents partially irrigated land. The site is in Central Lampung and has only 5-6 months of irrigation water. The wetland fields were developed in 1973. Before that the whole area was in dryland agriculture. Irrigation water comes from the Way Seputih river, which services an area of about 13,342 ha in the Terbanggi Besar district. Farmers typically wait for irrigation water in December to plow the land and sow the seedbed. They transplant the crop late December-February. Harvest is in June and then the land is fallowed for the rest of the year. Most of the farmers are transmigrants from Java who settled in Lampung more than 20 years ago. Each family still has some portion of upland where they grow cassava and other secondary crops.

TESTING OF CROPPING PATTERNS

Cropping systems research began in Lampung in 1975-76. The soils belong to the Podzolic group, which has a low pH and low natural fertility. Some chemical soil characteristics are presented in Table 1. Total annual rainfall ranges from 1,700 to 2,000 mm/year. Rainfall distribution is relatively even and great possibility exists for increasing cropping intensity. In 1975-76 alternative cropping patterns were designed and tested in the fields of several farmers.

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Table 1. Some chemical characteristics of a Podzolic soil at Nambahdadi, Lampung, Indonesia.

Chemical characteristics	Value	Relative level
pH	4.4	Low
Cation exchangeable (meq/100 g)	8.5	Slightly low
Organic carbon (%)	3.3	
Total nitrogen (%)	0.1	Low
Available phosphorus pentoxide (ppm)	70.3	Very low
Potassium (meq/100 g)	0.4	Low
Calcium (meq/100 g)	1.5	Very low

The *gogo rancah* [1] system was introduced as a superimposed treatment to the pattern of rice - rice -grain legume in 1976-77. The system was successfully demonstrated in the partially irrigated areas of West Java (Saefuddin and Tadjuddin 1976).

Results with *gogo rancah* in the cropping pattern were promising. Farmers started to see the possibility of growing two crops of rice per year. To obtain stronger evidence of the pattern's productivity, it was evaluated in trials with 9 farmer cooperators on 4 ha in 1977-78. Recommended cultural practices for the improved pattern are shown in Table 2. Figure 1 shows the cropping sequences and the rainfall data recorded during the test period. Actually, it was difficult to convince the farmers that *gogo rancah* would enable them to grow two rice crops per year. Their hesitation to cooperate caused a delay in planting and seeds were dibbled in November. We assumed that October would be the best time for *gogo rancah.*

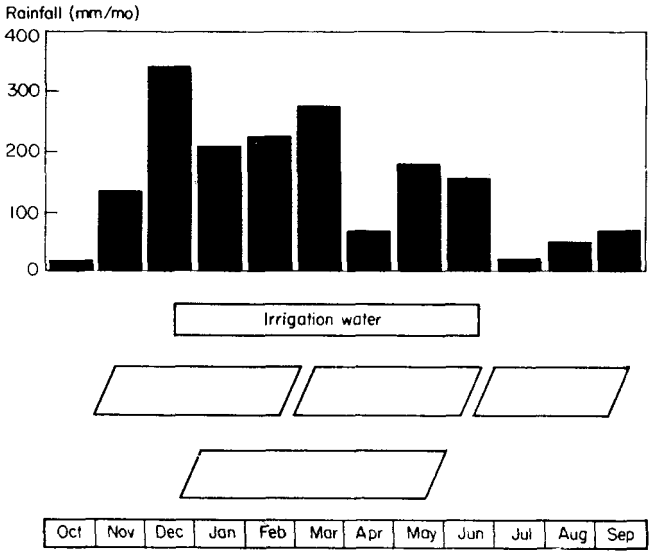
Results of the verification trial are summarized in Table 3. IR36, used for *gogo*

Table 2. Cultural practices for the improved pattern of GGR-TPR-CP [a] for the 6-month irrigation areas of Nambahdadi, Lampung, Indonesia, 1977-78.

	First crop (GGR)	Second crop (TPR)	Third crop (CP)
Variety	IR36	IR36	No. 126
Spacing (cm)	20 × 15	20 × 20	40 × 20
Planting	Direct seeded, unpuddled	Transplanted, puddled	Dibbled
Land preparation	2 plowings + 1 harrowing	1 plowing + 1 harrowing	No tillage
Fertilizers (kg/ha)			
Urea	250	200	None
Triple superphosphate	100	100	–
Pesticides:			
Furadan 3G (kg/ha)	3	25	–
Diazinon (liters/ha)	1	1	1
Sevin (kg/ha)	1	1	–
Zincfosfide (kg/ha)	1	1	–
Weeding (as necessary)	Hand weeding	Hand weeding	Hand weeding

[a] GGR = *gogo rancah* rice (dry-seeded rice), TPR = transplanted rice, CP = cowpea.

[1] Dry-seeded rice (*gogo rancah*) involves dryland dibbling of seed, but as the irrigation water arrives the rice is converted to wetland crop.



1. Cropping patterns tested and monthly rainfall pattern recorded in Nambahdadi, Lampung, Indonesia, 1977-78.

rancah, performed well and yielded 5.6 t/ha. There was no serious damage from insects and diseases. Two weeks before harvest of the *gogo rancah* crop, the seeds for the second transplanted rice were sown in the seedbed. Immediately after harvest, the field was plowed and harrowed once (the operations took about 10 days), and the second rice crop was transplanted. The low yield of the second rice crop (IR36) — only 2.9 t/ha — was attributed to the low rate of nitrogen and the method of phosphate fertilizers application. In this type of soil, phosphorus is the key element for crop growth and yield. For the *gogo rancah* crop, phosphate was banded in rows,

Table 3. Summary of results of the verification trial of the new improved cropping pattern for the 6-month irrigation areas, Nambahdadi, Lampung, Indonesia, 1977-78.

	Introduced pattern[a] (GGR - TPR - CP)	Farmers' pattern (TPR - fallow)
Yield of crops (t/ha)		
Rice	5.6	–
Rice	2.9	3.7
Cowpea	0.7	–
Total labor (days/ha)[b]	607	231
Labor cost (Rp/ha)[c]	182,100	69,300
Material cost (Rp/ha)	89,050	24,670
Total variable cost (Rp/ha)	271,150	93,970
Gross return (Rp/ha)	630,664	216,572
Return to material	5.04	5.97
Return to labor	2.97	2.77
Net return (Rp/ha)	359,514	122,602

[a]GGR = *gogo rancah* rice (dry-seeded rice), TPR = transplanted rice, CP = cowpea.
[b]1 labor day = 7 working hours. [c]US$1 = Rp 625.

but for transplanted rice the phosphate fertilizer was broadcast.

The second rice crop was harvested in June, leaving about a 3-month period for the third crop. A drought-tolerant cowpea was dibbled in the rice stubble without land preparation and the rice straw was used as a mulch. The crop performed well and its vegetative growth completely covered the ground. Growing the cowpea crop during the dry period minimized weed problems and made land preparation for the next *gogo rancah* rice easier (Mahyuddin and Soeharsono 1976).

By increasing the cropping intensity, the total yield obtained was 8.5 t/ha for rice, plus 0.7 t/ha for cowpea, compared with only 3.7 t/ha of rice from the farmers' cropping pattern. The net return obtained from the improved pattern was almost three times that from the farmers' cropping pattern. Obviously, this promising pattern was also labor intensive. High labor cost was especially needed for land preparation and weeding the *gogo rancah* crop.

For refinement of the improved pattern, possibilities for reducing the labor requirement still need to be studied. Minimum tillage and preemergence herbicide might solve the problems of land preparation and weeds; however, herbicides are not commonly used by Indonesian farmers. Another possibility is the use of simple implements or tools for cultural practices such as planting and weeding that will minimize labor and cost.

EVALUATION OF PATTERN ADOPTION

Surprisingly, in the year after the Central Research Institute for Agriculture left the target area, many farmers spontaneously adopted the new pattern. Starting with only 4 ha in 1977-78, adoption increased to 30 ha in 1978-79 and to 212.5 ha in the 1979-80 cropping season (Table 4). The late adopters went to the nine farmer cooperators and asked for seeds and information about cultural practices.

The new pattern was also spontaneously adopted in another village near Nambahdadi. In Karang Endah, which has about 700 ha of lowland of the same irrigation category, 225 ha were already planted with the *gogo rancah* system in the 1979-80 crop season. The major reason for the rapid adoption of the system might have to do with the history of the farmers' land development. Formerly, the farmers planted upland rice, which was called *padi gogo.* The early stage of *gogo rancah* is very similar to *padi gogo.*

A preliminary evaluation of the adoption process was made by interviewing

Table 4. Development of the improved cropping pattern in the 6-month irrigation area, Nambahdadi, Lampung, Indonesia

Cropping season	Area planted (ha)	Percent of total area	Av yield (t/ha)		
			New pattern	Old pattern	Total
1977-78 [a]	4	0.6	5.6	2.9	8.5
1978-79 [b]	30	4.1	4.5	2.0	6.5
1979-80 [b]	212.5	29.3			

[a]Verification plot involving 9 farmer cooperators. [b]Development after project research activities were completed.

several farmers who followed the new pattern after it had been successfully demonstrated by the nine cooperators. Since it might be too early to study the changes in their farming system resulting from adoption of the improved cropping pattern, the evaluation was limited to the question of why the improved pattern was rapidly and spontaneously adopted.

The farmers identified three major advantages of using the *gogo rancah* system in their cropping pattern:

1. It enabled them to produce two rice crops per year.
2. The yield of *gogo rancah* is higher than that from their transplanted rice.
3. The price of rice is higher when the *gogo rancah* crop is ready for harvest.

Based on experience, we found three preconditions that must exist for farmers to adopt the new cropping pattern. These are:

1. availability of seeds,
2. availability of inputs (fertilizers, insecticides, etc.), and
3. availability of markets for the rice.

For *gogo rancah* development in Nambahdadi, those three requirements are most likely met.

The IR36 seed from the 4 ha in 1977-78 was saved by farmers who followed the pattern that year.

With the increasing number of farmers who want to follow the new system and with the help of the extension workers. under the BIMAS program adopters can obtain credit for inputs from the local bank.

Adopters also benefit from the off-season harvest of *gogo rancah* in the new cropping pattern. Farmers receive only Rp 58/kg of rice during the normal harvest season, but because the *gogo rancah* crop was harvested during the off-season, the price received was as much as Rp 70/kg.

Besides the advantages, farmers also reported disadvantages associated with the *gogo rancah* system. Rat and rice bug damage was more severe and extra labor was needed for weeding. The pest problems are perhaps only temporary because only part of the whole area was planted as *gogo rancah.* The greater the area planted, the less important the pest problems will become.

Apparently, the new improved pattern of rice - rice - cowpea was only partly adopted. After the harvest of the second rice crop, farmers did not plant cowpea because they still had upland parcels where they grew secondary crops. Only a few planted secondary crops in lowland. However, farmers should be encouraged to plant cowpea after the second rice because it will reduce the weed problem as well as the cost for land preparation for the next *gogo rancah* crop. Another reason might be critical to cowpea use — cowpea is still a relatively new crop, seed is not generally available, and the market is still limited.

Adding one more crop of *gogo rancah* into the existing farmers' pattern is a major contribution of the cropping systems research activities in this area. We believe the innovation could be transferred to other areas having similar irrigation category, and agroclimate.

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Dogget: In areas where upland crops are not grown as part of traditional rice-based cropping systems, are there any examples of rapid adoption of upland crops by farmers? In the most successful cropping system adoption known to me, the *two rice crops* in place of *one rice crop* has really been strongly adopted in Sri Lanka, Indonesia, and partly at least in the Philippines.

Ismail: We do have studies of cropping systems for upland Podzolic soils where the traditional pattern is intercropping upland rice + maize + cassava. We introduced legume crops into the pattern and arranged it in a continuous cropping of maize + upland rice + peanut - rice bean. Evidently farmers realized the benefit of the improved pattern and they are willing to adopt it. The key is to make the seeds available, especially for legume crops. The market for peanut and rice bean is no problem; it is available at a good price. In the partially irrigated wetland we must motivate farmers to use cowpea as the third crop after the second rice crop because it suppresses the weed population and makes land preparation for DSR much easier.

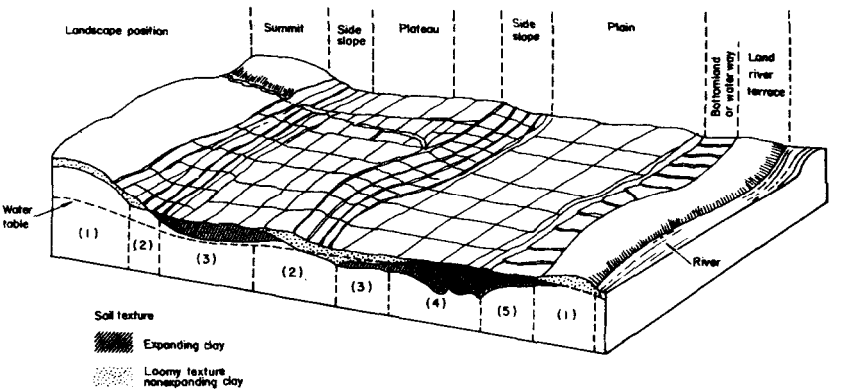
Adoption and impact of new cropping systems in Iloilo and Pangasinan, Philippines

Edwin C. Price

Research to increase cropping intensity and food production in rainfed lowland areas was begun at IRRI in 1975. Two sites were chosen as laboratories for the development of a methodology for on-farm research to identify rice-based multiple cropping patterns. As a test of the methodology, the technology developed at the sites must be acceptable to farmers and prove more productive for them. A cropping pattern can be recommended if it is at least 30% more profitable than the dominant traditional pattern.

Oton and Tigbauan municipalities in Iloilo Province and Manaoag municipality in Pangasinan Province were chosen as sites. In 1975 they were predominantly rainfed, having 5 to 6 months with rainfall greater than 200 mm and 3 to 4 months with rainfall less than 100 mm. In Iloilo the surface soils are dominantly clay or silty clays; in Pangasinan they are dominantly clay loam (IRRI 1980).

In Iloilo, land units where rice farming was practiced were further classed according to landscape as plateau, side slope, plain, and waterways (Fig. 1). In Pangasinan,



1. Schematic presentation of geomorphic and pedologic conditions at the Iloilo, Philippines, outreach site (source: Raymundo 1977). Hydrology: 1 = pluvic, 2 = fluxic, 3 = fluxic-cumulic, 4 = cumulic, 5 = cumulo-delugic.

Agricultural economist, Cropping Systems Network, IRRI.

land was divided into two units, deep water table and shallow water table. Table 1 shows the distribution of land by land unit. Some of the land units at both sites later became irrigated.

Multiple cropping technology was designed and tested according to the land units. In this paper we discuss the impact of new cropping systems technology at the two sites. In part we focus on differences in environmental conditions between the sites and how they led to the differential impact of new technology. We show that the differential impact resulted largely from distinctions in the technological alternatives of farmers; that is, compared to farmers' present systems, the experimental technology was more attractive in Iloilo than in Pangasinan.

TECHNOLOGICAL ACTIVITIES OF FARMERS

In 1974-75, before research began at the sites, 82% of cultivated land in Iloilo was planted to a single crop of rice (Table 2). The rice - fallow pattern was clearly the dominant pattern and the one for which researchers would design a replacement. In Pangasinan, only 10% of cultivated land was planted to the low-intensity rice - fallow pattern, and rice followed by upland crops, mainly mungbean, was the dominant pattern. Farmers relay-broadcast mungbean into maturing rice crops and thereafter gave the crop little attention. The mungbean yield was very low (about 200 kg/ha).

Table 1. Land types and percentage of irrigation in Iloilo and Pangasinan, Philippines, 1975-76 to 1978-79.

	Cultivated land (%)			
	1975-79	1976-77	1977-78	1978-79
Iloilo				
Plateau	56			
Plain	17			
Side slope	9			
Waterway	6			
Dryland	12			
Irrigated		7	25	25
Pangasinan				
High water table	40			
Low water table	51			
Dryland	16			
Irrigated		22	29	34

Table 2. Land allocation to cropping patterns in farmers' systems, Ilolio and Pangasinan, Philippines, 1974-75.

Cropping pattern	Land (%)	
	Iloilo	Pangasinan
Rice - fallow	82	10
Rice - rice	5	5
Rice - upland crops	11	81
Upland crops	12	4
Multiple cropping index	118	196

Researchers in Pangasinan attempted to replace the rice mungbean pattern with a more intensive technology.

In the 1975-76 crop year, Iloilo researchers had planned to test some double- and triple-crop patterns based on an early dry-seeded crop of the newly released short-maturing rice varieties IR28 and IR30. But the rains came early and the farmers cooperating in the trials, with researchers' agreement, switched to wet-seeding (Palada et al 1976). Table 3 shows the results of the main experimental patterns that year and of farmers' patterns. Simultaneous with the experimentation on double rice cropping a number of farmers, observing the trials, tried the technology themselves. The results from these early adopters' plots are labeled "transitional" in Table 3.

The data on farmers' patterns and on the transitional pattern reflect the activities of some of the 45 farmers who under the guidance of economists kept daily records of their farm activities. The "economics cooperators" were different from the "agronomic cooperators" on whose farms the experiments were conducted.

The farmers who adopted the double-rice pattern in the first year used lower levels of labor and cash inputs than the researchers on the same pattern, and obtained lower yields. But profit on the transitional pattern was twice that realized on the dominant farmers' pattern.

Table 4 shows the economic performance of cropping patterns with respect to a second criterion, that is, that a new pattern should show a higher marginal rate of

Table 3. Costs and returns of farmers' and experimental patterns[a] in Oton and Tigbauan, Iloilo, Philippines, 1975-76.

Cropping pattern	Total cost (₱/ha)	Total returns (₱/ha)	Net return (₱/ha)
Farmers' patterns			
TPR - fallow	1127	2107	980
TPR - grain legume	1088	2002	914
Experimental patterns			
WSR - WSR	4212	8708	4499
WSR - TPR	4276	8895	4619
Transltlonal pattern[b]			
WSR - TPR	1731	3713	1982

[a]TPR = transplanted rice, WSR = wet-seeded rice, US$1 = ₱7.35. [b]Experimental pattern adopted by farmers.

Table 4. Additional investment in total variable costs (TVC) and rates of return on additional investment for replacing farmers' present pattern with a different farmer's pattern or experimental cropping pattern, Iloilo, Philippines, 1975-76.

Farmers' cropping pattern for replacement	Rate of return on TVC	Replacement pattern[a]	Increase (%) in TVC	Incremental rate of return
Transplanted rice - fallow	1.9	TPR - legume (farmers)	0	0
		WSR - WSR (experimental)	274	2.1
		WSR - TPR (experimental)	279	2.2
		WSR - WSR (farmer's)	53	2.7

[a]TPR = transplanted rice. WSR = wet-seeded rice.

return on additional investment than other alternatives among farmers' technology. The farmers' present cropping pattern of rice - grain legumes offered a rate of return no higher than that of rice - fallow. Wet-seeded rice (WSR) followed by WSR (experimental) required a 274% increase in investment in labor and material inputs per hectare but gave a 2.1 rate of return on this investment. WSR - TPR (transplanted rice) was about the same. The rate of return was higher than that realized from TPR - grain legumes (zero), and even higher than the 1.9 rate of return from farmers' total investment in rice - fallow. When farmers grew the pattern WSR - WSR, they invested only 53% more than in rice fallow but obtained a 2.7 rate of return — 2.7 pesos for every peso of labor and materials. The favorable returns attracted farmers to convert much of their single-rice-crop land to rice - rice. Rice double-cropping had not been possible before the early-maturing varieties and direct-seeding technology.

The situation was substantially different in Pangasinan. The dominant pattern was relatively more intensive than the dominant pattern in Iloilo. An experimental dry-seeded rice crop was successfully established, but a severe weed problem occurred and zinc deficiency affected yields. The experimental trials in 1975-76 had negative returns (Table 5). Further experimentation was required to refine the direct-seeding technology for Pangasinan. The 1977-78 crop year shows the technological choices of farmers in Pangasinan (Table 6).

On the shallow water table with irrigation, farmers in 1978 grew 3 cropping patterns; 10% of the land had rice - fallow, 19% had rice - rice, and 58% had rice - mungbean. The land planted to a single crop of rice had a number of alternatives of both experimental and farmers' technology. Here the experimental technology paid

Table 5. Costs and returns (₱/ha) of dry-seeded rice, Pangasinan, Philippines, 1975.

	Pao	Lipit Sur	Caaringayan	All
Farms reporting (no.)	5	3	8	16
Cash cost				
Seeds	193	174	186	186
Fertilizer	634	570	667	638
Chemicals	620	477	748	657
Total cash costs	1448	1222	1601	1482
Labor costs				
Land preparation	240	150	333	270
Planting	20	30	25	25
Fertilizing	47	26	44	42
Spraying	40	15	35	33
Weeding	2414	667	894	944
Harvesting	304	579	623	515
Other cost	137	14	189	140
Total labor costs	3205	1485	2145	1970
Total variable cost	4654	2707	3751	3835
Gross return	1521	2898	3115	2576
Return above cash costs	72	1676	1514	1094
Return above labor costs	-1684	1412	969	606
Return above variable costs	-3133	190	-635	-1259

Table 6. Additional investment in total variable costs and rates of return on additional investment for replacing farmers' present pattern with a different farmers' pattern or experimental cropping pattern, Pangasinan, Philippines, 1977-78.[a]

Land type	Farmers' cropping pattern for replacement	Rate of return on TVC	Replacement pattern	Increase in TVC (%)	Incremental rate of return[b]
Shallow water table, irrigated	Rice - fallow	1.7	Rice - mungbean (F)	40	1.6
			Rice - rice (F)	120	2.1
			Rice - rice (E)	370	1.4
			Rice - rice - upland crop (E)	430	1.4
	Rice - mungbean	1.6	Rice - rice (F)	160	2.3
			Rice - rice (E)	240	1.4
			Rice - rice - upland crop (E)	280	1.4
	Rice - rice	1.9	Rice - rice (E)	120	1.1
			Rice - rice - upland crop (E)	150	1.2
Shallow water table, rainfed	Rice - mungbean	1.7	Rice - mungbean (E)	70	1.4
			Rice - rice (E)	80	.5
			Rice - rice - upland crop (E)	120	1.2
Deep water table, irrigated	Rice - fallow	2.3	Rice - mungbean (F)	90	2.2
			Rice - rice (E)	300	1.2
			Maize - rice - upland crop (E)	410	1.8
	Rice - mungbean	2.3	Rice - rice (E)	110	.7
			Maize - rice - upland crop (E)	170	1.7
Deep water table, rainfed	Rice - mungbean	1.9	Rice - mungbean	140	1.5
			Rice - rice (E)	220	1.3
			Rice - rice - upland crop (E)	260	1.6

[a]TVC = total variable costs (labor and materials), F = farmers' management, E = improved management, as grown in experimental trials. [b]Indicates the number of dollars returned per dollar spent on additional variable inputs required to switch to new pattern.

less on investment, and the best choice was farmers' rice - rice. On land in rice - mungbean, farmers' rice - rice technology looked also promising. On land that was in rice - rice no other alternative looked attractive to farmers: they could consider one of the experimental technologies but could expect only a 10 to 20% rate of return.

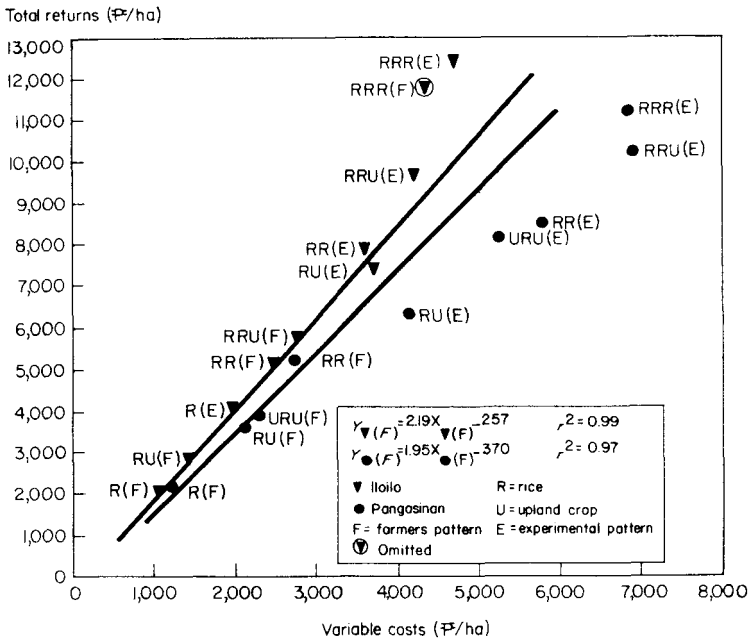
On the shallow water table, rainfed, 100% of the land was in rice - mungbean and there was no exciting alternative. Rice - rice was a losing proposition, and the two other experimental patterns showed fairly low marginal rates of return, below that realized in the dominant pattern. Using more inputs on rice - mungbean as in the experimental pattern would be the next step for farmers.

On deep water table, irrigated land, 13% of the land was single-cropped to rice and could be profitably shifted to farmers' rice - mungbean technology. The experimental rice - rice pattern would return only 70 centavos per additional peso's worth of investment in labor and materials. However, the experimental maize - rice - upland crop would be more profitable, but with a rate of return lower than that realized in the present pattern. In the rainfed area, using higher inputs on the present rice - mungbean pattern was the likely next step for farmers because the experimental rice - mungbean offered nearly the highest rate of return on additional investment but was a fairly easy step to take.

In summary, pattern changes were expected only on irrigated land. Where the water table is shallow, low-technology rice - rice could be recommended. Where the water table is deep, rice might be preceded by maize harvested green. On rainfed land, which is the main target of the Cropping Systems research group, increasing input levels rather than new patterns appeared to be the main recommendable practice. Compared to present practices the new technologies made available to farmers in Pangasinan were all less attractive than were the new choices offered Iloilo farmers.

The relative performance over 3 years of farmers' cropping patterns, both traditional ones and those newly adopted, and the experimental patterns grown under researcher's supervision are shown in Figure 2 (IRRI 1979). The mean performance of each pattern type was estimated by computing the annual mean performance of each pattern across farms, then taking the 3-year average of annual means. Land types and water availability were not distinguished; therefore, different pattern types may imply different fixed costs (in terms of land value), as well as different current input costs. The current input costs, labor plus materials, are shown on the horizontal scale. Because farmers' and experimental patterns of a given type were grown on similar land types, differences in yields and current inputs between farmers' and experimenter's patterns could not be attributed to differences in land types.

The linear relationships between gross returns and variable costs (Fig. 2), estimated from farmers' patterns for which there were at least 2 years of observations, represent the ratio of returns to variable costs in Pangasinan (lower line) and Iloilo (upper line). Four general conclusions can be drawn: farmers applied lower rates of variable inputs than experimenters; Pangasinan farmers received higher rates of returns on variable inputs than experimenters, but Iloilo farmers received lower; Iloilo farmers and experimenters received higher rates of returns on current inputs than did Pangasinan farmers and experimenters; and new multiple cropping technology increased net returns through higher levels of inputs, and not by increased efficiency of current inputs.



2. Costs and returns of farmers' and experimental cropping patterns, Iloilo and Pangasinan, Philippines, 1975-78.

ADOPTION OF NEW PATTERNS

Table 7 shows the changes in cropping patterns across all land types in Iloilo from 1974-75 to 1978-79, and Table 8 shows the changes by irrigation class. The baseline survey found low levels of cropping intensity in 1974-75. Now, large areas are devoted to multiple crops of rice and rice plus other crops. About 30% of rainfed lowland was allocated to rice - rice and almost 50% to rice followed by upland crops. The dryland areas were converted almost exclusively into production of dryland crops, possibly reflecting the sufficiency and competitive advantage of rice production in wetland areas. Partially irrigated and irrigated areas were allocated largely to double rice cropping. The increase in multiple rice cropping was closely associated with increases in wet-seeding of rice and, recently, dry-seeding (Fig. 3).

Table 7. Percentage of cropland in various cropping patterns, Iloilo Outreach site, Philippines, 1974-79.[a]

Pattern	Cropland (%)				
	'74-'75	'75-'76	'76'77	'77-'78	'78-'79
2 or more rice	5	20	38	49	45
I rice + 1 or more upland crops	11	28	30	17	31
2 or more upland crops	2	5	12	6	8
1 rice + fallow	82	47	20	27	14
1 upland crop + fallow	–	–	–	1	2

[a] The 1974-75 data represent average results of a 205-farm baseline survey conducted in January 1975. Data from 1975-79 came from a farm record-keeping study on 45 farmers selected randomly from the baseline list. Derived from: Genesila et a1 (1979).

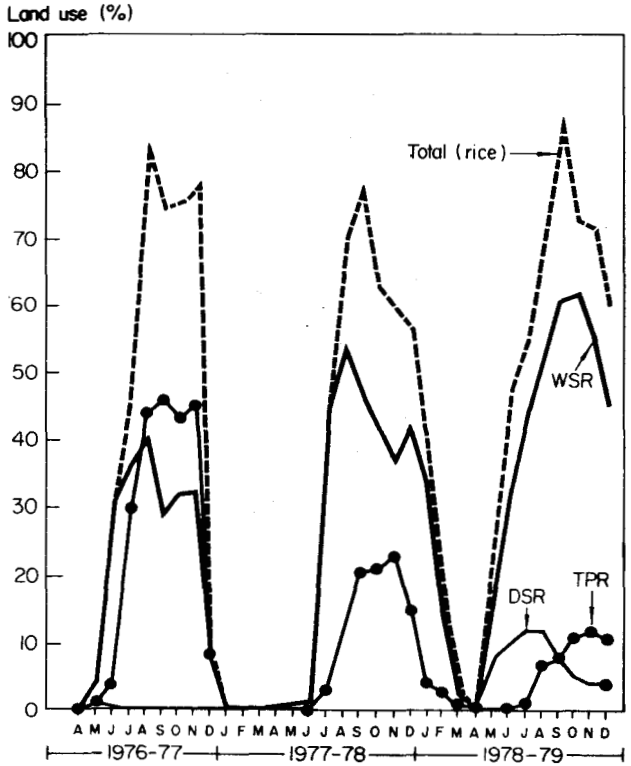
Table 8. Percentage of cropland of 45 farmers in various cropping patterns by water management category, Iloilo Outreach site, Philippines, 1976-79.

Cropping pattern [a]	Cropland (%)		
	1976-77 [b]	1977-78 [c]	1978-79 [c]
Rainfed lowland			
2 or more rice	30	19	28
1 rice + 1 or more upland crops [c]	43	30	46
2 or more upland crops	4	2	–
1 rice + fallow	21	48	25
1 upland crop + fallow	2	–	1
Rainfed upland			
2 or more rice	–	–	–
1 rice + 1 or more upland crops	66	8	6
2 or more upland	21	73	74
1 rice + fallow	–	6	–
1 upland crop + fallow	13	13	20
Partially irrigated			
2 or more rice	39	90	71
I rice + 1 or more upland crops	–	3	22
2 or more upland crops	–	–	–
1 rice + fallow	61	7	6
1 upland crop + fallow	–	–	1
Irrigated			
2 or more rice	96	100	96
1 rice + 1 or more upland crops	–	–	3
2 or more upland crops	–	–	–
1 rice + fallow	4	–	–
1 upland crop + fallow	–	–	1

[a] Upland crops imply all crops grown in the area other than rice. [b] Source: Roxas and Genesila (1977). [c] Source: Genesila et al (1979).

No such trend in cropping pattern shifts occurred in rainfed areas of Pangasinan. Dry-seeding was partially adopted. There was an upward trend in its adoption, but did not lead to increased rice multiple cropping. Table 9 shows a complete enumeration of all farmers who dry-seeded rice from 1975-76 to 1978-79 in the six cropping systems research villages in Manaoag, Pangasinan. The farmers' rice - rice pattern that appeared profitable on irrigated lands in the earlier analysis showed no positive trend. In the high water table area that was partially irrigated in 1975-76, the area in rice - rice actually declined in favor of rice - mungbean.

In high water table areas of Pangasinan, levels of crop inputs did not change; they ranged between 400 and 500 pesos/ha annually. In the deep water table areas, material inputs on a whole-farm basis increased from about ₱200/ha to ₱600/ha (Maranan 1979). Farmers said they learned better insect control techniques for mungbean, for which very high gains have been shown (Litsinger et al 1977), but there was little actual evidence in their practices or yields. They still sprayed too late to prevent the critical bean fly damage during the first 2 weeks after emergence and their highest insecticide rates showed no yield advantage over the untreated plots (Nicolas 1978).



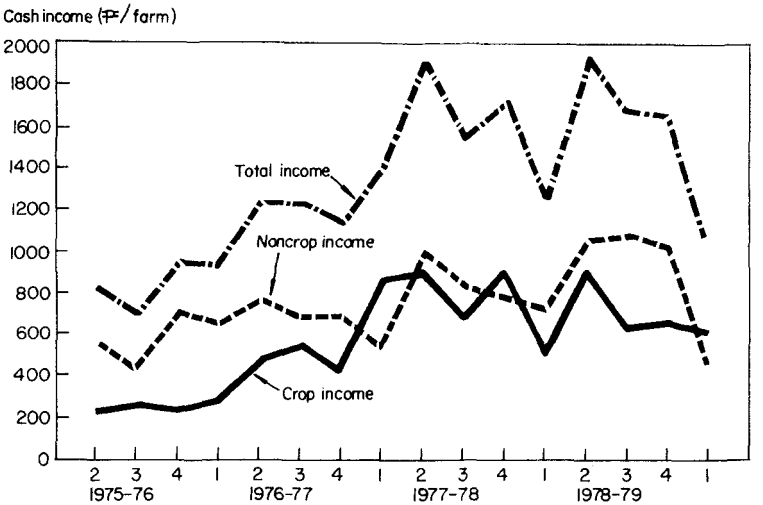
3. Percentage of land use by method of rice crop establishment Iloilo, Philippines, 1974-79. WSR = wet-seeded rice, TPR = transplanted rice, DS = dry-seeded rice.

IMPACT OF ADOPTION

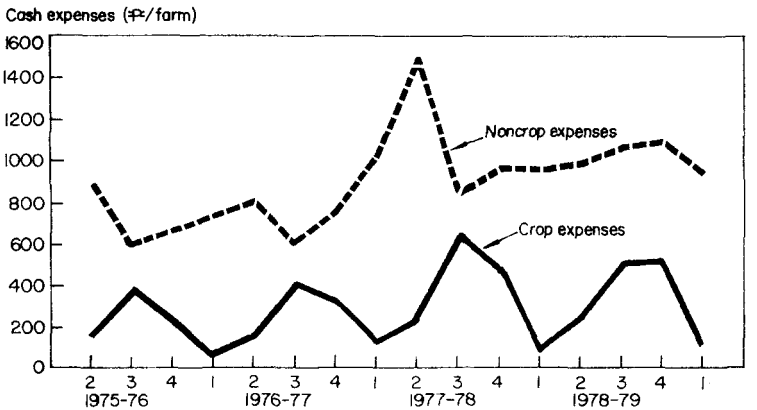
The adoption of new cropping systems in Iloilo had a major impact on incomes and expenses of farmers and patterns of labor use. The farmers cash income from crops increased from ₱970/farm per year to ₱2,780/farm per year from 1975-76 through 1977-78 (Fig. 4). The total cash income derived from crop sales increased from 26% to 44%. With higher incomes farmers spent more (Fig. 5). Crop expenses increased in absolute terms, but remained about constant as a percentage of total expenses (Table 10). Expenditures on nonfood consumption increased, but food consumption as a percentage of income declined.

Table 9. Farmers who adopted dry-seeding of rice, Manaoag, Pangasinan, Philippines, crop year 1975-79.

Crop year	Adoption of dry-seeding of rice					
	Agronomy cooperators		Influenced farmers		All farmers	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
1975-76	3	1.14	1	0.20	4	1.34
1976-77	2	0.72	1	1.63	3	2.35
1977-78	11	4.50	12	2.54	23	7.04
1978-79	32	13.07	29	7.92	61	20.99



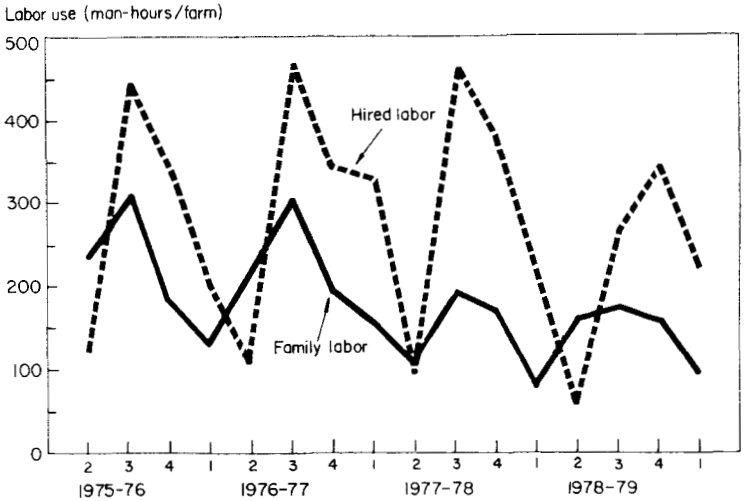
4. Average quarterly cash income of Iloilo farmers, Philippines, crop years 1975-76 to 1978-79.



5. Average quarterly cash expenses of Iloilo farmers, Philippines, crop years 1975-76 to 1978-79.

Table 10. Distribution of cash expenses by expenditure item, av of 45 farmers, Oton and Tigbauan, Iloilo, Philippines, 1976-79.

Item	1976-77	1977-78	1978-79
Food (%)	30	21	24
Crop inputs (%)	31	31	28
Household (%)	8	10	12
Education (%)	7	9	9
Livestock (%)	3	3	3
Others (%)	21	20	24
Total (₱/mo)	336	448	490



6. Quarterly labor use on Oton and Tigbauan farms, Iloilo, Philippines, 1975-76 to 1978-79.

There was a marked change in labor use. Total labor use at first increased (Fig. 6), but with the limited labor supply available during the critical turnaround time, threshing was mechanized. Total labor use appeared to be on the decline, but hired labor increased as a proportion of total labor. Hired labor was 57% of the labor force in 1975-76, increased to 67% by 1977-78, then declined to 60% in 1978-79. The number of farm workers declined from 2.8 to 2.3 persons per household, mainly because of a 35% decline in child labor. Adult workers declined 10%.

Mechanized threshing increased from zero in 1975-76 to nearly complete mechanization in 1979-80. Some increase in mechanical plowing occurred and the number of work animals declined (Table 11).

CONCLUSIONS

New cropping patterns designed and tested for Oton and Tigbauan, Iloilo, showed substantial advantages over the low-intensity, traditional crop activities of farmers. Rice double-cropping became the dominant technology of the area, based upon

Table 11. Average number of livestock owned by 45 farmers in Oton and Tigbauan, Iloilo. Philippines, 1975-79.

Year	Livestock (av no.)				
	Carabao	Cattle	Swine	Goats	Chickens
1975-76	1.32	.51	I.74	.31	10.7
1976-77	1.18	.52	1.10	.19	24.0
1977-78	1.10	.39	1.35	.13	21.6
1978-79	.96	.39	1.14	.13	25.2
t-statistics for difference 1975-76 to 1978-79[a]	34.6	4.2	6.7	8.7	3.6

techniques of early seeding of early-maturing varieties that were developed by the researchers. Experimental cropping patterns developed for Manaoag, Pangasinan, were less attractive than farmers' present relatively intensive system. Nevertheless, dry-seeding of early-maturing varieties was incorporated into present cropping patterns on rainfed and irrigated land. On land with a deep water table there was a threefold increase in expenditures for material inputs, spent chiefly on fertilizer.

The adoption of multiple cropping in Iloilo led to higher incomes from crops, a proportionate increase in the use of hired labor, but a decline in overall labor use, accompanied by mechanized threshing of rice. The earnings of hired laborers increased with the adoption of new systems.

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Assessment of the impact of the cropping systems program in Sri Lanka

N. F. C. Ranaweera and G. D. Siripala

The cropping systems program in Sri Lanka began in 1976. It was initially confined to Walagambahuwa in Anuradhapura District and Katupotha in Kurunegala District. Both sites were rainfed and the concepts developed were not new. In fact, for many years extension personnel had attempted to get farmers to start cultivation with the onset of the rains.

Since the inception of the cropping systems program there has been renewed interest in the importance of production programs in minor tank systems. Extension officers in areas similar to Walagambahuwa are encouraged to have at least one tank per season as a demonstration project.

We attempt to assess the possible impact the program has had in Anuradhapura and Kurunegala. But only the impact at Walagambahuwa, which is the minor tank system, is given in detail.

BACKGROUND AND RATIONALE AT WALAGAMBAHUWA

Walagambahuwa is a traditional dry zone tank village and is representative of about 3,000 similar settlements, covering about 104,000 ha of rice land. The region has a bimodal rainfall distribution, which is typical of most part of the country. The major cultivation season (maha) starts in mid-September with the onset of the northeast monsoonal rains and extends until mid-March. The settlement has a threefold land use pattern: the chena, which is land cleared for shifting cultivation on an 8-10 year cycle (the cycle has become much shorter and the cultivation more permanent); the settlement proper (Gangoda); and the paddy tract.

The traditional system of cultivation of paddy lands in the minor tank system is considered inefficient because of its lateness. Farmers did not begin cultivation till the tank was full. The results were relatively low cropping intensity and frequent crop losses. If the water stored in the tank was low, the area cropped was decreased and in the second season (yala) — from March to September during which minor southwest monsoonal rains are experienced — few crops are cultivated.

This practice made little use of the rainfall for crop growth and had about a

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3-month crop period. However, it was strongly felt that the uncertainty of the maha crop, induced by the variability in tank storage, could be eliminated by broadening the water-resource base. This could come from supplementing the current rainfall with tank water, which could act as insurance against crop failure. The water conserved could be planned for use from January to September when precipitation is low.

The broad objectives of the study for Walagambahuwa were:

- to understand the existing cropping systems in the paddy lands below the tank and in other lands, and their relation to the resources in the dry zone;
- to design, test, and evaluate rice-based improved cropping patterns for paddy lands below the small tanks for efficient use of irrigation water and other resources, and for adoption without seriously affecting other enterprises;
- to design, test, and define the crop management components of the patterns; and
- to develop, in cooperation with the Extension Division, a methodology to extend the findings to intensify cropping in similar areas.

The specific objectives during the first phase were:

- to study the feasibility and economics of cultivating a rice crop with the onset of the rains in the maha season;
- to take stock of the farm-level resources and their use and income under the changed pattern and to identify the possible constraints in resources allocation between paddy land and *chena* lands;
- to evaluate possible alternate crops for the yala season; and
- to design and test the management components of the crops — varieties, methods of crop establishment, and fertilizer use for maximum crop yields.

Walagambahuwa was identified as a typical traditional tank village in the Dry Zone and was close to the Dry Zone Agricultural Research Station at Maha Illuppallama. In view of the representative nature of Walagambahuwa and the large number of such village tanks in Anuradhapura, it can be assumed that, after nearly 3 years of research work, the impact of the basic concept proposed should be measurable.

METHODOLOGY USED

In dealing with impact assessment studies, many approaches could have been taken — impact on incomes of farmers, creation of more on-farm employment due to increased cropping intensity, variability in the net benefits among farmers in villages under minor tanks, etc. However, for any of those parameters to vary, there has to be a certain degree of adoption by the farmers in the village. Therefore, a one-shot survey was conducted to assess the present farming practices of nearly 250 farmers in nearly 25 villages around Anuradhapura. Information on their opinion about the concept in general was also obtained.

In the choice of villages for the survey, the following procedure was followed:

- An estimated 40 tank villages now follow the cropping systems practices at Walagambahuwa through a program directed by the extension officers in the district. A random sample of 10 of those villages was used (Category A).

- Ten tank settlement schemes not officially following the practices were also selected (Category B) as were five tank settlements close to Walagambahuwa (Category C).
- Kurunegala District had 10 minor tanks in cropping systems. Five of those were sampled (Category D) as well as 5 tank settlements not officially in the cropping systems program (Category E).

The survey was conducted in February 1980, during the 1979-80 maha season. The questionnaire sought data on time of land preparation, planting, cultural practices, and opinions about the program.

RESULTS

The results from the study are presented in two stages. One relates to the survey in Anuradhapura, the second for Kurunegala.

Anuradhapura district

Tables 1-8 illustrate the findings at Anuradhapura.

Land ownership. Table 1 shows the average ownership of land under the different crops. In almost all categories, nearly 80% of the land was cultivated.

Land preparation. Most farmers in all categories prepared their land after the tank was at least half-filled. This was particularly true in the ancestral rice land found immediately below the tank (puranawela). In recently acquired land in category C, a large number of farmers prepared their lands before the rain or at the start of the rains (Table 2).

Table 1. Land ownership at Anuradhapura, Sri Lanka. 1979-80.

Category [a]	Land ownership (ha)							
	Puranawela [b]		Akkarawela [c]		Olagama [d]		Chena [e]	
	Owned	Culti-vated	Owned	Culti-vated	Owned	Culti-vated	Owned	Culti-vated
A	0.52	0.48	0.76	0.72	0.88	0.76	0.68	0.64
B	0.40	0.32	0.48	0.44	0.24	0.24	0.44	0.44
C	0.44	0.40	0.72	0.72	1.12	0.72	0.60	0.60

[a] A = 10 tank villages in Walagambahuwa, B = 10 tank settlements not officially following the practices, C = 5 tank settlements near Walagambahuwa. [b] Ancestral rice land immediately below tank. [c] Recently acquired rice land slightly higher than *puranawela;* dependent on tank water. [d] Rice land owned in other villages near similar tanks. [e] Land in shifting cultivation.

Table 2. Land preparation at Anuradhapura, Sri Lanka, 1979-80. [a]

Category	Farmers (%) reporting time of land preparation								
	Puranawela			Akkarawela			Olagama		
	Before rain	With rain	After filling tank	Before rain	With rain	After filling tank	Before rain	With rain	After filling tank
A	12.3	32.1	55.6	5.5	31.9	62.6	14.3	35.7	50.0
B	14.3	21.4	64.3	16.0	34.0	50.0	11.6	26.3	61.5
C	14.7	26.5	58.8	27.9	39.5	32.6	18.2	18.2	63.6

[a] Footnotes as in Table 1.

Planting methods. As direct reflection of the delayed land preparation, plant establishment, too, was after the tank was partly or completely filled (Table 3). The method of planting was 100% broadcasting, and more than 65% of varieties used were late maturing (mostly 4 months) (Table 4). The seeding rate was considerably higher than recommended. The only type of weed control used was chemical (Table 5). The low percentage of dry seeding reported an analysis of the problem associated with it indicated the main problems were either financial, lack of power, or the preference for *chena* (Table 6).

Fertilizer use. Fertilizer use in categories A-C showed no clear pattern (Table 7).

At Walagambahuwa, more than 90% of the farmers in all categories indicated the possible applicability of the cropping systems concept (Table 8). However, they indicated that it is difficult to apply the concept, primarily because of the preference for chena or their inability to achieve unity among themselves. This was particularly so in the village close to Walagambahuwa.

Table 3. Planting method at Anuradhapura, Sri Lanka, 1979-80.[a]

Category	Farmers (%) using a given planting method								
	Puranawela			Akkarawela			Olagama		
	Dry sowing	With rain	After filling tank	Dry sowing	With rain	After filling tank	Dry sowing	With rain	After filling tank
A	2.2	35.7	62.1	0.9	21.6	17.5	9.3	28.4	62.3
B	7.2	24.8	68.0	15.3	32.9	51.8	11.6	24.5	63.9
C	11.4	25.3	63.3	27.9	39.5	32.6	17.8	18.5	63.5

[a]Footnotes as in Table 1.

Table 4. Varieties of different maturity periods used at Anuradhapura, Sri Lanka, 1979-80.[a]

Category	Farmers (%) reporting use of a given variety					
	Puranawela		Akkarawela		Olagama	
	Short maturity	Long maturity	Short maturity	Long maturity	Short maturity	Long maturity
A	22.8	77.2	29.5	70.5	15.4	84.6
B	35.3	64.1	33.3	66.7	64.0	36.0
C	31.4	68.6	38.9	61.1	78.3	21.7

[a]Footnotes as in Table 1.

Table 5. Chemical weed control at Anuradhapura, Sri Lanka, 1979-80.[a]

Category	Farmers (%) reporting					
	Puranawela		Akkarawela		Olagama	
	Yes	No	Yes	No	Yes	No
A	71.6	18.4	87.1	12.9	85.7	14.3
B	72.7	27.3	82.6	17.4	70.0	30.0
C	75.8	24.2	95.1	4.9	72.7	27.3

[a]Footnotes as in Table 1.

Table 6. Problems associated with dry seeding at Anuradhapura, Sri Lanka, 1979-80.

Category [a]	Farmers (%) reporting			
	Financial	Power	Preference for shifting cultivation (chena)	Lack of coordination among villages
A	49.0	12.0	29.0	10.0
B	22.0	41.0	20.0	17.0
C	12.0	38.0	42.0	8.0

[a]Footnote as in Table 1.

Table 7. Fertilizer use at Anuradhapura, Sri Lanka, 1979-80.[a]

Category	Farmers (%) reporting					
	Puranawela		Akkarawela		Olagama	
	Yes	No	Yes	No	Yes	No
A	44.3	55.7	46.2	53.8	33.3	66.7
B	64.1	35.9	77.1	22.9	45.8	54.2
C	67.6	32.4	90.2	7.8	40.9	59.1

[a]Footnotes as in Table 1.

Table 8. Popularity of the cropping systems at Anuradhapura, Sri Lanka, 1979-80.

Category[a]	Farmers (%) reporting				
			Reasons for inapplicability		
	Heard about it	Felt concept applicable	Power shortage	Lack of unity among farmers	Preference for shifting cultivation (chena)
A	53	93	17	25	58
B	64	92	27	18	54
C	92	93	24	76	–

[a]Footnote as in Table 1.

Kurunegala district

Land ownership. Nearly 90% of all the land was cultivated.

Land preparation. Land preparation was relatively uniform, with most farmers cultivating their lands either before the rains or just after the rains. In the previous maha most of the farmers prepared their lands either with the rains or after filling of the tank.

Planting methods. As a result of uniform land preparation, most farmers chose to dry seed. particularly in the areas under the extension program. The varieties used during 1979-80 maha were mostly early-maturing. Weed control was mainly with herbicides.

Fertilizer. The overall response to the acceptability of fertilizer was positive.

DISCUSSION

In assessing the impact of the cropping systems program, one can only determine the degree of acceptance and assess any shortfalls. Even in attempting to do this, we bear in mind what the researchers set out to achieve. It is clear that the main objectives were to encourage the farmers to:

- maximize the use of rainfall without depending on tank water for irrigation;
- consequently attempt a *yala* crop with the water saved in the tank; and
- increase farm incomes.

The results we present lead to a number of possible interpretations. We make no attempt to come to a positive conclusion as to whether the program succeeded or not. But a few facts emerge from our first analysis of the results:

- The farmers in Anuradhapura still do not have a positive preference for dry seeding of rice. Most farmers tend to wait for the rains to begin land preparation. The farmers also have a definite preference for recently acquired land primarily because the landholding in that category is larger.
- Although farmers indicate their preference for dry seeding of rice, factors such as lack of financial resources, farm power, and the influence of shifting cultivation constitute main reasons for nonadoption of this concept. At this point, it is worth noting that a part of the problem may lie in the lack of an adequate extension program to provide farmers with the information they require on the profitability of this approach.
- Because of late land preparation and sowing, farmers tend to use late-maturing varieties, which means that the possibility of getting two crops with the remaining water is not feasible.

Another important result in Anuradhapura is a clear farmer preference for broadcasting. Farmers felt it was relatively easier and cheaper to broadcast than to transplant or row seed.

The question that could be posed now is whether the Cropping Systems Program in Anuradhapura had any effect. The answer is in the affirmative. But it is clear that an active extension program is needed.

In Kurunegala analysis of the data indicates that the program is better appreciated and understood in tank villages under the extension program and in other villages. Most farmers prepared their land and sowed either before the rains or with the rains. This contrasted with the previous season's practice when most farmers cultivated their land only after the tank was filled. Consequently better varieties and cultural practices were used. Most farmers indicated that they heard of the program through either the extension officers, mass media, or neighbors, but that they could not adopt it because of the high risk involved.

It may be prudent at this point to assess the reasons for this nontransfer of technology. It may be due to inadequate understanding of the technology transferred, by both the extension worker and the farmer. It may also be due to lack of an understanding of the socioeconomic structure of farmers. There may also be lack of support to sustain this new technology.

One of the major constraints identified by farmers was the lack of cooperation in relation to timeliness of land preparation. If the water issue meetings are held before

the rains, it is possible to get all farmers to accept this technology. If some farmers are not prepared to ready their lands early, and wait till the rains come, problems are caused in terms of water issued from the tank. It is therefore essential that a certain degree of leadership be encouraged in the farming community.

CONCLUSION

It is difficult to positively conclude that the cropping systems program is a success or a failure. It is clear, however, that the concept is accepted among the farmers and that effective extension activities may be able to spread it.

Summary report

INSECT MANAGEMENT

The group made the following points:

1. There is a need for an entomology input in cropping systems research and development because insect control represents a major purchased input expenditure and needs local testing to optimize profits to farmers.
2. The number of entomologists working at cropping systems sites in Asia increases every year. But the number of sites increases faster than the number of available entomologists. This problem can be overcome in part by placing entomologists at sites that represent the most divergent agroclimatic zones and thus the most divergent insect problems.
3. To be relevant, insect control recommendations designed for cropping pattern testing at a site should be more specific than the national recommendations. However, the need for flexibility should be recognized. Final recommendations should give farmers a wider choice of insecticides and minimize the possibility of development of insect resistance.
4. The institutional isolation of entomologists in cropping systems research is a problem. One way of overcoming it is through annual meetings in national programs.
5. Good linkages between on-site entomology work and basic research are essential if the full benefits of cropping systems work are to be realized.
6. Better criteria for standardizing the results of insecticide screening trials are needed.
7. Even if credit programs are available, there is a need to develop less expensive insect control technology that can be adopted even by low-income farmers. This can be best achieved through the development of insect-resistant varieties, especially nonrice crops, insecticide seed treatments, or better insecticide delivery equipment (such as spinning disc or electrostatic sprayers).
8. Extension plays an important role in teaching farmers insect control technology. Cropping systems workers can assist extension services to make the farmers understand the technology better.
9. The complementarity between the objectives of cropping systems work and integrated pest management was stressed. Cropping systems is a pre-extension activity, whereas integrated pest management is an extension-related activity.

WEED CONTROL

The following points were discussed:

1. **Methodology for cropping systems weed research**

   The group reviewed the proposed research methodology and agreed to test it in their respective countries. Comments as to its feasibility will be made after the trials. Suggestions to improve it will be made later.

2. **Identification of major problem areas**

   Training in weed science. The group felt that this was a pressing need in their respective countries. At least one or two persons in each country should earn the MS or Ph D degree with specialization in weed science so that they can serve as leaders of the weed science component of the cropping systems program in that country.

   Additional people should be trained in a weed science training course of 3 to 6 months. It was suggested that IRRI arrange such a training course either at regular intervals or on request by concerned agencies as the need arises.

   Variabilities in weed populations. Everyone agreed that this was a problem. It was felt that little else could be done to overcome it, beside increasing the number of replications and trying to select fields that have similar weed populations.

   Report writing. In reporting experimental results such information as the dominant weeds, environmental conditions, and agronomic practices should be included. The conditions under which the crop is grown should be defined precisely. For example, using the term *direct seeding* for rice is unacceptable. One or two sentences to explain its exact meaning are needed.

   Training in taxonomy. Few people in the countries concerned have the capability to correctly identify weeds. People with MS or Ph D degrees in weed science and people who have attended a weed science training course should take courses or attend lectures in taxonomy. There may be a need for a person with a Ph D or MS in Botany with specialization in taxonomy.

   It was suggested that if weeds could not be correctly identified in the countries concerned, they should be sent to IRRI for identification.

   Books and colorslides that can be used for weed identification and as a tracking tool. Several books can be of help in weed identification. Each representative was asked to send IRRI a list of these books, together with the authors and publishers so that a compilation could be made. It was hoped that at least one copy of the best books can be bought for each country in the Asian Cropping Systems Network.

   The group felt a need for slides of the most common weeds (in the mature and the seedling stage) to be used in weed identification and in training people within each country. Because such slides are not available commercially, Dr. K. Moody was requested to prepare such a set that could be purchased by interested people. People from other countries were asked to take photos of other important species that are not available in the Philippines and forward them to Dr. K. Moody.

   Exchange of technical papers. The group felt a need to exchange technical

papers to keep the members abreast with ongoing work in the network and in other areas of the world. The materials for distribution should be sent to IRRI where they will be multiplied and forwarded on a regular basis to the member countries.

Weed science working groups. It was felt that a weed science group, with representatives from each of the countries of the Asian Cropping Systems Network, should be formed. Each country of the network will be asked to name a representative to that group.

At least one person in the group should be a member of the working group of the Asian Cropping Systems Network.

The weed science working group should meet from time to time to review each country's program and achievements and to discuss problems.

3. **Plans for collaborative research**

The group did not think a collaborative research program was necessary at the present time.

CROPPING SYSTEMS ECONOMICS

The economics working group considered in depth the problems faced by national programs in making a more meaningful contribution to the general development of the overall cropping systems progress.

Views on how that may be achieved differed. One suggestion was to look downstream — tackle the problems facing the implementation of the programs in the individual countries — in as much as the programs are now past the testing phase.

The main problem in most national programs is lack of adequately trained personnel at individual sites. Economists assigned to some sites did not know some basic analytical techniques. The problem is aggravated by the speed with which development of new sites is taking place.

The group found that a concise training manual, which can be used to train the economists involved in cropping systems-type research at the sites, was needed. The group agreed to prepare one.

The manual will contain the following topics:

1. The role of economists in cropping systems research
2. Agroeconomic profile of the site
3. Economic evaluation of agronomic experiments
4. Enterprise/partial/parametric budgets
5. Estimation of factor shares
6. Farm-level evaluation of cropping pattern options
7. Introduction to supply and demand (marketing) factors and product markets
8. Sampling procedures
9. Costs of production of crops

The first draft of the manual will be available by the end of May and final publication is later in the year. The handbook will be translated into the different languages of the respective countries.

Some methodological approaches that appear important in cropping systems-

type research were discussed. The consensus was that such research should be confined, in the first instance, to IRRI where computer facilities are available. The national programs will use *Simplified programming,* which requires only pocket calculators.

The issue of collaborative research among different countries and IRRI was also discussed. The group recognized that many problems, including evaluation of farming systems will surface in pilot production programs. It was agreed that future individual programs wil be drawn up in collaboration between the different countries in the network and IRRI.

CROPPING PATTERN MONITORING AND TESTING

The chairman reviewed the objectives and reasons for cropping pattern testing and monitoring. In brief, the cropping patterns are designed for specific land types based on previous information. The cropping pattern to be tested is specified in terms of management packages. Four to six fields are then chosen for each land type and pattern. During execution, there is a need to monitor the patterns. That provides a systematic way of collecting data for evaluating the test either in terms of agronomic or economic criteria or to explain why the pattern performed the way it did. Evaluation will help define any need for more information and future research priorities.

Monitoring during cropping pattern testing was discussed. Monitoring aims to devise an efficient and manageable means of handling data. A set of monitoring forms introduced in the network in 1977 and used by the IRRI program was discussed.

Form A, the climatic data sheet, elicits information on evaporation, solar radiation, temperature, and rainfall. The sheet can be modified to include other climatic factors considered important, e.g. wind speed in Sri Lanka; flooding in Bangladesh. Rainfall data vary even among adjacent areas and should be collected with rain gauges placed near (within 1 km) the fields where the patterns are tested. Other data can be collected from the nearest weather station.

Form B can be used for plot monitoring. Because of the variable quality of manpower at the sites and the problems of data collection, the minimal amount of data needed should be identified on the sheet. Problems differ between countries and between land types, hence the form should be flexible.

Similar comments were made for Form C, the crop record.

Form D is designed for plot monitoring. This modified form collects data as they occur. It was felt that the form needed some explanatory notes on how to measure and the degree of accuracy needed.

The crop status reports should be done at the end of the season and should indicate the seriousness of problems. A special form for soil moisture monitoring should be used if this is a problem at the site.

It was felt that in addition to these forms, another form should be developed to collect weekly or monthly economic data on input and output prices and labor costs for major operations at each site. The data may include both government price and farm gate price. The farm gate price would more closely resemble the return

ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM A: DAILY CLIMATE DATA
See instructions overleaf

Record all data to the nearest whole number in the units indicated

Country _____ Site _____ Calendar year 1 9 Month

Day	Evaporation (mm)	Solar radiation (cal/cm²/day)	Temperature (°C) Minimum	Temperature (°C) Maximum	Temperature mean	Rain gauge . . . . (mm) 1	2	3	4	5	Mean	Comments
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
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17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
Total												
Mean												
Initial of recorder												

[a]Readings from rain gauges located far from the research fields (e.g.,) at the site office) should not be entered on this form.

How To Use This Form

1. Below is an example of the form used for January 1976 at the Philippine site in the town of Oton.

2. Enter COUNTRY and SITE in words; they will be coded later at IRRI.

3. Enter the YEAR and MONTH in the boxes. Code months 01 for January through 12 for December. Take a new sheet for each month.

4. Enter all data as whole number (round 0.5 up). There should be no decimal points anywhere on this form.

5. EVAPORATION, SOLAR RADIATION, MINIMUM AND MAXIMUM TEMPERATURE may not all be available at the site but may be available from a nearby meteorological station. If suitable data for any of these variables are not available, leave the appropriate column(s) blank.

6. Each RAIN GAUGE at the site should be assigned an identifying number (1-10), which is retained as long as the gauge remains in use, and the data for that gauge always entered in the same column on the form from month to month, and year to year. Enter the location of each gauge in the correct box. When entering data from the different gauges, check across the gauges. Large discrepancies between gauges located nearby may indicate errors of recording and should be double checked.

7. Anyone entering data on the form should record his or her initials at the bottom.

8. COMMENTS should be written in whenever you think necessary. Always comment on:

   i) unusual events,
   ii) changes in the source of the data
   iii) whenever equipment is changed, serviced, or restandardized.
   iv) missing data (see note 9).

9. Missing data: when data are temporarily not available, enter a dash (-), and give an explanation under COMMENTS.

10. Copying data: we expect that the data on this form will be copied from other forms, for example the records of a local meteorological station for some or all of evaporation through maximum temperature, and field notebooks for rain gauges located at cropping pattern trial plots. Please double check when copying so as to preserve the accuracy of the data. If possible, keep the original data as a safeguard against loss of this form.

Country Philippines Site Iloilo - OTON Calendar year 19 7 6 Month 0 1

Day	Evaporation (mm)	Solar radiation (cal/cm²/day)	Temperature (°C) Minimum	Temperature (°C) Maximum	Mean	Rain gauge (mm) 1 BI[illegible]	2 BA[illegible]	3 [illegible]	4 [illegible]	5 BI[illegible]	6 [illegible]	7 BURAN	Mean	Comments
1	—	285	24	29	27	0	4	0	0	8	4	6	3	
2	3	332	23	31	27	0	0	0	0	0	0	0	0	
3	4	385	24	31	28	20	30	25	28	18	7	6	19	
4	4	440	22	31	27	0	0	0	0	0	0	4	1	
5	4	500	22	31	27	0	0	0	0	0	0	3	1	
⋮														
31	5	352	21	29	25	0	0	0	0	0	0	0	0	
Total			679	973	826	0	48	42	39	31	21	27	30	
Mean			22	31	27									
Initials of recorder	JL	JL	JL	JL		JL	CRD	DOL	NCB	WH	EBM	FCA		

ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM B: PLOT RECORD

Country _____ Site _____ Calendar year at start of crop year 19 ___ Plot no. ____

Use this form to describe the physical characteristics of the plot. If data is gathered from this plot for more than one crop year, retain the same plot number and enter a new form B for each crop year. Mark with dash (-) any nonapplicable, unavailable, or missing information.

1. PLOT DIAGRAM
Indicate length and width (in meters)

2. PLOT SPECIFICATIONS

Nearest Form A rain gauge Barangay _____ Number ___

Area of plot (sq m) ____

If plot is bunded: Bund Height (cm) ___; Bund Width (cm) ___

Landstratum ___

Slope of land (%) ___

Surface drainage (0=to adjacent field; 1=to a man-made or man-improved ditch; 2=to natural drain (small stream or gully) ___

3. DIAGRAM OF PROPOSED PATTERN
Month before first crop planting _____

Months: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th

4. DIAGRAM OF IMPLEMENTED PATTERN

Months: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th

5. MONTHLY IRRIGATION SUPPLY EXPECTED THIS CROP YEAR:

(0=none. 1=1-7 days per month. 2=8-14 days. 3=15-21 days. 4=22+ days)

Month: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th

6. SOIL DESCRIPTION
Soil series (local name) _____

PROFILE DESCRIPTION

Depth (cm)	Soil texture: Manual	Soil texture: Lab	Soil pH	Soil color	Organic* ( )	Fertility: P( )	Fertility: K( )

P soil test method _____
K soil test method _____
Organic method _____
Laboratory _____

Soil texture: S = sandy; LS = loamy sand; SL = sandy loam; L = loamy
SIL = silt loam; SICL = silty clay loam; CL = clay loam; SIC = silty clay; C = clay
*Indicate whether organic carbon or organic matter. Enter units, e.g. % or ppm in ( )

ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM C: CROP RECORD

Country _____ Site _____ Calendar year at start of crop year 19 ___ Plot no. ____

Cropping pattern (circle this crop) _____ Crop _____ Variety _____ Crop position ___

Use this form to describe the planting and harvesting of one crop. There should be a separate form C for each crop in the cropping pattern. If more than one crop shares the plot (e.g. intercrops, relay crops, split plots, strip crops), a separate form C is required for each crop.

1. PLOT-CROP DIAGRAM

Draw a plot-crop diagram only with superimposed trials. Indicate area of each sub-plot. Otherwise leave it blank.

Size of whole plot (m^2) ____ Total area of superimposed trial (m^2) ____

2. If this crop is not the crop in original pattern design, give reason for change

_____

3. AREA PLANTED WITH THIS CROP (m^2)
(Exclude any superimposed trial area) ____

4. PLANTING CHECKLIST

These questions refer to the establishment of the crop itself, not the establishment of seedbeds for transplanting.

Date of first planting (Year, month, day) ____

Planted on: 1=clean fallow; 2=stubble ___

Crop type: 1=sole; 2=relay; 3=intercrop; 4=ratoon ___

Method of planting: 1=broadcast; 2=row seeded 3=transplanted ___

Pregerminated seeds: 1=yes; 2=no ___

Seeding rate (kg/ha) ____

Row spacing (if not broadcast) (cm) ____

Plant or hill spacing (if not broadcast or drilled) (cm) ____

Age of seedlings (days) ____

Seedlings/hill (no.) ___

5. CROP DAMAGE REPORTS

	Rating		Rating
Weeds		Insect/pests	
Lodging		Other	

Weeks after planting when most lodging occurred ____

RATING SCALE: Weeds, Pest, and Lodging status

0 no economic damage
1 slight economic damage
2 moderate economic damage
3 severe economic damage

6. HARVESTING

Date Year, month, day	Product type	Crop cut sample(s) Area(m^2)	Yield (kg)	% moist	Calculated yield % moist	kg/ha	Initials of recorder	Comments (especially if crop failed or when yield is low because of drought, flooding, rodents, brids, and others)

7. Stand at harvest (%) ____. Reasons for low stand _____

ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

CODING FOR FORM D
SUMMARY OF CODING
(See manual for full details)

WHEN TO TAKE A NEW SHEET

each PLOT each CROP each CROP POSITION each YEAR

FERTILIZER/INSECTICIDE CODES

- are provided separately to coders

MANHOURS

Multiply the number of people working by the time worked. Round to the nearest whole number (round 0.5 up). Enter 0 for values 0.01 to 0.49 labor hours

QUANTITY UNITS

Record quantity to the nearest whole number. Enter units (e.g. kg, gm, cc, %)

POWER/TRACTOR CODES

1 draft animal
2 hand tiller
3 tractor

CROP CODES

High yielding rices	Native rices	Grain legumes	Coarse grains	Miscellaneous
01 Dry-seeded direct	06 Dry-seeded direct	12 Mungbeans	21 Corn (Maize)	31 Cassava
02 Wet-seeded direct	07 Wet-seeded direct	13 Cowpeas	22 Sorghum	33 Sweet potatoes
03 Transplanted	08 Transplanted	14 Peanuts		
04 Ratoon	09 Ratoon	16 Bush sitao		44 Others

UNIFORMITY SCORE

1 80% in 3 days or less
2 80% in 3-7 days
3 80% in 8 days or more

FIELD WATER STATUS CODES: 1 or greater = depth of water; S = saturated; W = wet; M = moist; D = dry

OPERATION AND CROP DEVELOPMENT CODES — Enter: date, operation, code and details in the columns indicated

(REPORT ONLY ACTIVITIES CONDUCTED ON THE PLOT .....)

h=time p=power source (tillage) m=material type q=material quantity c=comments s=score

Land preparation

01 Clearing residue. . h
02 Field repairs . . .
03 Plowing . . . . . hp

04 Harrowing . . . . . hp
05 Levelling . . . . . hp
06 Furrowing . . . . . hp

09 Other land prep . . hc

Crop establishment

20 Transplanting . . h
21 Planting . . . . h
22 Replanting . . . h

23 Thinning . . . . h
29 Other crop establishment . . hc

Crop care

30 Fertilizing. . . . . mqh
31 Pesticide application . . . mqh
32 Herbicide application . . . mqh

34 Handweeding . . . . . h
35 Mechanical weeding . . . . . hp
38 Hilling-up . . . . . hp

39 Off-barring. . . . . hp
49 Other crop care. . . . . hc

Harvesting

51 Manual harvesting. . h
53 Manual threshing . . h
54 Power threshing . . h

55 Manual winnowing . . h
69 Other harvest . . . c

Crop development

80 Initial emergence . . . . . sc
81 Initial flowering . . . . . sc
82 Crop cut sampling . . . . . sc
83 Crop failure c

ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM D (office)

Country _____ Site _____ Calendar year this month 19 ___ Plot no. ____

Recorder _____ Number of crops sharing the plot ___ If more than 1, use separate forms for each crop Crop _____ Crop position ___

Date Month 01-12 Day 01-31	Field water status	Operation	Code 1-99	Material (Name, formulation, % A.I.) m	Code 1-9999	Quantity/plot 1-99999 q	units q	Labor hours (people x hours) 0-99 h	Power traction p	Power 1-99 h	Non-SI	Area to which operations apply (m^2) Total Non-SI Comments c	Score s

"CROP FAILURE" should be indicated at the date the crop was discontinued.

obtained by the farmer.

Summarizing the data collected during monitoring was discussed. The group felt a strong need to identify the minimal criteria to be used in comparing cropping patterns for a particular year. Attention should be less on how to collect data than on the minimum amount needed. A small committee was formed to determine essential standard parameters. The results of its work are shown in the attached sheet.

In the past, results of an experimental pattern were reported but not compared with those of existing farmers' patterns. Existing patterns should be monitored and compared with the new pattern. It is essential that monitoring of the existing pattern be done concurrently with that of the new pattern.

Additional data to explain shifts or changes that occur in the new cropping pattern while they are being tested would also be needed; why do some crops fail, why is the cropping pattern not implemented as planned?

The question of how one designs new patterns was raised. It was felt that the farmer should be made aware that we are experimenting. If we fail, he should have some form of compensation. A close relationship with national research stations should be maintained. It is important that the physical environment of the station closely approximate that of the test site. We need also to include crops or researches that may not be feasible now — markets may change in the future. We need three levels of evaluation:

- agronomic feasibility — Is it better than the existing?
- economic feasibility — Can the farmer do it with his resources?
- economic incentives — Would the farmer want to do it? What are the market demands?

VARIETAL TESTING FOR RICE AND OTHER UPLAND CROPS GROWN BEFORE OR AFTER RICE

Varietal evaluation of promising varieties of rice and upland crops is one of the collaborative projects in the Asian Cropping Systems Network. The primary emphasis is on identifying promising varieties of upland crops that can be grown before or after wetland and dryland rice. The important upland crops are maize, sorghum, soybean, peanut, mungbean, cowpea, sweet potato, and other crops such as lentil, black gram, and chickpea. For rice, organized international and national varietal testing programs are in progress. The scheme allows interchange of genetic materials between international centers and national programs and between national programs. The cropping systems project in each country works very closely with breeders to get the recommended varieties from national variety trial schemes.

IRRI is collaborating with the Institute of Plant Breeding, University of the Philippines at Los Baños (UPLB), in screening upland crop varieties to identify those adapted to intensive cropping. Genetic materials for screening come from the international centers and institutes, and national programs. They are screened in rainfed wetlands after rice with zero tillage and before rice with high tillage, and in uplands with 40% shade and high tillage. The most promising varieties from the screening are turned over to IRRI for seed increase and distribution to collaborators in the network. Dr. Arturo Gomez presented in the conference the paper "Screening

of upland crops for intensive cropping in the Philippines." The number of genotypes evaluated for each crop is shown in Table 1. For each crop 4-6 most promising genotypes were presented. The genotype × environment analysis indicates that

- the correlation coefficients for performance in normal monocrop and multicrop environments are positive although *r*-values are low. That suggests that good monocrop varieties are more likely to be good in multicrop environments; and
- the *r*-values associated with the postrice environment are much lower than those associated with shade. This suggests the need for a breeding program that selects for varieties specially suited for the postrice environment.

The network is also collaborating with the Field Crops Division, Department of Agriculture, Thailand, on varietal screening of upland crops, mostly legumes. The paper "Varietal screening of grain legumes for cropping systems" was prepared by Dr. Arwooth Nalampang and Sorasak Maneekoa. The most promising early-maturing genotypes from their screening in Chiang Mai were evaluated in Roi-et Experiment Station before and after rice. Genotypes evaluated after rice matured earlier, had short plant height and lower yields than genotypes before rice. Seventeen of 26 entries were better than SJ 4 (recommended check variety) after rice. Of the entries before rice, 11 matured in less than 80 days (74-79 days). They yielded 1.09-2.20 t/ha, compared to SJ 4 which matured in 103 days and yielded only 0.27.

Earlier peanut screening was not encouraging but in the new collections from the International Crops Research Institute for Semi-Arid Tropics, 100 of 300 entries matured between 80 and 87 days. The yield potential of 27 high yielding materials was 1.5 t/ha before rice.

Papers on varietal evaluation for rice and upland crops in different countries involved in the network were presented at the conference. Each country had a paper on varietal evaluation, and during the conference a summary report for each crop was presented. The titles and authors of the papers are indicated below:

1. Varietal performance tests on food legumes and cereal crops from multiple cropping in Burma - Tung Saing, Pe Maung Thein, Aung Shwe, and Shirley Smellie
2. Varietal performance of sweet potato in the Asian Cropping Systems Network — Azucena L. Carpena

Table 1. Number of genotypes evaluated by the University of the Philippines at Los Baños program in 3 multiple cropping environments. IRRI, 1980.

Species	Genotypes (no.) evaluated		
	After rice	Before rice	With shade
Mungbean	221	2077	2557
Soybean	1828	837	620
Cowpea	953	399	170
Sorghum	215	16	142
Sweet potato	159	4	78
Tomato	129	90	148
Egplant	35	40	48
Maize	271	28	237
Adzuki bean	23	–	–
Peanut	–	–	25
Total	3834	3491	4025

3. Varietal performance of wetland rice under rainfed conditions in Northeast Thailand — Boriboon Somrith
4. Varietal performance testing of upland and rice crops in the Indonesia cropping systems outreach sites, 1977-79 — A. Rasyid Marzuki and Suryatna Effendi
5. Research highlights on peanut (Indonesia) — A. Rasyid Marzuki and Astuti Rais
6. Varietal development in relation to variable cropping systems, with particular reference to Bangladesh — Sharafot Hossain Khan
7. Role of grain legumes in farming systems in Sri Lanka — M. H. J. P. Fernando
8. Varietal performance of promising rice and upland crops at IRRI and Philippine cropping systems research sites 1978-79
9. Varietal performance of upland crops in Serdang and the cropping systems research sites of West Malaysia — Abu Kassirn b. Abu Bakar, Ramli b. Mohd. Noor, Halim b. Hamat, Fadelah bt Akd. Aziz, Zaharah bt Hassan, and Noor Rawi b. Abu Bakar
10. Grain legume improvement project in Nepal — M. P. Bharati

During the presentations, the organizers requested the following to summarize the individual crop reports for presentation in the conference.

Maize and sorghum — Virgilio R. Carangal
Rice — Boriboon Somrith
Root crops — Azucena L. Carpena
Soybean, mungbean, and cowpea — Arwooth Nalampang
Peanut — A. Rasyid Marzuki

A summary for each crop is presented in Tables 2-10. The tables show the site, type of rice land on which the trial was conducted, type of tillage, number of entries. yield range of up to five promising varieties better than the check — which in almost all cases was the present recommended variety — and the year of tests. In almost all trials the identified promising varieties were better than the best varieties presently recommended. More detailed information on each trial is in the individual papers. Additional information may also be obtained from the author or the IRRI Cropping Systems Network Coordinator.

A discussion and planning session on varietal testing and screening was held on 6 March. About 18 participants represented the collaborating countries. The significant results and conclusions from the discussions follow.

- To evaluate the need for simultaneously evaluating breeding lines in several environments, the yield correlations between monocrop and multicrop environments were used as an index of genotype × environment interaction. The correlations in grain yield between the monocrop and the shaded crop were positive and significant 50% of the time, suggesting that the varieties that do well as monocrop can be expected to do well with shade. On the other hand, the correlations in yield between the monocrop and a crop in the after-rice environment were much lower and were usually not different from zero, suggesting a more urgent need for separate selection in that environment.

  On the basis of these findings. it is suggested that:

Table 2. Summary of dry-seeded and dryland rice variety trial in 3 countries in Asia, 1977-79.

Site	Type of rice land[b]	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Los Baños, Laguna, Philippines	Rainfed wetland	16	1.36-2.92	IR8608-25-3-1, IR8608-125-3-3	1979
Manaoag, Pangasinan, Philippines	Rainfed wetland	9	1.55-2.91	None	1979
Oton, Iloilo, Philippines	Rainfed wetland	9	2.57-5.03	IR9703-41-3-3-1, IR9729-281-3-3-2, IR9224-22-2-2-2-3	1979
Indramayu, Indonesia	Rainfed wetland	6	3.3-6.3	IR26, IR30, IR28	1977
Av for 4 sites in Northeast Thailand[a]	Rainfed wetland	4	1.71-2.18	BKN6113-79, RD15	1978
Av for 2 sites in Northeast Thailand[a]	Rainfed wetland	4	1.39-2.01	Niaw Sanpahtawang	1978
Av for 4 sites in Northeast Thailand[a]	Rainfed wetland	4	2.19-2.66	RD8, RD15	1978
Oton, Iloilo, Philippines	Rainfed wetland	10	2.80-4.40	IR3380-10, IR1529-430-3	1979
Manaoag, Pangasinan, Philippines	Rainfed wetland	10	2.48-4.02	None	1979
Talacogon, Agusan del Sur, Philippines	Dryland	8	1.02-1.95	C171-136, C166-133	1978-79
Pangantucan, Bukidnon, Philippines	Dryland	10	2.55-4.63	C171-136, IR3838-10	1979
Dumarao, Capiz, Philippines	Dryland	12	1.57-4.50	C171-136, IR9575, IR3838-10	1979
Way Abung, Indonesia	Dryland	10	1.40-3.30	Bicol, B 58b, C22	1977-78
Baturaja, Indonesia	Dryland	10	0.70-2.60	Gamma-61, Cartuna	1971-78
Lahat, Indonesia	Dryland	10	0.60-4.00	Bicol. Gamma-16. Cartuna	1977-78

[a] Four varieties and 2 seeding methods: row drilling and dibbling. [b] All with high tillage.

Table 3. Summary of maize varietal testing in 3 countries, 1977-79.

Site	Type of rice land [a]	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Betinan, Zamboanga del Sur, Philippines	Dryland	16	0.80-2.35	CBWR DMR Comp. 1, Early DMR Comp. 1, Prolific DMR Comp. 1	1978-79
Manaoag, Pangasinan, Philippines	Wetland (before rice)	14	1.40-3.39	Thai Comp. 1 Early DMR Suwan DMR Source #5 & #2	1979
Pangantucan, Bukidnon, Philippines	Dryland	7	3.46-3.91	Early DMR Comp. #2	1979
Dumarao, Capiz, Philippines	Dryland	11	1.65-2.24	Phil. DMR Comp. #3 & #1	1979
Yezin, Burma	Dryland	16	1.95-4.59	TC_1 Medok, Suwan DMR Source #2 and #4	1977-78
Yezin, Burma	Dryland	16	3.19-5.31	South Asian Pop III x Swan F3, Suwan DMR Source #1 and #2	1978
Baturaja, Indonesia	Dryland	8	1.5-2.7	H-159, H-43, H-6	1977-78
Lahat, Indonesia	Dryland	8	0.8-0.25	H-159, H-6	1977-78
Tajau Pecah, Indonesia	Dryland	9	1.2-2.7	H-6, Harapan	1978-79
Madura, Indonesia	Dryland	7	0.6-1.3	Bogor DMR #4	1978-79

[a] All with high tillage.

Table 4. Summary of mungbean yield trials in different Asian countries. 1977-80.

Site	Type of rice land	Tillage	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Tajau Pecah, Indonesia	Dryland	High	8	0.2-1.0	MB 129, MB 423, MB 468	1979
Madura, Indonesia	Dryland	High	8	0.3-0.5	MB 129, MB 423	1979
Serdang, Malaysia	Dryland	High	8	0.72-1.53	M 304, EG Glabrous No. 3 CES 14	1977
Bechah Keranji, Malaysia	Dryland	High	10	0.39-0.50	CES 55	1978
Serdang, Malaysia	Dryland	High	8	1.85-2.54	EG Glabrous No. 3, VC 1163-3-2-2-6-2B	1978
Meraati, Malaysia	Wetland	High	4	0.41-0.84	VC 1089-B-29-3B-2B	1979
Yezin, Burma	Dryland	High	12	0.54-1.60	CES X-10, CES 14	1979-80
Khumaltar, Nepal	Dryland	High	10	0.10-0.49	Oklahoma 12, Shining Moong 1, Kjugkijacrai 5	1978-79
Los Baños, Laguna, Philippines	Rainfed wetland	Zero	10	0.51-1.20	CES U-1, CES 2C-1, CES 1T-2	1978-79
Oton, Iloilo, Philippines	Rainfed wetland	Zero	13	0.46-0.89	CES 1T-2	1978-79
Manaoag, Pangasinan, Philippines	Rainfed wetland	Low	13	0.36-0.82	CES U-1	1978-19
Manaoag, Pangasinan, Philippines	Rainfed wetland	High	13	0.38-0.72	EG MG 174-3, H70-16, CES U-1	1978-79
Los Baños, Laguna, Philippines	Rainfed wetland	Zero	8	0.49-0.90	CC, CES 1K-25Y (yellow)	1978-79
Oton, Iloilo, Philippines	Rainfed wetland	Zero	8	0.49-0.93	CC (yellow seeded)	1978
Manaoag, Pangasinan, Philippines	Rainfed wetland	Zero	8	0.53-0.76	Aa	1978
Manaoag, Pangasinan, Philippines	Rainfed wetland	Zero	8	0.30-1.03	MG 50-10A(Y)	1978
Cale, Batangas, Philippines	Dryland	High	14	0.88-1.19	CES 55, CES BN-1	1978
Cale, Batangas, Philippines	Dryland	High	10	0.58-1.08	Aa, Bb, MG 50-10AY	1978
Talacogon, Agusan del Sur, Philippines	Dryland	High	11	1.00-1.60	None	1978-79
Panganlucan, Bukidnon, Philippines	Dryland	High	10	0.06-0.35	ARV 31, CES 55, CES 35	1978-79
Betinan, Zamboanga del Sur, Philippines	Dryland	High	15	0.48-1.13	CES 87	
Los Baños, Laguna, Philippines	Rainfed wetland (before rice)	High	11	0.50-1.05	CES J-2Y, M350, CES 87	1979
Oton, Iloilo, Philippines	Rainfed wetland (before rice)	High	11	0.99-1.58	CES 1D-21 (check)	1979
Manaoag, Pangasinan, Philippines	Rainfed wetland (before rice)	High	11	0.48-1.12	CES 1D-21 (check)	1979
PiMai, Thailand	Wetland	High	16	0.12-0.38	None	
Katupotha, Sri Lanka	Rainfed wetland	High	10	0.70-0.86	CES J-2Y, Sel 76-187	1979
Maha Illuppallama, Sri Lanka	Dryland	High	20	0.56-1.18	ML-3, MI-3, MI-1	1979
Kilinochchi, Sri Lanka	Dryland	High	22	0.40-0.85	Sel 77-193, MG 50-10A	1979

Table 5. Summary of cowpea varietal trials in different countries, 1978-80.

Site	Type of rice land	Tillage	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Yezin, Burma	Dryland	High	10	0.41-0.75	TVx 1836-015, 4R-0257-lf	1978-80
Manaoag, Pangasinan, Philippines	Rainfed wetland	High	13	0.17-0.70	EG #2, TVx 1836-19E	1978
Oton, Iloilo, Philippines	Rainfed wetland	High	13	1.13-2.12	Vita 4, TVx-66-2H, TVX 1836-19E	1978
Manaoag, Pangasinan, Philippines	Rainfed wetland	Low	13	0.08-0.70	PI 221731, TVx-1836-19E, All season	1978
Oton, Iloilo, Philippines	Rainfed wetland	Zero	13	0.75-1.28	None	
Los Baños, Laguna, Philippines	Rainfed wetland	Zero	14	0.32-1.73	Vita 4, TVx-1836-19E	1978-79
Cale, Batangas, Philippines	Dryland	High	13	1.02-1.75	PI 221731, TVx 1836-187E	
Manaoag, Pangasinan, Philippines	Rainfed wetland	High	11	0.36-0.85	Vita 3, Pelungthay	1978
Manaoag, Pangasinan, Philippines	Rainfed wetland	Low	11	0.49-1.14	Pelungthay, Vita 3, TVx-1193-059 D	1978
Oton, Iloilo, Philippines	Rainfed wetland	Zero	11	0.49-1.06	Vita 3, Pelungga	1978
Cale, Batangas, Philippines	Dryland	High	11	0.60-1.85	TVx-289-4G, TVx-1193-059D	1978
Pangantucan, Bukidnon, Philippines	Dryland	High	10	0.80-1.30	TVx-66-2H, Vita 3, All season, EG #3	1978
Dumarao, Capiz, Philippines	Dryland	High	10	0.66-1.30	EG # 3, TVx-836-19E, TVx-66-2H	1978-79
Betinan, Zamboanga del Sur, Philippines	Dryland	High	12	0.75-1.32	Red cowpea, EG #1	1978-79
Indramayu, Indonesia	Rainfed wetland	Zero	6	0.8-1.20	EG #2, TVx 6-4H	1978
Barambai, South Kalimantan, Indonesia	Rainfed wetland	Zero	4	0.3-0.8	VS-l26R, VS-126G	1978-79
Maha Illuppallama, Sri Lanka	Dryland	High	16	0.03-3.31	None	1978
Maha Illuppallama, Sri Lanka	Dryland	High	20	1.5 1-2.72	TVX 64H, TVx 930-01B Floricream x Arlington Sel. 75	1978-79
Katupotha, Sri Lanka	Rainfed wetland	High	8	0.14-0.94	Bombay, Arlington, Pelungthay, Pelungga, EG #2	1979

Table 6. Summary of sweet potato variety trials in the Philippines, 1978-80.

Site	Type of rice land	Tillage	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Los Baños, Laguna, Philippines	Rainfed wetland	Zero	10	14.0-22.4	Minuras, Kinbakab (Japan x US 1)-10	1979-80
Manaoag, Pangasinan, Philippines	Rainfed wetland	Zero	10	3.2-11.4	Kinbakab, Catanduanes 3, Minuras	1979-80
Cale, Batangas, Philippines	Dryland	High	7	12.4-20.1	(Japan/US 1)-10 (Japan/US 1)-5	1978-79
Isabela, Philippines	Dryland	High	15	8.7-35.3	Kinbakab, Minuras	1978-79
Los Baños, Laguna, Philippines	Dryland	High	20	14.7-23.9	(Japan/US 1)-5, Hsinchu, Tinipay	1978-79
Betinan, Zamboanga del Sur, Philippines	Dryland	High	7	9.06-52.34	Karja, Binasayon	1978-79
Dumarao, Capiz, Philippines	Dryland	High	11	1.2-11.4	SP #45, C-35-1	1978-79
Talacogon, Agusan del Sur, Philippines	Dryland	High	10	2.27-3.51	None	1978-79

Table 7. Summary of peanut variety trials in 3 Asian countries. 1978.

Site	Type of rice land[a]	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Cale, Batangas, Philippines	Dryland	16	0.80-1.19	EG Bunchy, Acc 12, PI-118200	1978
Tigbauan, Iloilo, Philippines	Wetland	9	0.50-1.08	CES 102, PI 259692	1978
Manaoag, Pangasinan, Philippines	Wetland	10	0.15-1.44	PI 259692, CES 102, CES 2-25	
Betinan, Zamboanga del Sur, Philippines	Dryland	9	0.77-1.27	None	
Talacogon, Agusan del Sur, Philippines	Dryland	8	0.60-2.70	None	
Pangantucan, Bukidnon, Philippines	Dryland	10	0.52-0.94	M-10	
Dumarao, Capiz, Philippines	Dryland	10	0.71-1.27	Dixie Giant, CES 102, Gadja	
Kuala Brang, Malaysia	Dryland	3	1.79-2.18	Matram	
Baturaja, Indonesia	Dryland	5	2.3-3.2	A-6, Gadja	
Lahat, Indonesia	Dryland	6	1.5-2.0	Gadja, Kidang	
Madura, Indonesia	Wetland	6	0.8-1.5	A-6, AH-5, Gadja Kidang	

[a] All with high tillage.

Table 8. Summary of soybean varietal performance in different countries, 1977-79.

Site	Type of rice land	Tillage	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Los Baños, Laguna, Philippines	Rainfed wetland	Zero	9	1.17-2.01	30290-11-11, Clark 63 30047-2-36	1978-79
Oton, Iloilo, Philippines	Rainfed wetland	Zero	9	0.34-0.67	30229-8	1978-79
Manaoag, Pangasinan, Philippines	Rainfed wetland	Zero	9	0.29-0.82	Clark 63	1978-79
Cale, Batangas, Philippines	Dryland	High	9	0.73-1.05	Clark 63	1978-79
Talacogon, Agusan del Sur, Philippines	Dryland	High	6	0.30-2.5	SL-6, Clark 63	1978-79
Dumarao, Capiz, Philippines	Dryland	High	5	0.25-0.62	Clark 63, TK5	1978-79
Betinan, Zamboanga del Sur, Philippines	Dryland	High	18	0.11-0.91	Clark 63, Gilbert	1978-79
Pangantucan, Bukidnon, Philippines	Dryland	High	8	0.58-1.39	Clark 63, SL6	1978-79
Indramayu, Indonesia	Rainfed wetland	Zero	11	0.8-1.50	Orba, CEX 16-103, Clark 63, Lincoln, CES 16-17	1977
Baturaja, Indonesia	Dryland	High	7	0.9-1.4	CES 16-23	1977
Serdang, Malaysia	Dryland	High	14	1.14-2.10	Bossier, Jupiter	1977
Serdang, Malaysia	Dryland	High	13	0.34-1.64	Palmetts, Bossier, Orba	1977
Kuala Brang, Malaysia	Dryland	High	13	0.40-2.01	Improved Pelican, KE 32, Orba	1977
Tumpat, Malaysia	Dryland	High	10	0.68-2.09	Jupiter, CES 434	1977
Tumpat, Malaysia	Dryland	High	11	1.28-2.56	30213-1-3, Palmetto	1978
Khumaltar, Nepal	Dryland	High	16	0.44-1.76	Ks 419 x 525, Tainung 3, Higo Daizu Hill, Tainung 4 1.93	1979
Av for 6 hill sites, Nepal	Dryland	High	18	0.98-1.93	Tainung, Rillito, Ramson	1978-79
Av for 6 Tarai sites, Nepal	Dryland	High	15	0.70-1.60	Hardee, Pk-71-39, Cobb, P44, B1	1978-79

Table 9. Summary of sorghum varietal trials in the Philippines and Burma, 1977-79.

Site	Type of rice land	Tillage	Entries (no.)	Yield range (t/ha)	Promising varieties better than check [a]	Year tested
Oton, Iloilo, Philippines	Rainfed wetland	Zero	17	2.01-3.28	CS 182, Pioneer 8417 CS 137, CS 226	1978-79
Manaoag, Pangasinan, Philippines	Rainfed wetland	Low	18	1.36-2.65	None	1978-79
Manaoag, Pangasinan, Philippines	Rainfed wetland	High	18	0.51-3.16	CS 102, CS 124, CS 220, CS 171	1978-79
Cale, Batangas, Philippines	Dryland	High	18	1.99-5.08	CS 226, Pioneer 8417	1978-79
Betinan, Zamboanga del Sur, Philippines	Dryland	High	13	3.22-6.72	Monsoon, CS 137, Tropic, Gold Finger	1979
Pangantucan, Bukidnon, Philippines	Dryland	High	8	2.70-3.40	None	1979
Dumarao, Capiz, Philippines	Dryland	High	10	0.43-1.87	IS-2940, BPI Sor I, D67-4	1979
Av for 4 sites in Batangas, Philippines	Dryland	High	6	2.844.97	WLB SG 5, D67-4, Pioneer B 815	1978-79
Yezin, Burma	Dryland	High	16	0.28–0.80	CS 108, CS 104, CS 137	1977
Yezin, Burma	Dryland	High	15	0.63-2.25	WLB Sor 5	

[a] Checks used were Cosor 3 for Burma and 4 sites in Batangas, and UPLB Sor 5 for all other Philippine sites.

Table 10. Summary of varietal tests for chickpea, lentil, and black gram in Nepal and Burma, 1978-79.

Site[a]	Entries (no.)	Yield range (t/ha)	Promising varieties better than check	Year tested
Chickpea				
Janakpur, Nepal	16	1.67-2.77	IC 7358, G 130, JG 74	1978-79
Parwaniphur, Nepal	16	0.22-1.41	G0332-10 JG 74	1978-79
Lentil				
Janakpur, Nepal	16	1.34-1.82	L-0111-25, L-0223-12, BR 25	1978-79
Parwaniphur, Nepal	16	0.97-1.68	P-43, L-0222-9, L-0222	1978-79
Nepalgunj, Nepal	16	1.23-2.10	LG-7, L-0222-9, L-0223-12	1978-79
Khumaltar, Nepal	16	0.69-1.34	L-0111-25, LG-7, LL-1	1978-79
Black gram				
Yezin, Burma	21	1.08-2.87	BP-3, P33-39, H70-3, K10	1978-79

[a]All sites were wetland with high tillage.

Table 11. Minimum data to be gathered for each crop.

Sorghum	*Maize*	*Mungbean*
seedling vigor	maturity	seedling vigor
days to flowering	downy mildew	date of flowering
plant height	plant height	date of maturity
disease rating	lodging	plant height
insect rating	insect rating	lodging index
no. of plants harvested	disease rating	disease and pest rating
plot yield	field weight	no. of plants harvested
moisture content	yield per hectare	moisture content
yield per hectare		plot yield (g)
		yield per hectare

Cowpea	*Peanut*	*Soybean*
seedling vigor	seedling vigor	seedling vigor
date of flowering	date of flowering	date of flowering
date of maturity	date of maturity	date of maturity
plant height	disease and pest rating	plant height
disease rating	no. of plants harvested	disease rating
no. of hills harvested	plot bean yield (g)	lodging index
moisture content	moisture content	moisture content
plot yield	yield per hectare	no. of hills harvested
yield per hectare		yield per hectare

1. For shaded environments, varietal evaluation should be initiated only at the advanced replicated trials where only a few promising varieties are being tested; and
2. For the after-rice environment, evaluation should start not later than the preliminary yield test and probably as early as the observational nursery stage.

- The member countries of the network are testing promising varieties of upland annual crops for suitability to the various multicropping environments. The extent of this activity is given in Tables 2-10. Testing will be continued and the

PLOT AND MANAGEMENT RECORD FOR VARIETAL TESTING

Country _____ Cooperator _____
Site or station _____
Latitude _____ Elevation _____

Soil texture: light /_/ medium /_/ heavy /_/ Classification _____

Drainage: good /_/ fair /_/ poor /_/ wetland /_/ or dryland /_/

Crop: _____
Land preparation:
No. plowings and harrowings _____ No. of reps. _____
Spacing (cm): Between rows _____ Between hills _____
Date: Planting _____ Emergence _____

Fertilizer applied in kg/ha:

	Kind	Amount
Basal		
Side-dress		

Pesticide applied:

	Kind	Amount/ha	Date of application
1st			
2d			
3d			
4th			

Weed control:
Herbicide applied

	Kind	Amount in kg a.i./ha	Date of application
1st			
2d			

Nonchemical weeding: Number _____ Date _____
Flooding: Yes /_/ No /_/ How many times _____

Weekly rainfall in mm and temperature in centigrade (start two weeks before planting)

Week	Rainfall	Temp	Week	Rainfall	Temp
1st			13th		
2d			14th		
3d			15th		
4th			16th		
5th			17th		
6th			18th		
7th			19th		
8th			20th		
9th			21th		
10th			22th		
11th			23th		
12th			24th		

Date harvested _____

Remarks _____

agronomists involved will collaborate with the breeders. IRRI will provide new materials from the screening programs of UPLB and Thailand for incorporation in the new trials. Collaborators will try to establish a good seed production scheme to evaluate the promising materials at more sites.

- In addition to the performance test of promising varieties, evaluation of many genotypes will continue at UPLB, Thailand, and, possibly, Bangladesh or Nepal for the semitropical areas, particularly for cold-tolerant crops such as chickpea, lentil, and soybean crops.
- For varietal trials in 1980, the participants agreed on:
  1. a uniform set of minimum data to be recorded for all advanced trials (Table 11),
  2. the inclusion of early-maturing field maize varieties from Centro Internacional de Mejoramiento de Maiz y Trigo,
  3. the type of trials that each country will conduct, and
  4. the collection and inclusion in their reports of a data sheet indicating the environmental conditions and management of the variety trial (see Plot and Management Record for Varietal Testing).

Closing remarks

N. C. Brady

This Conference has been a success. You have shared with each other research accomplishments as well as the difficulties and frustrations encountered in that research. You have also shared information on your research methodologies. And you have spelled out the needs for better research in the future.

But the *show and tell* component of this Conference was not its most important feature. The more significant component is that which we commonly call the *so what* Component — the small group discussions yesterday and the reports of those discussions today. We have all benefited from the comments and suggestions in the group sessions. The reports have identified actions to be taken as we look to the future. And you have made specific suggestions to scientists at IRRI as to what we should be doing to help you in your national program.

As is frequently the case, the *show and tell* aspects are more easily handled than are the *so what* components. What about a better way of estimating yield damage from insects and diseases? What about simple methods that can be used to ascertain the economic advantages of different patterns and systems? These are the questions with which you have tried to deal.

I emphasize only two or three of the topics you have covered during discussions today and yesterday. First are problems associated with crops other than rice in the cropping sequences. Often, much less is known about them than about rice. Which variety is best adapted to a given area? What cultural practices are most appropriate to get good stands and high yields? How do you control pests — insects, diseases, and weeds? It is obvious that progress must be made in answering these questions if the future potential of the cropping patterns and systems you have developed is to be realized. Because you, and we, cannot obtain the answers to all these questions, we must get help from others, especially from the international agricultural research centers such as the international Institute of Tropical Agriculture, International Centre for Tropical Agriculture, and International Crops Research Institute for the Semi-Arid Tropics, which deal directly with these crops.

You have identified several things that you expect from IRRI. Your concern over economics training is well founded. At many research sites we expect from the young scientists more than what they can deliver. You seek a simplified training manual that can be used at the various sites. We shall try to oblige. We hope that once this manual is published, you can have it translated into languages other than English

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and increase its effectiveness.

Training needs in weed science were also noted. IRRI's weed scientists have been acutely aware of the need for such training and have discussed with our entomologists and plant pathologists the possibility of an overall pest management training course that will include weeds, diseases, and insects as well. We will keep you informed on plans for such a course.

I make one suggestion as you leave this conference. Take time to evaluate the Conference. What benefits did you receive? Was your coming here worthwhile? How could the conference have been more useful to you'? I would appreciate receiving a copy of your evaluation as would your research supervisors or administrative heads. Your evaluation will help us develop better conferences. And it will help your administrative superiors judge the usefulness of such conferences.

I thank you again for coming and sharing your research findings and your plans for the future with us and each other.

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