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International Symposium on Development and Transfer of Technology for Rainfed Agriculture and the SAT Farmer

ICRISAT Center
Patancheru, India
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Vrinda Kumble, Editor

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Foreword

The work of an international agricultural research institute becomes meaningful only when the results can be effectively conveyed to their ultimate user — the farmer — through the scientists and extension agencies of the many nations served by that institute. It seemed appropriate to us that a symposium inaugurating the new facilities of ICRISAT Center should focus on the development and transfer of technology for rainfed agriculture — a vital but hitherto largely neglected area of agricultural production that ICRISAT has a mandate to improve.

The symposium was held 28 August to 1 September 1979 as a major event of inaugural week activities. It was attended by scientists and development officials from 28 countries and by representatives of four international organizations — the UNDP, World Bank, FAO, and the Consultative Group on International Agricultural Research (CGIAR), which supports the work of the international research centers. Collectively, the participants represented many years of extensive and varied experience in research and development of agriculture in the semi-arid tropics (SAT).

They reviewed ICRISAT's research since the inception of the Institute in 1972 and the relevance of that research to the theme of the symposium. They explored the philosophy, concepts, and practice of technology transfer and its problems and potential, particularly in the semi-arid areas of India, Africa, and Latin America where ICRISAT pursues its mandate. Scientists working in various countries of the SAT shared their experiences and the particular problems of their own regions, as did representatives of other international organizations.

Finally, integrating all these topics, was a session on establishment of linkages for the transfer of technology — the problems and prospects. A six-member panel of scientists representing different regions defined areas of high priority in the development of technology and its transfer to the resource-poor small farmer of the rainfed semi-arid tropics.

ICRISAT is pleased to present this volume of the papers delivered and summaries of discussions held. We hope it will serve both as an up-to-date review of work being done and as a stimulus for further consideration of how best to convey to the small farmers of the SAT technological advances that should improve their crops, their farming systems, and their lives.

We acknowledge with gratitude the efforts of all of those who came from far and near to share the benefits of their experience and make the symposium a success. I also thank Dr. J. S. Kanwar, Director of Research, and those staff members who assisted him in planning and organizing the symposium. The Institute benefitted immeasurably from this experience.

L. D. Swindale
Director General

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Opening Session

Chairman: C. F. Bentley

Rapporteurs: L. R. House
D. S. Murthy

The Mission of ICRISAT

L. D. Swindale*

It is my pleasure indeed to welcome to Patancheru and ICRISAT Center so many friends of ICRISAT, so many people who have contributed to the development of ICRISAT, so many people who are interested in ICRISAT, who want to cooperate with the Institute, and want to learn more about it. I am very pleased to see you here.

There were times I thought this building would never be finished. The fact that you are sitting here today and that we have started this session is testimony that it is indeed finished — enough, at least, for us to hold an international symposium on Development and Transfer of Technology for Rainfed Agriculture and the Semi-Arid Tropical Farmer.

This is a very important subject, and a very fitting one, I think, for a symposium connected with the Inaugural Week of ICRISAT. Only if we have a reasonable ability to transfer agricultural technology will ICRISAT's work — particularly its work in farming systems — be really worth doing. The same is true for the work of all the international agricultural research centers — indeed, it is also true for national systems of agricultural research — both because they themselves are able to accept the benefits of transfer of technology as well as contribute to it internationally and because within any country, however rich, it is never possible to set up research units for every single environmental and sociological niche. Transfer of technology is necessary to ensure that all can benefit from its value.

In spite of the importance of this subject, however, the literature about it is fairly sparse. I know; I have long been concerned with and interested in the subject, particularly in relation to my work in the Benchmark Soils Project of the University of Hawaii, and, more recently, in preparing a paper for this symposium on the problems and concepts in the transfer of technology. There is not a great deal in the literature about the concepts and even less about testing their efficiency and validity. So this symposium will do an essential job in the field of international agricultural research and its transfer and communication around the world, giving us some idea of the state of knowledge in this field.

As many of you know, ICRISAT was the first center created by the Consultative Group on International Agricultural Research. Five other centers — CIMMYT, IRRI, CIAT, IITA, CIP — existed prior to the formation of the Consultative Group itself. But in late 1971, the Consultative Group decided on the basis of a 1970 report by Clarence Gray that the lack of an upland crop research institute constituted a major gap. They called upon an expert team — Hugh Doggett, Louis Sauger, and Ralph Cummings — to recommend the nature of such an institute. As a result, ICRISAT was formed with a mandate to serve as a world center for the improvement of the genetic potential of sorghum, pearl millet, pigeonpea, and chickpea; to develop farming systems; to help increase and stabilize agricultural production through more effective use of natural and human resources in the seasonally dry semi-arid tropics; to identify socioeconomic constraints and to evaluate means of alleviating them; and to communicate information through conferences, training programs, etc.

The first mandate of ICRISAT did not include groundnuts but the report of the experts had recommended that this crop be added at a later date, and this was done in 1976.

This is where our stated mandate stands today. But I believe a significant change occurred in 1977 and 1978, when the Governing Board accepted requests made by the International Board for Plant Genetic Resources to have ICRISAT serve as a primary repository for genetic resources of its five crops and for minor millets. This decision has increased our work in the Genetic Resources Program significantly. We will serve not only to collect these resources, but also to describe them, to maintain collections, and to distribute the germplasm itself.

Now, the mandate of any international institute covers a broad field of activities — far more than we can do at any one time. So it is

* Director General of ICRISAT.

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necessary, for any given period of years, to focus on some particular aspect or group of aspects of the mandate and leave others for a later time. Our Governing Board at the present time has focused our attention upon the small farmer of limited means working in rainfed agriculture.

This is clearly in accord with the desires of the Consultative Group. First, the Center was set up to work specifically on crops that are more subsistence than commercial. Second, the Consultative Group itself has made several statements that clearly indicate its belief in the importance of working for this particular sector of humanity. In the words of a Swedish delegate to the CG meetings a couple of years ago, "the research should be problem-oriented and produce results that benefit the majority of farmers in low-income countries, on food commodities which are widely consumed and collectively represent a majority of the food resources of the developing world." ICRISAT accepts this directive. In our work you will see emphasis upon biological and technological research. But our goal also has social content, with an important input from the social sciences. All these inputs are designed to serve the needs of this particular group of disadvantaged people. So it is only fair to say that ICRISAT is *people*-oriented. With that in mind, we look forward to receiving your views on how new technology, once developed, can best be transferred to those it is intended to benefit — in our case, the small farmers of the semi-arid tropics.

Research at ICRISAT – an Overview

J. S. Kanwar*

Abstract

In recognition of the need to improve the well-being of the farmers of the semi-arid tropics and bridge the gap between food production and demand, the Consultative Group on International Agricultural Research constituted ICRISAT in 1972. The Institute has a global responsibility for crop improvement research in sorghum, millet, chickpea, pigeonpea, and groundnut. It also has a special mandate for research in farming systems, socioeconomic constraints, and transfer of technology for the seasonally dry semi-arid tropics, to catalyze a breakthrough in the agricultural production of the region.

ICRISAT has established a gene bank of 48 000 accessions and exchanged more than 250 000 seed packets with research workers in 67 countries. It is improving crop yield potential and stability consistent with good nutritional quality and is developing concepts and practices for optimizing production and increasing monetary returns to farmers. Our scientists are working and interacting with national scientists in Asia, Africa, and South America to develop and transfer a more efficient and more remunerative technology to produce a visible change in the food production of the SAT.

As the name implies, ICRISAT is a crop research institute that is international in character. It has global responsibility for five crops — sorghum, millets, pigeonpea, chickpea, and groundnut — and a special responsibility for research for the development and transfer of technology in the seasonally dry rainfed areas of the semi-arid tropics (SAT). All five crops of concern to ICRISAT are of major significance in the SAT, where 44% of the world's sorghum, 55% of the pearl millet, 90% of the chickpea, 96% of the pigeonpea, and 67% of the groundnut are produced and consumed directly as human food. They are the main source of calories, protein, and fat for about 600 million people living in 49 countries of the semi-arid tropics.

To appreciate the challenges facing ICRISAT's scientists, one has to keep in mind the following specific characteristics of the semi-arid tropics:

1. Most of the cropping in the SAT is, and will continue to be, under rainfed conditions; a majority of the farmers are small farmers with meager resources — our target group, as Dr. Swindale has aptly called them. ICRISAT's technology must be relevant to these resource-poor farmers and be transferable to them. This does not mean that one searches for a technology based on no inputs but rather one based on a range of inputs, with high payoff. It should result in greater monetary return than the traditional technology in use by the farmers, even under the normal conditions in which they operate. Thus, relevant and excellent technology for the SAT farmer is the mandate of ICRISAT; how to develop and how to transfer such a technology to small farmers of the SAT is the focus of this symposium.
2. The crops of concern to ICRISAT are low-value crops and generally do not enter the world market, except for groundnut; thus price incentives for their production are often missing.
3. These are the least researched crops in the developed countries and are also ignored by the LDCs; thus most of the new ground in research must be broken by ICRISAT.
4. Fertilizer-responsive genes like those that produced the so-called "miracle seeds" of wheat and rice are yet to be discovered in many ICRISAT crops, especially in pulses and groundnut.
5. Technology based on high inputs is not practicable for these crops.
6. Their yields are low and production is unstable due to too much aberrant

* Director of Research, ICRISAT.

weather and a high incidence of diseases and pests.

The yield data in Table 1 show the average yields in the SAT and the potential yields of these crops realized at ICRISAT under rainfed conditions.

Table 1. Average yields and experimental yields of ICRISAT's five crops (kg/ha).

Crop	Average yield in SAT	Experimental yield at ICRISAT: Under high soil fertility	Experimental yield at ICRISAT: Under low soil fertility
Sorghum	842	4900*	2627*
Pearl millet	509	3482	1636
Chickpea	591	3055 (Hissar)	3079 (Hissar)
		1450 (Hyderabad)	1399 (Hyderabad)
Pigeonpea	666	2530*	2326
Groundnut	794	2573*	1712

* Farming Systems' operational-scale trials.

From these results it may be observed that, even under low fertility conditions, the new technology can give yields two to three times higher than the average yield obtained by SAT farmers. These yields give some idea of the prospects for the new technology. How to bridge this gap is a big question with technological and socioeconomic aspects.

Historical Background

ICRISAT was constituted in 1972, but most of its activities started in 1973, after the Director, Associate Director, and several scientists joined. Without waiting for the building facilities that are being inaugurated this week, the Institute started work in earnest to attain the goals that the Doggett-Cummings-Sauger Committee had mentioned in its feasibility report and that ICRISAT's Governing Board adopted as the mandate. These objectives can be briefly summarized as:

- Genetic resources and crop improvement research
- Farming systems or resource management research
- Socioeconomic research relevant to the above themes
- Transfer of the knowledge acquired, the material generated, and the concepts developed

To appreciate the value of the research activities, it may be desirable to examine our research organization and the mandate area of the SAT.

ICRISAT has six main research programs — sorghum, millets, pulses, groundnut, farming systems, and economics — and seven support programs. Every research program has an interdisciplinary team of specialists who work together to achieve the common goal.

The Government of India generously provided 1394 hectares of land at Patancheru for the research farm and the campus of the Institute. The area is comprised of both Vertisols and Alfisols, the two important soil groups of the semi-arid tropics. ICRISAT's research activities are not confined to this one station; it has access to a number of cooperative research stations in different environments in India and Africa. It also has a cooperative network with the national programs in the SAT. Without these facilities, the Institute would not have been able to fulfill its global responsibilities.

ICRISAT's geographical mandate area is restricted to the SAT as defined by Troll.[1] ICRISAT's agroclimatologists are trying not only to define the boundaries of the SAT but to develop models of cropping systems based on the climatological and soil parameters and the information collected by ICRISAT biologists, engineers, physical scientists, and economists.

I need hardly emphasize that in all our researches we are keeping in mind the overall constraints of water and capital in the SAT. To develop technologies relevant to the small farmers of the SAT, spread over 49 countries of the world, we have set apart special areas in both Alfisols and Vertisols at ICRISAT Center. These include:

- a low-fertility area comparable to the farmer's situation for testing crops with no or low inputs

1. D. Troll, 1965, Seasonal climates of the earth, Page 28 *in* World maps of climatology, eds. E. Rodenwaldt and H. Jusatz. Berlin: Springer-Verlag.

- a pesticide-free area for evaluation of material under natural conditions — i.e., without an umbrella of pesticides
- a number of watersheds with natural topography suitable for testing all technologies under natural environments

We have also developed an international system of cooperative work for sampling the range of environments of the SAT. This is done through international nurseries that evaluate material under natural pressures of diseases, pests, climate, and soil conditions.

We have recognized that an international center can act only as a catalyst, pacesetter, and concept builder; it has to work with the national programs to develop and transfer appropriate technology and reach its target group of farmers and its client group of scientists.

Research Overview

Let me now give you an overview of our research efforts. My colleague program leaders will give you a comprehensive picture of the research, so I will only stress some important points.

The high priorities in crop improvement research have been:

- Collecting genetic resources and evaluation, storage, and exchange of these resources
- Increasing yield potential through genetic engineering for rainfed conditions and low monetary inputs
- Increasing stability of high yield by incorporating resistance to yield reducers
- Developing appropriate technology for the SAT
- Improving nutritional quality of crops

The first task before us was assembling, collecting, evaluating, and cataloging germplasm of sorghum, pearl millet, pigeonpea, chickpea, and groundnut. Special importance has been given to the collection of wild species of those crops that provide a rich source of resistance to diseases and pests and of tolerance to environmental stress. Table 2 shows the number of germplasm lines in our collection today. The present collection of more than 48 000 accessions is the world's largest in these crops. It also includes the wild species that our scientists have collected from hitherto inaccessible areas all over the world. On behalf of the International Board for Plant Genetic Resources (IBPGR) and our clients, we also maintain germplasm collections of minor millets. Much of this material was in danger of extinction, and ICRISAT was requested to move in quickly to become the world repository for it. Dr. Melak Mengesha and his colleagues are making a strenuous effort to complete the collections and make this rich heritage available to users all over the world. The information has been computerized and is being updated systematically. We are in a position to supply lines with specific traits to the national programs and thus catalyze and strengthen their research. In the last 5 years, our Quarantine Unit has been able to exchange more than 250 000 seed samples from our gene bank and breeders' labs with scientists in 67 countries. We have also developed seed-exchange arrangements with China, the USSR, and gene banks in the USA, besides the 49 countries of the SAT.

Table 2. Number of accessions with the Genetic Resources Unit.

Crop	Accessions of cultivated spp	Accessions of wild spp
Sorghum	16 579	145 (8)*
Pearl millet	5 332	33 (17)*
Pigeonpea	5 971	56 (14)*
Chickpea	11 225	47 (20)*
Groundnut	7 000	27 (20)*
Minor millets	2 076 (6)*	

* Numbers in brackets indicate species.

Sorghum

Our sorghum research is confined to sorghum grain for human food. We realized that for a breakthrough in its production, first priority should be given to research on yield and on quality reducers such as downy mildew, head mold, *Striga*, shoot fly, stem borer, and drought and soil stress. Genotypes resistant or tolerant to these stresses need to be developed. Incorporating genes for high lysine and high protein has been given consideration, but we realize that considerable basic research is needed to

attain any tangible results. Our conclusion is that nothing should be done at the cost of the yield and its stability; however, we must ensure that high yield is consistent with optimum protein and lysine content and consumer acceptability.

When ICRISAT started its work, major emphasis in the world was on development of sorghum hybrids. Our scientists realized that population breeding needed emphasis. A number of lines from this program that performed well in overseas and local trials were selected for use in the national programs in Ethiopia, Niger, Mali, Upper Volta, Sudan, and India. Several entries showed lowest mold score in the international nurseries of grain mold for 3 years successively. Five other entries have shown resistance to downy mildew. One line, QL3, has been found immune to downy mildew in Africa, Asia, and South America. In the future, breeding for resistance to charcoal rot, stem borer, and midge will be intensified.

We have observed that the consumer's appraisal of the product — chapati in India and enjira in Africa — gives a good idea of the quality of the grain. Our scientists have considered this in making evaluations.

Pearl Millet

Downy mildew had been identified as the villain affecting the future of hybrids and all improved varieties of pearl millet. Development of a technique for screening for resistance to downy mildew and breeding for resistance was given highest priority. Today we have controlled this problem and made the resistant lines available to national programs. In fact, all the hybrids, experimental varieties, and synthetics being developed by ICRISAT have low susceptibility to downy mildew.

In the case of pearl millet, the population breeding approach has paid rich dividends; many of the experimental varieties and synthetics developed by ICRISAT have proved their merit in international tests in Africa and India. Some of them are under testing at prerelease stage. This has opened a new chapter in the development of pearl millet. An outstanding example is WC-C75, which has gone to minikit trials on farmers' fields in India. Even better material than this has entered the national testing programs. In 1978, ICRISAT contributed 19 entries to the trials under the All India Coordinated Millet Improvement Project — one hybrid (ICH-105) and three experimental varieties (WC-C75, IVS-A 75, and MC-C75) are in advanced trials; two new hybrids (ICH-154 and ICH-165), two experimental varieties (SSC-H76, MC-P76), and a synthetic (ICMS-7703) have entered initial trials; and ten elite restorer lines are in parental trials.

Breeding work to combine high yield and good protein is under way, as the data over the last 3 years indicate the possibility of selecting for increased protein content without detriment to yield or seed size.

The Pearl Millet Improvement Program has entered a very exciting phase. Breeding for resistance to ergot is receiving the greatest attention, and many promising lines are under test. Resistance to smut, rust, and *Striga* will receive more attention in future. The preliminary studies by our microbiologists show that some lines of sorghum and millets have even up to ten times as much nitrogenase activity as the check; the consistency and practical significance of these results are yet to be determined.

Pulses

In chickpea and pigeonpea, the major handicap has been the absence of photoperiod-insensitive plant types responsive to monetary inputs such as fertilizer, irrigation, and pesticides. Also, the "green revolution" has pushed these crops onto marginal lands, thus reducing the production and availability of pulses to consumers. As a consequence the prices of pulses have shot up to abnormally high levels, thus putting them out of reach of poor people in countries like India.

Thanks to our cooperators in India and at ICARDA, the research on chickpea is progressing very well. A few lines with high-yield potential have already entered the coordinated yield trials in India. International nurseries are providing valuable information. The pulse pathologists have made considerable progress in identifying disease-resistant genotypes and developing techniques to help breeders in producing lines that combine high yield and disease resistance. The confusion about chickpea

wilt has been resolved, and genotypes resistant to wilt have been identified.

In pigeonpea, the male-sterile lines have been identified, and hybrids capable of giving 30 to 40% higher yields have been developed. Breeding lines resistant to sterility mosaic and wilt have also been developed. Eight early maturing, two medium-maturing, and one hybrid have been entered in tests of the All India Coordinated Program. High yield potential of pigeonpea planted in the *rabi* (postrainy) season in areas of the Indian subcontinent has been demonstrated, and the possibility of ratooning has been studied. Vegetable-type pigeonpeas are being developed. Other important developments are in prospect for the future.

Groundnut

The program on groundnut started in 1976. First priority has been given to building up a germplasm bank and incorporating disease resistance, particularly to rust, leaf spot, and viruses. Breeding for high-yield potential is in progress. It is gratifying to note that the hybridization technique in groundnut has been successfully employed; the success rate, which was less than 10% in the field, has been increased to more than 50%. Interspecific hybrids of cultivated and wild species are promising sources of resistance to diseases. The segregating elite populations are being supplied to national programs in India, Africa, and Southeast Asia.

Our breeders have found new sources of resistance to groundnut rust and have developed techniques for screening material in the rainy and postrainy seasons. Our work on groundnut virus diseases is entering an exciting phase. Many new virus diseases have been discovered and sources of resistance identified. The microbiologists have identified some progenies of normally nodulating groundnuts that did not nodulate. This seems to be a useful indicator for nitrogen-fixation studies. A new assay method, based on measurement of Allantoin concentration as an index of nitrogen uptake from biologically fixed nitrogen as compared to soil nitrogen, seems to be promising.

Farming Systems

The main goal of farming systems research is to develop concepts and techniques for increasing production through better use of natural and human resources in the seasonally dry semi-arid tropics. These areas are characterized by harsh climate, erratic rains, and impoverished soils; they are inhabited by some of the world's poorest farmers, with meager resources for innovative and efficient agriculture. Rainfed crops and subsistence farming, intercropping, low intensity of cropping, use of human muscle and animal power are common features of agriculture of these areas. Keeping this background in mind, ICRISAT's Farming Systems Program has developed:

- a technology for double cropping of deep Vertisols, 20 million ha of which normally are single cropped in SAT India.
- efficient intercropping that improved production 20 to 70% over sole cropping; millet/groundnut on an average recorded 25 to 30% advantage.
- a small-watershed concept for land and water management and increased crop production, with a broadbed-and-furrow system and the Tropiculteur or bullock-drawn wheeled tool carrier serving as kingpins of the technology.
- a technique of harvesting, storing, and reusing runoff water for life-saving irrigation, extending the cropping season, or increasing the intensity of cropping. It is a concept of using rainwater in situ against the concept of irrigated farming based on transported water or mined water.
- a concept and technique of combining various steps in technology for a synergistic effect on increasing production in both Alfisols and Vertisols.

Farming systems research is integrating all aspects of research in a holistic way and studying the possibility of its transferability under farmers' conditions. With this objective in view, operational-scale trials on cultivators' fields have been started in three villages — Shirapur (Sholapur), Kanzara (Akola), and Aurepalle (Mahbubnagar) in the states of Maharashtra and Andhra Pradesh, India. This work is being done in cooperation with the national and state research organizations.

The farming systems research is also being extended to West Africa, and it is interacting with national and regional programs in South America and Southeast Asia. We feel that in the

future farming systems research will advance more in the direction of on-farm trials, entering into this phase with the help of national programs and with the cooperating farmers acting together to bring about a revolutionary change in the agriculture of the SAT.

Socioeconomic Research

Our economists are interacting with the farming systems scientists to measure the efficiency and economic feasibility of various practices. An analysis of the operational-scale data from ICRISAT watersheds has confirmed that the broadbed-and-furrow system on deep Vertisols was more profitable than the traditional flatbed system; this has not yet been proved to be the case on the medium-deep Vertisols and on Alfisols. The Village-Level Studies have indicated the relevance of intercropping research by ICRISAT, and the unsuitability of chemical weed control for the low-wage situation of SAT India, where the price of herbicides is high and labor is plentiful. Studies on risk aversion have shown that both small and large farmers are moderately risk averse. In the next phase in India, the Village-Level Studies will be extended to the chickpea-, groundnut-, and peart-millet-growing areas of northern India.

Transfer of Technology

All these researches that I have discussed are aimed at fulfilling ICRISAT's mission. They focus on the development of suitable technology and lead to the last, but not the least important, aspect called Transfer of Technology. In the next few days you will hear from our colleagues and cooperators about the mechanism of transfer of technology. I may only mention at this stage that to transfer knowledge and exchange information, we have held ten international workshops, trained 216 research workers, and facilitated visits to ICRISAT of a few thousand visitors who could see our experiments in field and lab and exchange ideas with our scientists.

Looking Ahead

We recognize that ICRISAT's task is difficult but know it is well worth the effort. Our scientists are engaged in problem-solving research, keeping in mind its relevance and excellence to meet the needs of our target group in the SAT. We believe that with the dedicated efforts of our scientists and cooperators, the support of our donors, and the participation of farmers, a technology highly remunerative, appropriate, and transferable to farmers of the SAT will become available. It is a slow process, but we are on the right path. ICRISAT has entered a distinctly new and exciting phase in the development of technology and its transfer to farmers of the semi-arid tropics for improving their well-being.

Session 2

ICRISAT Researches for Development of Technology for the SAT

Chairman: R. W. Cummings
Co-Chairman: Ampol Senanarong

Rapporteurs: J. R. Burford
K. L. Sahrawat
R. Jambunathan
S. C. Gupta

Cereals Improvement Research Technology for the Semi-Arid Tropics

J. C. Davies*

Abstract

The major cereals of concern to ICRISAT are sorghum and millet, which rank fourth and fifth in terms of world cereal production. They are grown extensively in the semi-arid tropics as staple foodstuffs, since they have an ability to withstand dry conditions. They have a low cash value and are usually grown as subsistence crops in poor agricultural situations; hence, they cannot stand high agrochemical or expensive technological inputs. The Cereals Program at ICRISAT has been formulated with these points in view. Research in all disciplines has focused on production of seed with desirable characteristics to help to reduce the impact of the major yield-reducing factors — drought, insect pests, diseases, and parasitic weeds. Major advances have been made in the area of screening and breeding for resistance to these factors. Many of these techniques are already being used extensively in India and Africa.

The two cereals of concern to ICRISAT are sorghum (*Sorghum bicolor* Moench) and pearl millet (*Pennisetum americanum* Leake). These, with maize, are classified as coarse grains and rank fourth and fifth, respectively, in terms of world cereal production. This is not a reflection of their real importance however, as they are often the main subsistence food crops of some of the poorest and least privileged people on earth. The relative importance of sorghum and millet in terms of total cereal area and production in the world is shown in Table 1.

If the People's Republic of China is included in world figures, some 58% of the world's sorghum area (about 59 million ha) and 65% of the world's millet area (about 55 million ha) are in the SAT. However, only 44% and 55%, respectively, of the production is obtained from this area. The yields from the SAT sorghum areas are about 800 kg/ha; from millet areas, about 500 kg/ha, both significantly lower than the world average. In the non-SAT area of Africa, for instance, mean sorghum yields of 1771 kg/ha are quoted, whereas in the developed world the figure is 4194 kg/ha. There is, therefore, considerable scope for technological innovation to improve the situation in the SAT.

Table 1. Relative importance of sorghum and millet to total cereal area and production in the world.

Crop	Percentage of world cereal	
	Area	Production
World sorghum	8.1	4.9
World millets	7.5	2.4
World sorghum & millets	15.6	7.3

There is also a need for it. Although production of coarse grains has been increasing steadily, if not spectacularly, since 1964, there is a deficit forecast for West Africa in 1980, with a supply/demand balance in India — a very considerable producer — in the same year. The demand for coarse cereals is projected to increase at about 2.4% annually, and there are forecasts that by the mid-1980s there will be deficits of 8 to 10% in India and 28% in eastern and west-central Africa. By the 1990s, the LDCs will have deficits of about 37%.

Against this background, our cereals program seeks, as a basic objective, to increase food supply in the SAT countries through the national programs. It recognizes that several major yield-reducing factors are in operation in the SAT, such as insect pests, plant diseases,

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parasitic weeds, and drought. By combating these, it seeks to include an element of stability in the higher yield levels that we hope will be developed by breeders from exploitation of germplasm being assembled at ICRISAT. To succeed in this aim, a fully integrated approach is being used, in which all the major disciplines — genetic resources, entomology, pathology, physiology, and microbiology — contribute to the new genotype produced by breeding.

Research Technology for the SAT

The technology currently used and the cultivars grown by subsistence farmers in the SAT have often evolved together over eons and produce an equilibrated, if low-yielding, situation. Patterns of agriculture are adapted to suit conditions, but the existing technology and patterns cannot cope with the rapidly increasing SAT populations.

Knowledge in agriculture and progress in the agricultural sciences have made quantum leaps in the last 40 or so years in temperate climates, and modification and adaptation of this knowledge can contribute to research in the SAT. However, many of the innovations developed in agriculture in temperate zones have already been shown to be environmentally questionable; some are downright exploitive and, of late, highly energy-consuming, which serves to underline the care that must be taken to study and explore thoroughly the prospective technology for the SAT. There also exists a need to develop suitable research technology that takes into account the known facts and possible future trends in agriculture for the benefit of the SAT farmer, and to consider political and socioeconomic factors involved in introduction of new research technology that can, further down the line, have significant effects on the economics of nation states.

Clearly, with sorghum and millet, there are strict economic limitations on what can be done by way of technological innovation, and these should be reflected in the type of research carried out at an institute such as ICRISAT, at least in the short term. Although the crops are so crucially important to indigenous populations of the SAT, they are low in cash value and are essentially items of internal trade. Obviously they will not stand big agrochemical inputs — either fertilizer or pesticide — although both can usually be demonstrated to provide considerable yield advantages. These known constraints have fashioned the approach we have taken in the ICRISAT Cereal Program. We have accepted that both the breeding stock and any technology coming from research programs must be applicable to the situation existing on the peasant farmer's land and research techniques developed must be of use to scientists working in less than ideal conditions.

It is convenient to consider developments in our research technology in cereals improvement in the light of this, under the different discipline headings. It is necessary to stress that each discipline has its part to play in crop improvement but that success in our objective will come only by a close integration of research at all stages, and by adoption of input from national researchers, who are close to the farmer.

Pathology

Serious yield-reducing diseases affect sorghum and pearl millet; severe downy mildew epidemics, for example, decimated the Indian pearl millet hybrid crop during the early 1970s. The major aim of the ICRISAT Cereal Pathology team is to identify, and help the breeder utilize, stable disease resistance. Effective screening techniques are basic to this work, and they need to be based on a sound understanding of the biology and epidemiology of the diseases. A major part of the technology generation in cereal pathology has been the development of new, or adaptation of existing, screening techniques so that truly resistant sources can be identified.

A good example is the work with the pearl millet downy mildew mentioned earlier. Our scientists elucidated the role of sporangia in the epidemiology of this disease and, based on this, developed highly efficient screens. The joint use of this technique by breeders and pathologists has enabled us to rapidly select downy mildew resistant versions of our populations and to develop resistant hybrids and varieties, several of which are performing well in the All India Coordinated Millets Improve-

ment Project (AICMIP). The technique is being successfully used in ICRISAT cooperative programs and increasingly by national program scientists. Similar screens have been developed for a range of other diseases — pearl millet ergot, sorghum grain molds, and charcoal rot, for example — and are already in use both here and overseas. This is an important, though nonquantifiable, technology development and contribution.

Entomology

Several innovations and adaptations have been made with regard to screening for two of the major insect pests of sorghum — shoot fly and lowland stem borer. These involve, for shoot fly, the use of susceptible spreader rows and fish meal attractant for large-scale germplasm screening and, for stem borer, the development of an artificial diet that enables extremely large numbers of larvae to be reared and to be available at the blackhead stage by the very beginning of the sorghum season. These larvae are introduced into the funnels of sorghum at the appropriate stage for infestation, using a gun developed at CIMMYT and modified for use at ICRISAT. Between five and seven larvae are introduced into each plant in a measured quantity of finger millet seed. Whole fields of material under test can be rapidly treated by this method, enabling us to screen both germplasm and breeders' material. The diet is already being successfully used by several cooperators.

These are examples of adaptation of existing techniques and rapid dissemination of ideas, a task which an institute such as ICRISAT is unquestionably well set up to carry out.

In the field of insect population dynamics, one of the major research areas is development of trapping methods — light, chemical attractant, and pheromone. A technique using fish meal, ammonia, and brewers' yeast proved highly successful in attracting female shoot fly and is now used in India and Africa to assess shoot fly populations, particularly in the off-season between crops. Tests were carried out with pheromones of stem borer moths, large numbers of which were trapped, and the aldehyde was shown to be the major attractive source. Subsequently, experiments have been done on loading and ratios; results will be compared with those obtained from light traps. Collaborative work to test pheromones from other major pest species is under way, utilizing various trap designs and techniques that will have applicability elsewhere.

It is possible that control techniques will be evolved from such work; certainly the pheromones will be used in detecting pests and their numbers and will possibly be of use in timing accurately any insecticide applications that may be economically possible on cereals.

Physiology

Undoubtedly the major constraint to increased production of sorghums and millets in the SAT is availability of water. It is normally inadequate in quantity and erratic in delivery. While a major thrust of the ICRISAT Farming Systems Program is to ensure that all the rain that falls is properly utilized, it is also recognized that landrace cultivars exist that are able to tolerate water stress relatively better than others. The detection and confirmation of these lines and their utilization in breeding programs could be a significant technological breakthrough in SAT agriculture. Field techniques for location and confirmation of stress resistances have been developed so that the lines detected are used and refined in breeding programs as a priority. The complexities of the situation make progress slow, but technology is being developed that will be transferable to other research workers.

Our physiologists are also involved in assisting breeders to make selections of plants with resistance to insect pests and plant parasite weeds. This has necessitated development of laboratory techniques to identify factors associated with resistance, such as trichomes and degree of lignification in seedlings and study of haustorial attachment on the roots of growing seedlings. These techniques are already being used in both developed and developing countries in an effort to hasten breeding of resistant cultivars.

Microbiology

It has been recognized for some time that certain cereals and grasses possess an ability to fix atmospheric nitrogen. This is potentially extremely important, as poor nitrogen availability is a major limiting factor in production and fertilizers are seldom available to poor

farmers. It has been demonstrated at ICRISAT that some wild *Pennisetums* have considerable potential to fix nitrogen, and a field technique has been devised that uses acetylene reduction to detect plants with enhanced fixing ability. Some problems have been experienced initially with plant-to-plant variability, but a technique will soon be available to research workers in the SAT. Additionally, technology is being developed for differentiation of various strains of N_2-fixing bacteria and for culturing of useful strains.

Breeding

Considerable progress has been made in testing and comparing different breeding methods for the two crops. Full analysis of data accumulated over several sites in several seasons will enable breeders to assess which breeding methods give most rapid advances and also to determine which methods enable desirable traits to be incorporated simultaneously and most rapidly in seed material. ICRISAT has pioneered research into populations breeding methodology in pearl millets, and breeding material is already under test in the AICMIP trials; several ICRISAT hybrids have shown promise both in India and overseas.

Our breeders have also been particularly concerned with nutritional and food preparation quality. In collaboration with the biochemists, they have determined some of the desirable quality traits in sorghum and millets for a range of food preparations. Work is conducted with scientists in several countries — and this is proving an interesting exercise — for use of these cereals in tortillas in Mexico, beer in East Africa, teau in Upper Volta, chapati in India. It is in the breeding programs that the technologies and techniques developed in all disciplines come together to interact on the germplasm base. Here we are at the farmer's level — the seed.

The Future

These few examples may serve as an indication of the type of technology that is being developed for use in the SAT. It is not complex; if it were, it would be unlikely to have an impact where it is needed — on food production. It is strongly field-oriented and hence has the greatest chance of being used, and it does not involve the use of expensive or complicated machinery. It can be quickly communicated and utilized by research workers under difficult conditions. We believe that this technology will be a real contribution in the struggle to feed the rapidly increasing population of the semi-arid tropics.

Pulse Improvement Research Technology for the Semi-Arid Tropics

J. M. Green*

Abstract

Pulse crops, with higher nutrient requirements than cereals but without marked response to added fertilizer, present difficult problems to researchers trying to increase production. Promising results have been obtained in increasing yields of pigeonpeas by using hybrids and in chickpeas by modifying plant type, and in stabilizing yields of both crops by incorporating genetic resistance to diseases. Innovations in agronomy have resulted in promise of increased production outside of traditional systems.

When we speak of "developing a pulses technology," we are very largely speaking of a technology that can be contained in a seed. If we limit our considerations to chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* [L.] Millsp.), we are dealing with food crops that (1) are not produced in adequate quantity, (2) are overpriced as a result of short supply, (3) are planted on a slowly diminishing acreage, and (4) are experiencing no noticeable change in average farm yield.

Of two alternatives for increasing production — either increasing the yield per unit area on land currently used for the crop or extending the area on which it is grown — the first option favors the small farmer who currently grows the crop and contributes to an increased total food supply; the second alternative implies either competition with other crops for land, or extending the adaptation of chickpea or pigeonpea to land currently submarginal for crop production. Success in the first option will result in something of an increase in acreage also, but increased yield per hectare is essential.

A natural expectation (to some) of the combination of an international agricultural research center and a crop mandate is that there should be a "green revolution": a breakthrough in genetic potential for yield, combined with a responsiveness to fertilizer, that will provide a quantum jump in yield. Unique circumstances that were peculiarly similar provided the mechanism for such breakthroughs in the cases of rice and wheat; the combination of dwarf genes that reduced plant height and permitted better standability of the crop plus responsiveness to high levels of fertilization resulted in quantum jumps in yield of these grains.

We must recognize at the outset that there are fundamental differences between cereal crops and legumes. The consequences of these differences are illustrated by the progress of the soybean and the maize crops in the USA.

Hartwig, in reviewing cultivar development in 1973, reported a 17% yield advantage for the cultivar Lincoln over introduced strains previously grown in the midwest, and an advantage of 30% for the cultivar Ogden over introductions in the southern United States. Aside from a mention of a 25% yield advantage for cultivar Clark over the same introductions compared with the Lincoln cultivar, there is no other mention of notable yield gains in the history of soybean cultivar development in the United States to 1973.

Soybeans were a new crop in which the base yields were produced by direct introductions, and cultivars from the latitude of the source area in northern China were limited in adaptation to the central Corn Belt of the United States. The potential for yield advance through breeding in areas of the United States where soybean introductions were not adapted should have been greater than is the opportunity for improving yields of chickpeas and pigeonpeas in areas where local landraces have evolved over thousands of years.

Such is the challenge facing us in increasing production of pulses. To help us to keep our

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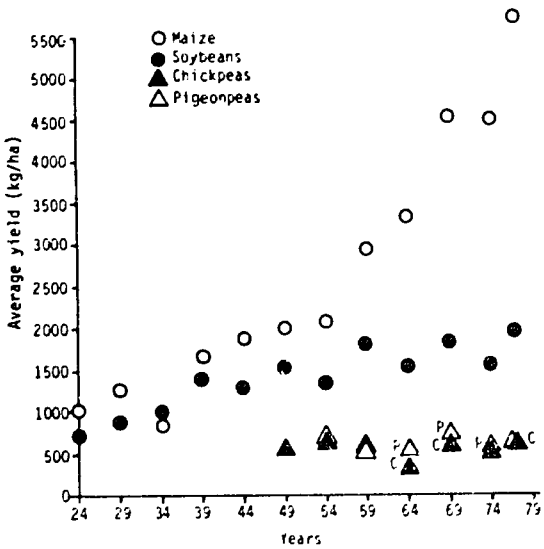
perspective on realistic goals, a comparison of chickpea and pigeonpea yields in India with soybean and maize yields in the United States over 33 years is presented in Figure 1. With a background of intensive research on maize for many years, and a breakthrough in the teens that started reaching the farmers in the late 1920s and early 1930s, productivity has increased dramatically. Soybean yields have increased, but only in a linear fashion, and researchers are still looking for a breakthrough.



Sources: Maize - U.S. Dept. Comm., 1975; FAO 1978
Soybeans - Probst and Judd, 1973; FAO 1978
Chickpeas - Govt. of India
Pigeonpeas - Govt. of India

Figure 1. Annual mean yield (kg/ha) at 5-year intervals of maize and soybeans in USA and chickpeas and pigeonpeas in India, 1924–1977.

Prospects for Improvement

A brief description of the crops in question will be helpful in identifying possibilities for improvement. Chickpea is an annual plant, short in stature, with a relatively high harvest index (40–60%), adapted to growing in the absence of rainfall, either on residual moisture or with irrigation. Conventional wisdom in Syria is that a minimum of 400 mm of rainfall is required to accumulate enough stored moisture to produce a chickpea crop, but in India the crop is grown in areas receiving less than 400 mm. There are two main market types: kabuli (garbanzo) which has relatively smooth, generally large, light-colored seeds and is most often grown as a summer crop in the Middle East, the Mediterranean region, and in the Americas; and the desi (garbanzo porquero), which can have yellow to black seed (generally smaller and with a rougher surface than seed of the kabuli) and is usually grown as a winter crop in more tropical areas. World production statistics, indicating our best estimates of relative proportions of kabuli and desi types, are presented in Table 1.

Table 1. World production of chickpeas in 1977.

	Area harvested[a] (1000 ha)	Yield[a] (kg/ha)	Total production[b] Kabuli (1000 tonnes)	Total production[b] Desi (1000 tonnes)
Africa	309	703	57.5	123
Asia	9 504	786	1401.2	5035
Europe	175	763	99	0
Mexico	210	833	35	140
South America	40	674	23	0
Totals	10 238	745	1615.7	5298

a. From FAO production yearbook, except Tunisia data from Boustama, 1979.
b. Kabuli-desi division by author on basis of information gleaned from contacts in the countries.

Pigeonpea is a perennial shrub, with a quantitative short-day photoperiod response, relatively high total biological production, and low harvest index (15–30%). Stems and primary branches are woody. When planted at ICRISAT Center soon after the longest day, maturity ranges from 4 to 10 months, and height from less than 1 to more than 2 m. However, the same cultivar that is over 2 m tall and matures in 10 months will be less than a meter tall and will mature in 5 months if planted from 30 to 60 days before the shortest day. (These descriptions

apply at ICRISAT Center, latitude 17° 40'N; reactions vary with latitude and resulting differences in daylength.) Pigeonpea generally has a slow growth rate for 45 days, followed by maximum growth between 45 days and flowering. This is apparently an adaptation to the traditional intercropping; more than 90% of the crop is grown in this fashion in India. Pigeonpea grows well during the rainy season but performs best when flowering and podding occur after the rains cease. Production statistics for 14 countries are listed in Table 2, we have had contact or correspondence with 59 countries in which pigeonpeas are grown and utilized, but in many countries the crop is scattered in small patches and does not enter normal crop production statistics.

Table 2. World production of pigeonpeas by countries and use as reported for 1973 (last year in which FAO reported pigeonpeas as a separate crop).

Country	Area harvested[a] (1000 ha)	Yield[a] (kg/ha)	Dry grain[b] (1000 tonnes)	Green[b] peas (1000 tonnes)
India	2330	750	1748	Tr
Burma	65	348	23	
Bangladesh	3	723	2	Tr
Pakistan	2F	500	1	
Uganda	90F	444	40	
Kenya*	61	NA	NA	NA
Malawi	35F	571	20	
Tanzania	22F	523	12	
Dominican Republic**	14	2191		30
Haiti	7F	538		4
Puerto Rico	3	1154		3
Trinidad	1	1585		1.6
Venezuela	10F	403	2	2
Panama	2F	750		1.5

a. Source: FAO 1973, except:
* F. N. M. Onim (Pigeonpea Project Breeder and Coordinator, University of Nairobi, Kenya: personal communication, 1976) and
** J. Diaz Gomez (Assistant to the Director, in charge of Investigation Project, State Secretariat of Agriculture, Dominican Republic; personal communication, 1976).
b. Author's allocation based on information gleaned from contacts in the countries.
F = FAO estimate
Tr = Trace

Increasing Yields in Traditional Production Systems

Fertilizer Response/Nitrogen Fixation

Comparison of the nutrient requirements per tonne of grain of three cereal and three legume crops (Table 3) shows that nutrient requirements for legumes are actually higher than for cereals; the N requirement is approximately twice as high. However, neither pigeonpea nor chickpea gives marked response to fertilization; slight increases from applied phosphate and low levels of nitrogen in infertile soils have been reported (Saxena and Yadav 1975).

A search for chickpeas responsive to phos-

Table 3. Total uptake of major nutrients by certain crops, and calculated nutrient requirements per 1000 kg grain produced.

Crop	Grain yield (kg/ha)	Uptake (kg/ha) N	P_2O_5	K_2O	Source
Maize	9418	247	90	219	Donahue et al. 1971
Rice	5000	100	46	120	Athwal 1972
Wheat	4036	140	56	123	Donahue et al. 1971
Soybeans	2690	163	45	84	Donahue, et al. 1971
Chickpeas	3000	144	31	80	Singh 1969
Pigeonpeas	2000	132	25	64	Rao 1974
		(kg/1000 kg grain produced)			
Maize		26.2	9.6	23.3	
Rice		20.0	9.2	24.0	
Wheat		34.7	13.9	30.5	
Mean, three cereals		27.0	10.9	25.9	
Soybeans		60.6	16.7	31.2	
Chickpeas		48.0	10.3	26.7	
Pigeonpeas		66.0	12.5	32.0	
Mean, three legumes		58.2	13.2	30.0	

phate fertilization has not been successful, and high levels of N fertilization have not resulted in increased yields, either under rainfed conditions or limited irrigation. Modest yield responses to foliar application of N during flowering and pod development have been observed. All of these results indicate that nutrient starvation is not a likely factor in limiting yields under rainfed conditions. If optimum moisture supply and temperature were provided, nutrients might become limiting, but such conditions are not likely to exist in our mandate area.

Significant differences have been observed among cultivars in N_2 fixing ability, and also in the effectiveness of different *Rhizobium* strains. It is not unreasonable to expect to realize yield gains from utilization of favorable combinations of cultivars and *Rhizobium* strains, and vigorous research in this area is under way.

Plant Stands

Farmers' yields of both crops could be increased through improved plant stands. Pigeonpeas planted at the onset of the rains can be planted to the desired stand. However, pigeonpea is often the secondary crop in intercropping, and its stand is limited, by design, to maximize production of the primary crop. Studies at ICRISAT have shown that it is possible with cereal intercrops to produce normal cereal yields and up to 70% of the sole-crop yield of pigeonpea.

Poor stands of chickpea often limit yields in farmers' fields. In the short term, improvements in land preparation practices and in planting equipment can correct this problem. Since chickpea yields are depressed by planting too early, farmers are faced with the problem of delaying planting to the optimum date, even in years when the rains stop early. Long-term approaches to a solution of this problem include development of cultivars capable of germinating at low moisture potential and/or the development of cultivars tolerant to heat at the beginning of the growth cycle. Preliminary research on these aspects has shown that genetic differences for both exist; in both cases the breeding process will take time. Aside from improving stands, planting of cultivars that compensate for low plant population will result in higher yields. We have identified cultivars that will give equal yields with four plants or with 33 plants m² (Hissar, Table 4); the latter density is recommended as constituting a full stand. Displacement of nonresponsive local landraces with such "plastic" cultivars would result in substantial yield improvement.

Table 4. Yield response of chickpea cultivars to optimum and suboptimum plant populations at Hissar in 1978 (kg/ha).

Density	Cultivars			
	850–3/27	L–550	G–130	L–144
(Plants/m²)				
33	3060	3610	3087	3427
8	2967	3090	3043	2200

LSD. (0.05): For comparison of Means of Plants/m² within a cultivar = 765
For comparison of Means of Cultivars within a spacing = 507

Weed Control

Loss of yield to weeds does not appear to be a major factor in the traditional system. While there are occasional examples of disasters, we do not consider this an area of urgent need or high potential payoff.

Disease Control

Nene (1979) has listed the diseases reported in the literature and observed by ICRISAT personnel in producing countries. In India, 25 pathogens have been reported on chickpeas and 26 on pigeonpeas, but on each crop few diseases are generally serious The occurrence of two major diseases of pigeonpea in six states of India in recent years is shown in Table 5. In general, diseases are regional in occurrence, and the breeding of adapted cultivars with specific resistances can be best accomplished through local programs. However, we recognize the opportunity to increase yields through disease control as one to be shared, and have an active program that has (1) provided diagnostic characters for disease identification, (2) developed screening techniques and identified

Table 5. Prevalence of wilt and sterility mosaic in pigeonpea in selected states of India.[a]

State	Distance covered (approx) (km)	Samples (farmers' fields) (no.)	Districts (no.)	State average incidence[b] Wilt (%)	State average incidence[b] Sterility mosaic (%)	Range in farmers' fields Wilt (%)	Range in farmers' fields Sterility mosaic (%)
Andhra Pradesh	4000	102	19	5.26	1.59	0–92	0–43
Karnataka	2000	37	14	1.12	9.77	0–17	0–95
Madhya Pradesh	5000	83	27	5.42	3.65	0–96	0–99
Maharashtra	4000	82	19	22.61	1.09	0–93	0–47
Tamil Nadu	2000	46	11	1.36	12.84	0–65	0–92
Uttar Pradesh	3000	109	44	8.50	16.10	0–86	0–93

a. Roving surveys carried out between 1975 and 1979.
b. Arithmetic average of all fields surveyed.

sources of resistance, and (3) incorporated resistance in advanced breeding lines with high yield. Advanced lines — including pigeonpea lines with resistance to sterility mosaic, wilt, phytophthora blight, and combinations of these, and chickpea lines with resistance to wilt, stunt, root rots, and combinations of these — have been supplied to national programs.

Pest Control

The pests that damage pigeonpea and chickpea have been identified, and pod damage in pigeonpeas has been assessed in parts of India (Table 6). In either crop *Heliothis armigera* is a major pest. Losses in chickpea are less serious than those in pigeonpea and, interestingly, more progress has been made in identifying less susceptible genotypes in that crop. The spectrum of damaging pests is broader in pigeonpea, and losses are higher. Both crops, by virtue of flowering and podding in the dry season, tend to escape the peak populations of pod borers, and both are capable of compensating for damage by the production of successive flushes of flowers.

We have found mechanisms of pod borer resistance in wild relatives of pigeonpea, and attempts are being made to transfer these. The problem in pigeonpea is complicated by the podfly (*Melanagromyza obtusa*), which tends to be more serious where pod borers are less serious; in recent years this pest appears to have been spreading southward. A much more specific feeder than *Heliothis*, it may be easier to control through host plant resistance.

In traditional systems in India, little insecticide is used. It is our intent to reduce losses to pests without increasing use of chemicals. Pest-management-systems research complements our research on host plant resistance.

Host plant resistance to both diseases and

Table 6. Pigeonpea pod damage observed in various states of India 1976–78.[a]

State	Year	Fields sampled (no.)	Pod damage[b] Borers (%)	Pod damage[b] Podfly (%)
Uttar Pradesh	1977	43	7.0	25.6
	1978	28	32.8	25.9
Bihar	1976	22	10.0	25.7
Assam	1978	38	28.9	12.6
Rajasthan	1978	28	4.5	15.0
Madhya Pradesh	1978	25	27.2	22.6
Gujarat	1978	70	12.6	25.3
Maharashtra	1978	31	47.8	24.9
Andhra Pradesh	1976	112	38.4	1.8
	1978	21	34.1	5.4
Karnataka	1977	37	23.1	5.2
Tamil Nadu	1977	42	13.7	4.2

a. Based on unpublished survey data collected by ICRISAT scientists in cooperation with national scientists.
b. Percent pod damage does not directly indicate crop loss. Actual crop losses were not determined.

insects would help stabilize yields and raise average production. This is a priority area of research at ICRISAT Center.

Increased Yield Potential

For the traditional farmer, the best technology is a cultivar that will produce higher yields and fit into his cropping system without additional inputs and meet his requirements in visible (and invisible) quality characteristics.

We currently have two approaches to developing higher yielding chickpea with a goal of exceeding the small incremental increases often attained in pulse breeding. One is to develop taller plants with more pod sites, better light penetration, and stems stiff enough to support the superstructure. This is not an original idea with us; IARI in New Delhi is using the same approach, and there are already tall Russian cultivars adapted to mechanical harvest. We are encouraged, however, for as early as the F_3 generation we found substantially higher yields in the new plant type (Table 7). Beyond the description above, we are not wedded to a specific ideotype, but will evaluate tall plants with varying degrees of branching, including one found this year with zero branches.

Table 7. Comparison of 10 best F_3 lines selected for tall stature and high yield, with standard check and tall cultivars.

	Height (cm)	Maturity	Grain yield (g/plot)
Standard checks			
Annigeri	30–35	E	995
K-4	35–40	ML	985
G-130	35–40	L	889
10 best F_3 lines	54–68	M	995–1293
Tall checks			
K-1170	65–70	VL	78
K-1184	65–70	VL	187
K-1481	65–70	VL	280

The other approach now in use is breeding for high yield as a single objective, using a quantitative approach (Byth, Green, and Hawtin 1979). We will evaluate early generation bulks in multilocation tests, derive lines in the F_4 generation, and test the derived lines in multilocation tests. We believe that yield, for which selection on a visual basis is relatively ineffective, can be shifted upwards if we conscientiously ignore all other characters in the selected program. If (or when) we have derived lines giving quantum yield increases, simply inherited characters can be incorporated by backcrossing. (We are already capitalizing on reduced generation time and can complete four generations per year.) If, on the other hand, we develop an exceptionally high-yielding line that has nonpreferred color and shape of seed, it might be surprising to see how rapidly esthetic preferences could change to accommodate profitable yields.

In pigeonpea, our major hope for a substantial increase in yields is in the use of hybrids. We have tested two groups of hybrids made on male-sterile female lines, using standard cultivars and selected germplasm lines as pollinators, during the past 2 years. In both years a hybrid gave the highest yield; last year it was 31.5% above the best cultivar, and this year the best hybrid's advantage was 17%. The real advantage of hybrids in the traditional production system is that the gain can be realized in single rows on rice bunds, in pure stands of pigeonpeas, and anywhere in between. We also expect better stability of performance in hybrids.

There is a need for purification of the male-sterile lines in hand and converting more lines to sterile; both activities are under way. There is a need for testing many hybrid combinations.

We have multiplied seed of available steriles and have distributed lots to cooperating breeders, suggesting that they use part of the seed for increase of the sterile and part for hybrid seed production, using their best local cultivar as pollinator. We have demonstrated the hybridization technique to visiting breeders; it requires removal of 50% of the plants in the female rows at flower initiation (the genetic male sterile is maintained by sibbing) and then cross pollination by bees, which at ICRISAT Center are exclusively wild bees of several different species.

Pigeonpea hybridization is much less laborious and much less expensive than cotton hybridization, which has flourished in India.

Looking Beyond the Traditional Systems

ICRISAT works with its mandate crops in its mandate area but is also concerned with these crops wherever they are grown. On this basis, the chickpea programs of ICRISAT and ICARDA have been integrated. At both centers, emphasis is placed on extending the adaptation of the crop. In Syria, much higher yields have been obtained in winter (Nov planting) than in the normal spring (Feb planting) crop. Rains fall on the winter crop, and the development of ascochyta blight resistance is essential. There has been excellent progress in identifying sources of resistance, and cultivars adapted to winter planting will soon be available. Even without such a cultivar, a Syrian farmer planted 50 acres of winter crop in November 1978 (which received fungicidal sprays to control *Ascochyta*) to test this new technology he had seen in ICARDA's research plots.

Chickpeas are temperature sensitive and react badly to excessive heat at the beginning and at the end of the season. Early plantings at ICRISAT Center and late planting at Hissar (29° 11'N) are being made for screening germplasm lines and breeding material for heat tolerance. It is too early to tell if the evolutionary pathway has led chickpeas into a box, but observed differences perhaps reflecting more heat tolerance is desis and more cold tolerance in the kabulis suggest that hybridizing these two types — being done by almost all chickpea breeders — might provide the needed variability. The advantage of early season heat tolerance has been mentioned; heat tolerance later in the season would permit normal senescence and maturity — and higher yields.

In Chile, chickpea is grown between latitudes 32° 30' and 39°S on conserved moisture in the summer. In that area, there is a need for a high-yielding short-season legume crop, adapted to mechanized production, for animal feed. A photoperiod insensitive pigeonpea line, which matures in 110 days, has been selected at the University of Queensland, Australia. Near Brisbane, 2500 kg/ha of grain have been combine-harvested from a field planted with this line at 400 000 plants/ha. (The UQ program is supported in part by ICRISAT to provide research on breeding for and agronomy of mechanized production.) The new line has not yet arrived in Chile, but it has been sent for study at IARI, New Delhi, and to Senegal for summer production (1 March planting) under irrigation.

In West Africa, pigeonpea lines adapted to the ICRISAT Center area have produced grain yields of 1000 to 2000 kg/ha grown without intercrop and without monetary inputs. In that area, farmers' yields of sorghum are about 400 kg/ha, and of the cowpea intercrop about 100 kg/ha. This is outside the traditional area for dry pigeonpea consumption, and the adoption of the higher-yielding crop will require changes in dietary habits.

Pigeonpea as a *rabi* (postrainy season) crop in India is not new; it was reported as a practice in Gujarat by Watt in 1908. Until recently, this practice was still largely limited to Gujarat, with limited acreages planted in Nepal. Investigations at ICRISAT Center showed (1) October plantings at 300 000 plants/ha gave grain yields equal to June/July plantings at 44 000 plants/ha, (2) September plantings gave higher yields than later plantings, and (3) medium- and late-maturing cultivars yielded higher than early cultivars in this season. This technology has moved out from ICRISAT; a number of research centers in India have active programs, some exclusively, on postrainy season pigeonpea.

Implicit here is a "substitution technology." Farmers in a frost-free area, faced with early loss of soil moisture, can substitute pigeonpea for chickpea.

We have demonstrated the feasibility of harvesting a crop of forage and two additional grain crops following the first season's harvest of pigeonpeas planted in the postrainy season. Planting a dense stand in October, harvesting pods in March, removing two-thirds of the plants for forage after onset of the monsoon, harvesting a grain crop in November/December (and under favorable conditions a ratoon crop 3 months later) is a system that saves through elimination of land preparation and weeding after the first establishment of the crop. This technology is also under investigation by the Indian national program.

International Interchange of Technology

The international center must have a strong

core program of sufficient scope to be productive. The research effort must be planned so that useful genetic material can be supplied in the mandate area. Along with genetic material, research technology must be projected to local programs. Since the ultimate objective is self-sufficiency of national research programs, the clear warning of Weiss (1979) that the Center program not "swamp . . . national institutions it is supposed to serve" must be heeded.

We initiated international cooperation by hosting a workshop in 1975; since then most scientists from abroad who missed the workshop have visited ICRISAT Center. We have visited many of the local research centers and followed up with a workshop for chickpea in 1979. One for pigeonpea is planned for 1980. Our continuing communication with scientists is through: (1) the conduct of international trials and distribution of results of yield and disease nurseries, (2) annual progress reports, which are detailed summaries of research in progress in each discipline at ICRISAT (they describe experiments in progress, give results to date, and indicate what we think about the problems to be solved), and (3) annual breeders' meetings at ICRISAT and ICARDA research plots, where national breeders identify plants, populations, and germplasm lines for use in their own programs. Unfortunately, budget constraints severely limit the number of scientists we can bring from abroad for these annual meetings. In India, working relationships are formalized further in the All India Coordinated Pulse Improvement Workshops.

We are dependent on our colleagues at the local level for their inputs in the overall improvement program. Where there are identifiable deficiencies in their programs, we must seek resources to correct those. Unfortunately, recognition of the need for intensive work on the problem of witches' broom in the Dominican Republic, developmental agronomic work in the Cape Verde Islands, West Africa, and a genetic resource center in East Africa have not resulted in action programs by ICRISAT.

From training of technicians in research methodology to extended seminars with specialized scientists, worthwhile experiences have been made available to pulse research workers. We would like to see, for countries limited in scientific manpower, much more availability of support for advanced study.

Conclusion

We are optimistic about the probability of increasing production of these two pulse crops. The optimism is generated by (1) encouraging results in the improvement program, (2) increasing cooperation and interaction with national programs, and (3) the possibilities of broadening the adaptation of both crops.

The results achieved in improvement of chickpea and pigeonpea will pay off to the extent that local adaptive research is possible, to the extent that extension efforts are effective, and only to the extent that local seed-production facilities are effective. The time lag involved will be inversely related to the sense of urgency felt by personnel involved in the program. We try continually to communicate a sense of urgency; our best method of communication is by example.

Acknowledgment

Contributions of ICRISAT pulse scientists to the research developments reported herein and to the preparation of this report are gratefully acknowledged. The positive response of many national scientists to our various cooperative efforts has contributed significantly to the program; their cooperation is greatly appreciated.

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Groundnut Improvement Research Technology for the Semi-Arid Tropics

R. W. Gibbons*

Abstract

Groundnut is one of the most important legume crops of the semi-arid tropics (SAT) and serves as a source of food, cooking oil, and a cash income. Yields, however, are low in the SAT due mainly to losses caused by pests, diseases, and unreliable rainfall patterns. The main emphasis of the program is on producing high-yielding breeding material with stable resistance to the major pathogens, which include rust, leaf spots, and Aspergillus flavus. *Viruses and insect pests also cause large yield reductions, and sources of resistance are being sought. Large-scale breeding programs are under way and early and advanced segregating populations are being distributed to cooperating national breeders. Efforts are being made to improve the nitrogen-fixing capacity of groundnuts. Yield advantages are being achieved by intercropping groundnuts with pearl millet. Wild* Arachis *species are being exploited for sources of useful genes.*

Groundnut became the fifth ICRISAT mandate crop in 1976, some 4 years after the Institute was created. In 1974, a team of four consultants was invited to Hyderabad to review the world research needs of groundnuts, to consider whether ICRISAT ought to help meet those needs, and, if so, to suggest a possible program of international research. It was concluded that the crop required international research, that it would be an appropriate subject within the mandates of the international agricultural research system, and that ICRISAT was the appropriate center, as groundnuts are primarily a crop of the semi-arid tropics (Bunting et al. 1974). In mid-1976 a detailed plan of research was accepted by the Governing Board of ICRISAT (Gibbons 1976) and breeding, germplasm, pathology, and microbiology programs commenced. Since then entomology, cytogenetics, and some preliminary physiology projects have commenced.

Groundnuts in World Agriculture

Production

The cultivated groundnut, *Arachis hypogaea* L., originated in South America and is now grown on a commercial scale in some 82 countries. In 1976, it was estimated that 19 million hectares were planted and over 18 million tonnes were harvested at an average yield in shell of 958 kg/ha (FAO Trade Statistics). The limits of present commercial production are within the latitudes 40°N and 40°S. Asia is the largest producer (10.3 million tonnes), followed by Africa (5.4 million tonnes), North and Central America (1.8 million tonnes), South America (0.9 million tonnes), Oceania (0.29 million tonnes) and Europe (0.24 million tonnes). The largest individual producer is India, which in 1976 produced 5.7 million tonnes of groundnuts in shell from 7 million hectares of land. Large-scale producing countries in Africa are Nigeria, Senegal, and Sudan. Approximately 70% of world production comes from the developing countries, many of which lie in the semi-arid tropics.

Adaptation

Groundnut is generally considered to be a day-neutral plant although Wynne et al. (1973) have suggested that sensitivity to daylength depends on temperature. The relative insensitivity to daylength means that cultivars developed anywhere in the world can be evaluated at any latitude where favorable growing conditions exist (Varnell and McCloud

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1975). The ideal soil for groundnuts has been defined (York and Colwell 1951) as a well-drained, light-colored, loose and friable sandy loam, well supplied with calcium and organic matter; in practice, however, groundnuts are grown on a variety of soils that vary from alkaline to acid, and from clays to fine sands.

Generally, under rainfed conditions where supplemental water is not available, the choice of cultivar depends on the length of growing season available. Where season length is limiting, cultivars of *A. hypogaea* subsp. *fastigiata* (Spanish and Valencia) are grown; where the rainy season is longer, cultivars belonging to subsp. *hypogaea* (Virginia) are selected. Maturation also depends on temperature, radiant energy, and elevation. In the West African lowlands, for example, Valencia and Spanish types may mature in 90 days, whereas in the Central African plateau areas, 1200 m above sea level, development can take 120 days. Similarly, Virginia cultivars may take only 120 days to mature in West Africa and 150 to 160 days in Central Africa (Smartt 1976).

Uses

Groundnut is the most important legume crop of the semi-arid tropics (Table 1). With 25% protein and approximately 50% oil, groundnut is also an important food crop in the SAT and, after soybean and cottonseed, is the most important source of edible oil in the world. To the subsistence farmer, it may be another pulse crop and consumed at home but as a cash crop it may be considered too valuable to consume and the total crop is sold (Smartt 1976). It is estimated that about 66% of the total world production is crushed for oil (Woodroof 1973). Traditional SAT exporters of groundnuts for crushing are Nigeria and Senegal, but there is a trend for local oil expressors to be built and the surplus oil exported (Smartt 1976). Nigeria now has a capacity to crush 0.8 million tonnes of groundnuts annually (Harkness et al. 1976).

The export of kernels or unshelled pods for confectionery purposes is also an important source of revenue for countries in the SAT. The traditional main sources of confectionery groundnuts are China, India, and the USA, although the export performances of China and India have been erratic due to large domestic demands. A number of African countries in the SAT — including Malawi, Nigeria, and the Sudan — each supply about 10% of the total world confectionery groundnuts (Wilson 1975).

Groundnut hay is used extensively in the SAT as cattle feed and can command high prices, particularly in urban areas for stallfed cattle (Harkness and Dadirep 1978). The shells may be used as a fuel, as a soil conditioner, in cattle feed, and as a source of building material and organic chemicals (Patel 1964).

Production Constraints in the SAT

Yields in the SAT are low, around 800 kg/ha, compared with yields of around 3000 kg/ha — or even higher in localized areas — in the developed world (Gibbons 1977). The major constraints are pests, diseases, and the unreliable rainfall patterns of the SAT. Certain pests and diseases are worldwide in their distribution and are being studied intensively as part of the ICRISAT research program.

Relatively small numbers of groundnut researchers are available to combat the natural

Table 1. Semi-arid tropical production of food legumes (1971) (1000 tonnes)

	Legume crop					
Region of semi-arid tropics	Dry beans	Soybeans	Chickpeas	Cowpeas	Pigeonpeas	Groundnuts
Asia	2 265	1 228	5770	10	1910	6 977
Africa	613	65	205	1069	51	3 847
Central and South America	3 441	2 227	173		26	1 459
Total: Semi-arid tropics	6 319	3 520	5948	1079	1987	12 242
Total: World	11 073	48 457	6594	1195	2024	18 211

Source: FAO Production Yearbook 1972, Rome, Italy (vide Bunting et al. 1974)

hazards that restrict groundnut production. Few programs have been mounted to actively breed for resistance to pests and diseases, which annually cause serious reductions in yield. Without the means to control these pests and diseases, the small-scale farmers of the SAT desperately need sources of resistant material that will allow reasonably stable yields of groundnuts to be harvested. Once the farmers have this material, they will become much more amenable to adopting other improved farming practices. Many farmers have become discouraged because they know that even with good agronomy and much hard work the natural hazards of pests, diseases, and drought will still ravage their groundnut crop.

Objectives of the ICRISAT Groundnut Program

The main objective of the program is to produce high-yielding breeding lines with resistance to the main factors presently limiting production. Stability of yield is important over years and across sites However, because of the diversity of groundnut environments, and the uses to which the crop is put (oil crushing or confectionery), it is not possible to foresee the use of relatively few cultivars over very wide areas; nor is it desirable to flood whole areas with single, or closely related, cultivars because of the dangers of genetic vulnerability (Hammons 1972). Requirements vary greatly, even within a country. For example, in the Sudan, large-seeded, long-season groundnuts are grown under irrigation in Wad Medani for export; but under rainfed conditions, small farmers cultivate short-season cultivars that are more adapted to these conditions (Osman 1978). In Malawi, long-season groundnuts, primarily for the confectionery export trade, are grown on the plateau areas; oil-crushing cultivars are grown on the lakeshore; and short-season cultivars are adapted in the low-elevation, drier and hotter areas of the Shire Valley (Gibbons 1972).

Research Organization

Although the groundnut research program is divided into subprograms of breeding, cytogenetics, pathology, entomology, physiology, and microbiology, the relationship between these groups is close and fully integrated. Similarly, there are close ties with other ICRISAT programs concerned with groundnut research; these include the Genetic Resources Unit and Farming Systems Program, as well as the Training Unit.

As the program is still young, no formal outreach activities have yet been formulated although they have been planned (McGinnis 1979). Linkages with national programs, overseas institutions, and individual scientists are being evolved and will be discussed under the individual research technology approaches.

Germplasm Base

ICRISAT has been designated as a world center for the collection, preservation, and documentation of the genus *Arachis* by the International Board for Plant Genetic Resources (IBPGR). Since the inception of the Genetic Resources Unit in January 1979, all staff and materials have been transferred to this unit. In September 1979, an ad hoc working party consisting of experienced groundnut scientists representing different areas of the world will meet at ICRISAT, under the auspices of IBPGR, to:

1. assess the present known collections of germplasm, their geographical representation, and adequacy,
2. identify priority areas for collection material,
3. explore quarantine problems and obstacles, and
4. draw up a list of essential descriptors and descriptor states for characterization of accessions.

Much anticipatory work has been done by the groundnut germplasm botanist at ICRISAT.

Acquisition and Quarantine Procedures

After 3 years our groundnut accessions now total over 7000 entries (Table 2).

Initially, in 1976 and 1977, we received very close cooperation from Indian research centers which handed over to us duplicates of their entire collections. These collections consisted of both exotic and local accessions. The importation of exotic material also commenced in 1976 and accelerated over the subsequent 2 years. Because of the danger of seed-borne viruses in groundnut, the plant quarantine arrangements

were fully discussed and agreed upon with the Government of India. The present arrangements are as follows. Small quantities of seed are received at the Central Plant Protection Training Institute (CPPTI), at Rajendranagar, near Hyderabad. They are examined by quarantine officials and apparently healthy seeds are grown in 80 mesh screenhouses; the plants are examined regularly for up to 6 or 8 weeks. Plants showing any sign of disease are destroyed. The healthy plants are then transferred to the post-entry quarantine area at ICRISAT Center, Patancheru, and are again monitored on a weekly basis by CPPTI quarantine staff. Only at maturity are the seeds released to us from the healthy plants. Any diseased plants are uprooted and burned. Although the procedures are stringent, and the release of exotic material is slow, we feel that they are necessary to prevent any introduction of new diseases into India.

Table 2. Accessions of groundnut germplasm at ICRISAT.

Year	Accessions received during the year	Total accessions
1976	2443	2443
1977	3565	6008
1978	925	6933
1979*	79	7012

* To end of February only.

Maintenance, Multiplication, and Evaluation

After release of material from quarantine, the initial multiplication takes place on the ICRISAT farm under optimal conditions, including assured irrigation. Apart from germplasm personnel who record a wide range of plant characters, other scientists from the program regularly visit these plots and assess characters such as reaction to pests and diseases, nodulation capacity, and yield potential. New sources of resistance to rust (*Puccinia arachidis*) and insect pests such as thrips and jassids have already been identified from the germplasm collection. Long-, medium-, and short-term storage facilities are being developed, but the active exploitation of a dynamic working collection is emphasized.

Dissemination of Germplasm

Germplasm has been distributed to many countries and requests are becoming more frequent. Some requests are for specific material and others are for large collections to initiate new research programs. Up to April 1979 nearly 3500 accessions had been dispatched to cooperators.

Collection

Although the ad hoc working group will decide collecting priorities in September, five ICRISAT groundnut-collecting trips have been made in India. An expedition to Malawi, mainly for cereal germplasm, also collected groundnut samples during 1979. The groundnut germplasm botanist is currently collecting in Somalia. Earlier this year a groundnut breeder accompanied an IBPGR expedition to South America to collect wild *Arachis* species and primitive landraces. We also collaborate with other international institutes; for instance, the germplasm unit of the International Institute of Tropical Agriculture in Nigeria has collected groundnuts for us in West Africa and we have collected one of their mandate crops, cowpeas, for them in India.

Documentation

Groundnut germplasm catalogs have been received from 11 institutes in nine countries. Data on all known accessions of wild *Arachis* species have been entered into the computer and will be constantly updated, with the printout serving as a newsletter to scientists involved in their study on a worldwide basis. A paper entitled "Development of a descriptive language for groundnut (*A. hypogaea*)" has been jointly prepared by ICRISAT scientists and staff of the Information Sciences/Genetic Resources Program of the University of Colorado, USA, to be discussed by the ad hoc working group in September.

We consider that the germplasm program is the base of the research program and technology being developed.

Integrated Research Technology

Some of the research approaches to solve the major problems restricting good yields are discussed below:

Disease Resistance

Rust

Rust of groundnuts, caused by the fungus *Puccinia arachidis* Speg., has become a worldwide problem since 1969 (Subrahmanyam et al. 1979). Although this disease can be controlled by certain fungicides, they are costly and are not readily available to small-scale farmers in the SAT. At ICRISAT the germplasm collection was thoroughly screened for new sources of resistance in addition to the cultivars already known to be resistant (Table 3); the new sources were found and are listed in Table 4. In a cooperative program, all the previously reported sources of resistance, which had been assembled in Georgia, USA, have been transferred here and, together with the new sources, they will be jointly assessed by USDA and ICRISAT scientists later this year. With an assured inoculum at Patancheru, suitable screening techniques have been evolved. Known susceptible cultivars are sown systematically through the test fields and infected with rust uredospores. Spreader plants, already infected with rust, are also placed systematically through the field. During the postrainy season further screening of material is possible with a perfo-irrigation system to ensure high humidity and disease development (Subrahmanyam et al. 1978).

Table 3. Sources of marked resistance to rust in *Arachis hypogaea* L.

Identification	Plant introduction (PI) numbers	Botanical type	Origin
Tarapoto	259747, 341879 350680, 381622, 405132	Valencia	Tarapoto region of Peru
Israel line 136	298115, 315608	Virginia	Introduction to Israel from the USA
DHT 200	314817	Valencia	Juanji, Peru
FESR lines 1–14	Hybrids between 298115 and an unknown pollen donor	Segregating	Puerto Rico, from the USDA rust nursery

Table 4. New sources of resistance to rust in *Arachis hypogaea* L., identified at ICRISAT.

Cultivar	Origin
* NC Acc 17090	Peru
* EC 76446 (292)	Uganda
NC Acc 17129	Peru
NC Acc 17130	"
NC Acc 17132	"
NC Acc 17135	"
NC Acc 17124	"

* Cultivars with greater resistance to rust at ICRISAT than the Tarapoto lines PI 259747 and Israel line PI 298115.

The rust-resistant cultivars PI 259747, PI 298115, NC Acc 17090, and EC 76446 (292) have been used extensively in hybridization programs with a wide range of high-yielding susceptible parents. Segregating populations are subjected to the previously described screening procedures, and resistant selections are advanced. Basic studies on the inheritance of resistance to rust are being carried out. Some F_3 populations received from the USDA rust nursery in Puerto Rico have been carefully screened and studied here on an individual and family basis to the F_8 generation. From these, it appears that resistance is controlled by at least several genes. These advanced selections are now being yield-tested here, and they will shortly be sent out for multilocational testing. Early generation hybrids, bred at ICRISAT, have also been sent out for selection to various centers.

The biology, distribution, and dispersion of the fungus have been extensively studied in India initially (Subrahmanyam et al. 1979). A collection of cultivars with known reactions to rust has been distributed to centers in India to ascertain whether races of the fungus occur on a national basis. Negotiations are also under way for rust samples from all over the world to be studied in the United Kingdom, which is not a groundnut-growing country, to identify races if they exist.

Leaf Spots

The leaf spots caused by *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk. and Curt.) Deighton are the most serious diseases of groundnut on a worldwide scale. Bunting et al. (1974) estimated that these fungi alone cause a loss of about 3 million tonnes of kernels per year. Losses in kernel yields of around 10% have been estimated in the USA, where fungicide application is normally practiced (Jackson and Bell 1969). In the SAT, where chemical control is rare, losses in excess of 50% are commonplace (Garren and Jackson 1973).

Although fungicides are being tested at ICRISAT, the main emphasis is on incorporating resistance to these diseases. Limited resistance has been reported in the cultivated groundnut, and these accessions are being studied. The germplasm has also been extensively screened at ICRISAT for resistance to *C. personatum* and cultivars have been identified that have restricted lesion growth, sparse sporulation on the lesions, and infected leaves that do not readily defoliate. Interestingly, some of these cultivars are also rust resistant and include NC Acc 17090, EC 76446 (292), and PI 259747. The cultivar PI 259747 has also been reported as showing resistance to *C. arachidicola* in the United States (Sowell et al. 1976). Therefore, progenies in the rust-breeding nurseries are also being screened for their reaction to the leaf spot fungi. *C. personatum* is the dominant leaf spot pathogen at Patancheru; therefore, sites are also being selected where *C. arachidicola* dominates to test material for resistance to this fungus as well. Laboratory and field-screening techniques are being jointly used, as it has been shown that the former alone can give misleading results (Hassan and Beute 1977).

An intensive program has been established at ICRISAT to utilize the wild relatives of the cultivated groundnut as sources of resistance to the leaf spot fungi. Within section *Arachis* two wild diploid species, GKP 10017 (*A. cardenasii – nomen nudum*, Krap and Greg., unpub.) and GKP 10602 (*A. chacoense – nomen nudum*, Krap and Greg., unpub.) have been reported as immune and highly resistant to *C. personatum* and *C. arachidicola*, respectively (Abdou 1966, Sharief 1972, Abdou et al. 1974). Hammons (personal communication) observed that HLK 410, another diploid species in section *Arachis* (*A. stenosperma – nomen nudum*, Krap and Greg., unpub.), was not infected with either leaf spot in the field in Georgia, USA. Hybrids between these wild species and the cultivated groundnut have been made in the United States (Sharief 1972), the United Kingdom (Spielman and Moss 1976), and at ICRISAT. The F_1 hybrid is triploid and sterile. Colchicine treatment restores fertility at the hexaploid level (Fig. 1).

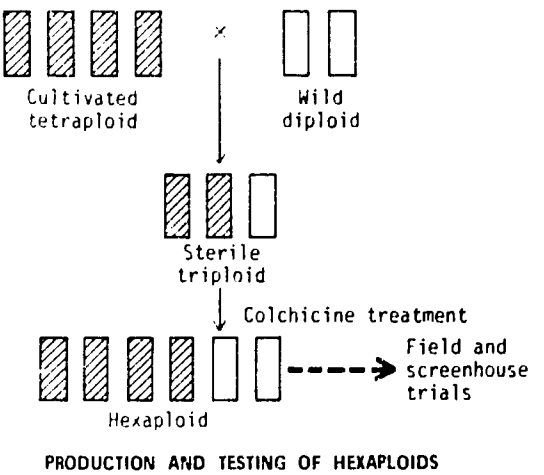


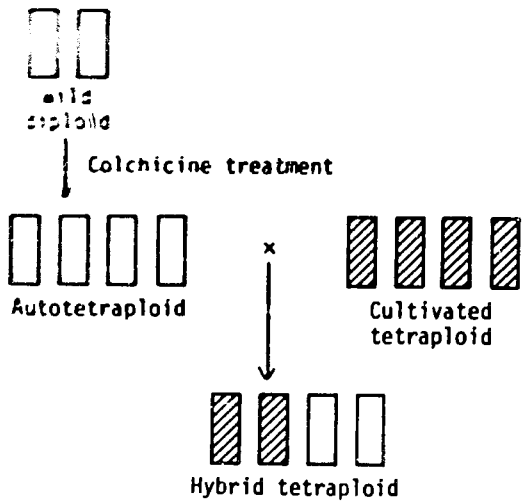
Figure 1. Method of producing interspecific hexaploids for leaf spot resistance.

Hexaploid progenies have been assessed at ICRISAT, under a high incidence of *C. personatum*, and in Malawi with *C. arachidicola* as the dominant fungus. Leaf spot resistant hexaploids are currently being backcrossed to the cultivated groundnut; the pentaploids obtained will again be backcrossed to obtain near-tetraploid, high-yielding, leaf spot resistant cultivars. Alternative methods are also being used to produce tetraploid interspecific hybrids for use in the leaf spot resistance breeding program (Fig. 2).

Aspergillus flavus and Aflatoxins

Aflatoxins are toxic secondary metabolites produced by strains of fungi of the *Aspergillus flavus* group growing on suitable substrates. Research on aflatoxins dates back to 1960 and the outbreak of Turkey 'X' disease, which killed

young birds fed on a diet containing groundnut meal (Blount 1961).



PRODUCTION OF HYBRID TETRAPLOID FROM DIPLOIDS

Figure 2. Method of producing tetraploid interspecific hybrids for leaf spot resistance.

Factors found to favor invasion of groundnut seed by *A. flavus* include damage to pods by other fungi, perforation of pods by termites and other insects, mechanical damage to pods during cultivation and at harvest, overmaturity by delayed harvesting, and drought stress. Poor drying conditions are also a common reason for fungal invasion and aflatoxin contamination.

Simple recommendations for growing the crop and handling the produce to minimize aflatoxin contamination have been made but are often not followed by the small farmer of the SAT.

Research technology at ICRISAT includes the incorporation of resistance to invasion of the testa by the fungus. Two breeding lines with this character have been identified in the United States (Mixon and Rogers 1973). However, if the testa becomes damaged or split, this resistance breaks down. The new approaches being initiated at ICRISAT include the testing of cultivars that may support the growth of *A. flavus* but in which the toxin is not produced. This happens with seeds of soybean and cowpea, which get infected, but in which aflatoxin is rarely produced. Preharvest and postharvest infection, or lack of infection, is being studied on developing and mature pods and seeds of many cultivars. The entomologist is also studying cultivars for resistance to pod damage by soil fauna.

Other Fungi

Many other fungi affect groundnuts, but rust, leaf spots, and *A. flavus* are the major ones on a worldwide scale. We are interested in seedling diseases, and germplasm is being screened for sources of resistance to such common fungi as *A. flavus, A. niger, Fusarium, Pythium, Rhizoctonia*, etc. Any cultivars with reported sources of resistance to any disease are being acquired by the germplasm unit.

Viruses

Virus diseases of groundnuts are common and serious. In Africa, groundnut rosette virus (GRV) is important south of the Sahara. Approximately 0.5 million hectares of groundnuts were destroyed by this disease alone in Nigeria in 1975 (Yayock et al. 1976). Peanut mottle virus (PMV) was estimated to cause losses amounting to $11.3 million in Georgia alone in 1973 (Kuhn and Demski 1975). This disease is worldwide in distribution. In India, bud necrosis virus (BNV) can cause serious yield losses of up to 50% (Chohan 1972).

However, much confusion exists in the literature on the distribution and identification of these viruses. Identification has often been solely on the appearance of symptoms, which are confusing and variable. At ICRISAT we are attempting to identify precisely the causative viruses by purification and electron microscopy. Sensitive serological techniques are being used to help in the identification of the viruses (Reddy et al. 1978). Antisera are also being prepared and sent to cooperating laboratories to aid them in their studies. Mass-screening techniques are being developed to identify sources of resistance both in the cultivated and wild species of *Arachis*. So far, PMV has been identified in India (Reddy et al. 1978) and BNV has been shown to be caused by tomato spotted wilt virus (TSWV). A new disease of economic importance in northern India has been shown to be caused by a soil-borne

virus. This virus has been purified and an antiserum has been produced (Reddy et al. 1979). Cooperative projects are being established with workers in West Africa who are investigating a similar soil-borne virus. Cultivars with resistance to rosette are being used in our breeding programs and have been crossed with high-yielding cultivars and with cultivars resistant to other diseases.

Insects

Although many insect pests are limited in their distribution and importance, some are of worldwide importance. Among the latter are aphids, jassids, thrips, and termites. At ICRISAT, screening of germplasm has commenced to identify sources of resistance to these important pests. Sources of apparent resistance to jassids and thrips have been identified; they are presently being reassessed in special pesticide-free areas specifically set aside for this purpose at the ICRISAT farm. Control of pests by insecticides and agronomic practices is also being examined.

Two species of thrips have been identified as the vectors of bud necrosis virus (BNV), and the biology and bionomics of these pests are being studied. Alternative hosts of BNV, including both crop plants and weeds, have been identified (Amin, unpub.). Observations made in breeding blocks by the entomologist have shown that some advanced rust-resistant lines show promise for thrips resistance also. Material emanating from the entomology program will be tested over different environments for stability of resistance and will be extensively used in the breeding programs.

Nitrogen Fixation

Very little work has been done outside the United States on groundnut symbiosis. At ICRISAT, we are trying to manipulate both the *Rhizobium* and host-plant component of the symbiosis in an attempt to increase nitrogen fixation — and yields — as well as the residual benefit to subsequent crops.

We have collected, isolated, and tested for nitrogen-fixing ability some 40 *Rhizobium* strains. Surveys of farmers' fields indicate a large range in nodulation capacity and nitrogenase activities.

Nitrogen fixation has been measured for several released cultivars during the growing season, using N uptake and acetylene reduction assays. The nitrogenase activity per gram of nodule tissue in groundnuts is probably the highest recorded for any legume. With groundnuts, nitrogen fixation continues well into the pod-filling stage, but there are large differences between cultivars, as well as seasons, in nodule number, nodule weight, and nitrogenase activity (Fig. 3). Nodule distribution also varies considerably between cultivars. Some lines have nodules extending to the hypocotyl and even to the bases of the stems. From this array we are selecting lines for the breeding program to try to incorporate desirable features into high-yielding or disease-resistant cultivars. Close cooperation exists between the groundnut microbiology programs at ICRISAT and North Carolina State University, USA. We are jointly assessing material — under both advanced farming and SAT farming conditions — to try and enhance fixation by this widely adapted crop.

Two new discoveries will aid us in this program. Nonnodulating lines of groundnuts have been identified in crosses between two normally nodulating parents. These will be very useful controls for any N-balance studies. A new field assay technique for simultaneously measuring plant nitrogen uptake from the nodules and from soil is based on recent findings that legume nodules export more than 90% of the fixed nitrogen from their nodules as allantoin. This substance and nitrate can be measured in very small quantities in bleeding xylem sap or extracts of stem tissues. This assay will provide us with a method for comparing nitrogen fixation and soil nitrogen uptake over a wide range of field situations, which was not possible with previously used techniques.

Cropping Systems

Although intercropping is part of the Farming Systems Program, we have been cooperating particularly in the choice of cultivars to fit into pearl millet/groundnut combinations. This method of intercropping is common in many parts of the SAT, particularly in Africa (Okigbo and Greenland 1976). Willey and Rao (1979) have demonstrated yield advantages up to 25 to 30% when these combinations have been tried

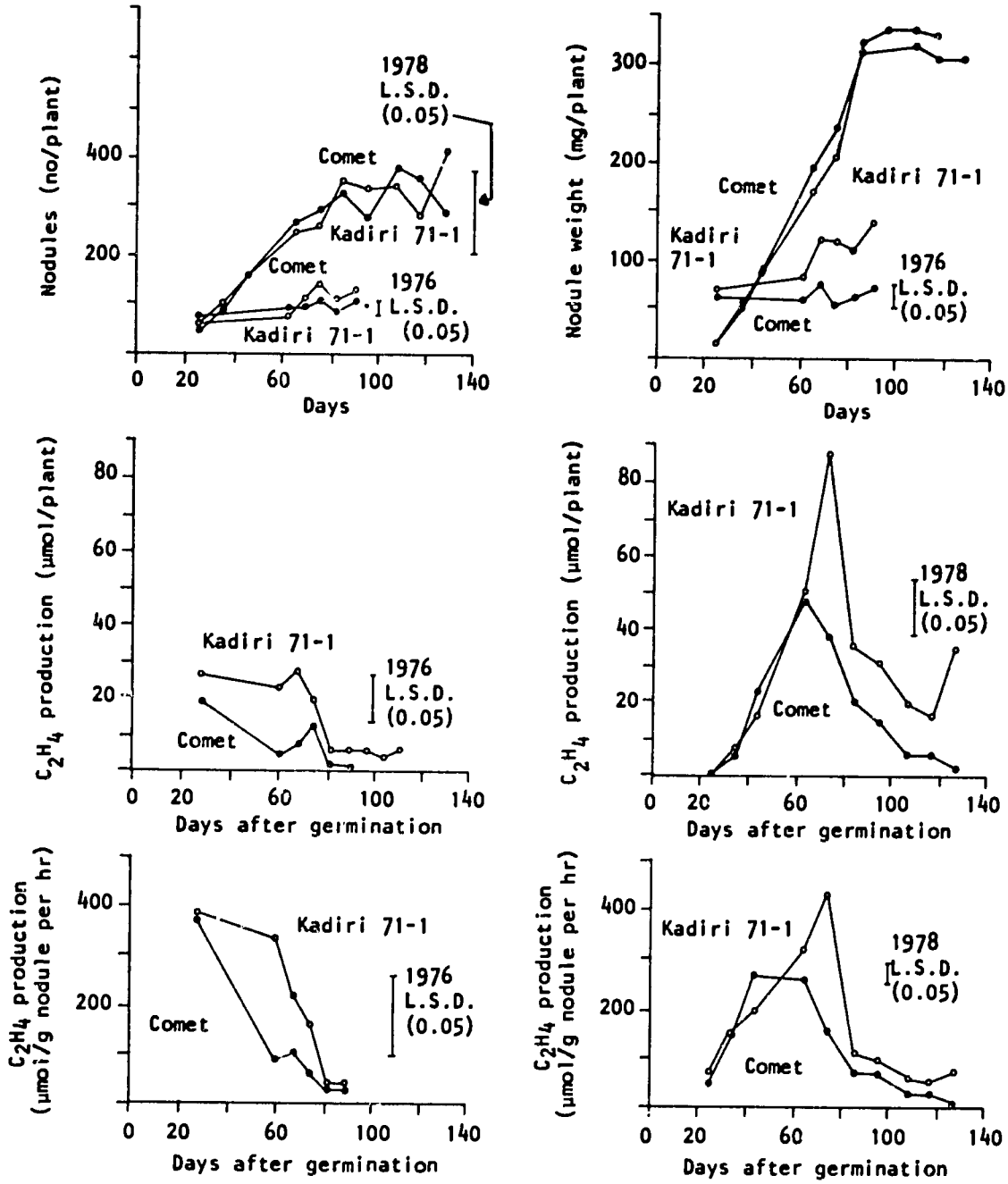


Figure 3. Seasonal variation in nodule number and nodule weight per plant and nitrogenase activity per gram nodule weight and per plant in cv Kadiri 71-1 and Comet grown during rainy season 1976 and postrainy season 1977 at ICRISAT Center. The postrainy season planting was irrigated.

at ICRISAT. The magnitude of the yield advantage was mainly determined by the groundnut genotype, whereas the proportion of groundnut yield to millet yield was mainly determined by the millet genotype (Reddy and Willey 1979).

We are also breeding for earliness in groundnuts. A very early cultivar would fit into relay cropping systems, particularly after the rice crop is harvested in Southeast Asia. Sources of earliness (Chico 91176 and 91776) have been identified and are being crossed with high-yielding and disease-resistant cultivars.

Yield

Although we feel that the incorporation of stable disease resistance is a primary objective to help the small farmer of the SAT, yield per se is also obviously important. This is not being neglected. High-yielding cultivars are being used to generate breeding material on a large scale (some 60 000 pollinations can be made in the two growing seasons per year at the ICRISAT farm). Replanting normally dormant cultivars or progenies immediately after harvest, to ensure a rapid advance of generations, is achieved by treating seed with a commercial ethylene-releasing dust. Since the program commenced in 1976, we are now able to send out F_5 to F_6 generations for national breeders to test and select from.

The Future

We have been operating for a very short time, so we obviously have a long way to go before we can achieve marked success for the farmer of the SAT. We feel, however, that our major research emphasis on stable disease resistance and increased yield will begin to be achieved in the not too distant future. We need to expand our programs at ICRISAT, particularly our cooperation with national and regional programs. We have the capacity to generate large quantities of breeding material with desirable characteristics. It is now our duty to disseminate this in a logical manner to areas with specific requirements for their groundnut crops.

Major developments are needed at ICRISAT Center. One is a full-scale physiology program with emphasis on drought resistance; another is to expand our entomology program; and a third is to exploit the untapped sources of the wild *Arachis* species. The species are not yet fully collected and those collected have not been completely assessed for desirable characters. We do know, however, that sources of resistance to diseases, insects, and nematodes — as well as sources of desirable yield and quality aspects — are available (Moss 1979). But incompatibility barriers occur between sections of the wild species and with *A. hypogaea*; these have to be overcome before useful genes can be incorporated into the cultivated groundnut. Much basic work is being done on this aspect at North Carolina State University, with which we have close working relationships. These joint ventures of basic and applied research will pay dividends in the future.

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Farming Systems Research and Technology for the Semi-Arid Tropics

Jacob Kampen*

Abstract

ICRISAT's farming systems research contributes to raising the quality of life in the SAT through interdisciplinary and cooperative efforts to improve the use of natural, human, and capital resources. It has been found that dry sowing on Vertisols is successful if the early rains are dependable; introduction of tool carriers results in greater timeliness and improved efficiency of draft-animal use; the broadbed-and-furrow system controls excess water and facilitates cultural operations; double cropping on Vertisols appears promising; intercropping increases total yields substantially on Vertisols and Alfisols; and effective weed control can be attained through the integration of mechanical, biological, and chemical means. Watershed-based resource development and management contributes to increased and more stable yields; the combined effect of different production factors applied together far exceeds the total effect of these factors applied singly; and improved farming systems tested in operational-scale research watersheds consistently result in three- to five-fold increases in rainfall productivities. On-farm studies to involve farmers in appropriate technology development and to search for effective forms of group action have begun.

The farmers of the semi-arid tropics (SAT) in Asia, Africa, and Latin America have found through long and often bitter experience that there is no certainty in agriculture because nature itself is so unpredictable. They know that their systems of farming are a hazardous way of life. Because of the uncertainties and ever-present risk of drought (or flood), farmers are reluctant to use high-yielding varieties, fertilizers, and other inputs even when available. Thus unstable food production and low crop yields are common in the SAT (Kampen et al. 1974, Krantz et al. 1974, Virmani et al. 1979). For many developing countries in this ecological zone, rainfed agriculture has failed to provide even the minimum food requirements for the rapidly increasing populations.

The Consultative Group on International Agricultural Research (CGIAR) recognized the lack of suitable technology for soil- and water-management and crop-production systems as primary constraints to agricultural development in the nonirrigated SAT and included farming systems research in ICRISAT's initial mandate (Doggett et al. 1971). The Institute's objectives of special relevance to its Farming Systems Research Program (FSRP) are:

- To develop farming systems that will help to increase and stabilize agricultural production through better use of natural and human resources in the seasonally dry semi-arid tropics.
- To assist national and regional research programs through cooperation and support and by sponsoring conferences, operating international training programs, and assisting extension activities.

This paper attempts to highlight ICRISAT's approaches to farming systems research. It must be realized that this is done at a stage when our concepts are still evolving, particularly with regard to cooperative research networks and technology transfer methods. Some selected areas of work will be discussed for illustrative purposes; it is impossible within the scope of this paper to give a detailed account of FSRP results.

We believe that substantial progress has been made since June 1972 when the first few exploratory farming systems experiments were planted. At that time "farming systems" was a

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vague, unknown phrase in the SAT. Now, 7 years later, ICRISAT's FSRP is providing leadership in farming systems research to scientists in many regions, cooperative systems research activities have begun, and on-farm studies to develop more effective means for technology transfer have been initiated (Krantz et al. 1978, Kampen and Doherty 1979).

The credit for the development of ICRISAT's FSRP and its early achievements goes to a dedicated interdisciplinary team of scientists assisted by a highly motivated technical staff, and especially to Dr. B. A. Krantz, program leader during the critical early years.[1] The contributions of our colleagues from national research programs in Africa, Brazil, and in particular the All India Coordinated Research Project for Dryland Agriculture of the Indian Council of Agricultural Research (ICAR), are also acknowledged.

Goals, Activities, and Organization of ICRISAT's FSRP

Erratic rainfall results in a low effective use[2] of precipitation, and the water-use efficiencies[3] of present farrning systems are also low. Thus, low rainfall productivities[4] are an important characteristic of agriculture in the SAT (Kampen and Krishna 1978). Improved land- and water-management technology and the development of optimum cropping systems are required to increase effective utilization of rainfall. To improve water-use efficiencies, better varieties, cropping systems, and crop-management techniques must be developed. These components are considered basic elements of farming systems offering the greatest potential to attain higher and more dependable yields.

During the past 30 years, populations in many areas have doubled, and farmers have therefore attempted to double agricultural production. Since there has been no substantial increase in per hectare yields, increased agricultural production could be achieved only through a tremendous increase in cropped area and livestock numbers. This trend seriously endangers the conservation of the natural resource base. Steeper and more erodible lands are frequently being overcropped and overgrazed and forest lands are being denuded, causing permanent damage to vast areas (Figs. 1–2). The decreasing productivity of the land in turn increases the quest for more land. To break this vicious circle, more stable forms of land use that preserve, maintain, and better utilize the productive capacity of all resources are urgently needed.

We therefore believe that farming systems research at ICRISAT must be "resource centered" and "development oriented." The major goals of the FSRP are:

- To generate economically viable, labor-

Figure 1. Existing practices studied at ICRISAT; runoff, soil erosion, and sedimentation observed on a rainy season fallowed Vertisol in 1974.

1. The present research team consists of: R. K. Bansal, V. S. Bhatnagar, J. R. Burford, K. S. Gill, A. K. S. Huda, F. P. Huibers, Harbans Lal, J. Kampen, M. C. Klaij, J. H. Krishna, M. Natarajan, P. Pathak, M. R. Rao, A. N. Rao, M. S. Reddy, S. J. Reddy, T. J. Rego, Sardar Singh, R. C. Sachan, K. L. Sahrawat, M. V. K. Sivakumar, O. P. Singhal, K. L. Srivastava, P. N. Sharma, S. K. Sharma, S. V. R. Shetty, G. E. Thierstein, S. M. Virmani, and R. W. Willey.
2. "Effectively used rainfall" is defined as the proportion of the growing season precipitation actually used for evapotranspiration of the soil-crop complex (expressed as a percentage).
3. "Water-use efficiency" is defined as the agricultural production (in kg/ha or the monetary equivalent) in relation to the actual evapotranspiration contributing to crop growth (in cm).
4. "Rainfall productivity" (RP) is defined as the agricultural production (in kg/ha or the monetary equivalent) in relation to the seasonal precipitation (in cm); it is the product of the effectively used rainfall and water-use efficiency.

Figure 2. Resource degradation in its final stages; cattle grazing sparse vegetation on rocky subsoils in Bijapur, India.

intensive technology for improving, utilizing, and conserving the productive potential of natural resources.

- To develop technology for improved land- and water-management systems that can be implemented and maintained during the extended dry seasons, resulting in additional employment for people and better utilization of available draft power.
- To contribute to raising the economic status and the quality of life for the people of the SAT by developing farming systems that increase and stabilize agricultural output.

If new technology is to be successfully applied to existing production systems, it is important to recognize the particular constraints and characteristics of the farming systems to be improved. In the semi-arid tropics, these generally consist of: intense rainfall interspersed with unpredictable droughts, short rainy season, variable rainfall between seasons, high evapotranspiration, low infiltration capacity of soil, great water erosion hazard, small farms, fragmented holdings, limited capital resources, mainly animal or human labor for power, severe unemployment in the dry season, limited biological resources, lack of credit facilities and seasonal labor shortages at peak times (Kampen and Burford 1979, Krantz et al. 1974, Ryan et al. 1979, Virmani et al. 1979).

ICRISAT's FSRP aims at assisting in the development of agriculture in the seasonally dry tropics with a special focus on the problems encountered by small farmers of limited means. The FSRP recognizes that the applicability of food production technology will vary by agroclimatic region and therefore focuses its research efforts on the development of principles, concepts, and methodologies that are transferable and have broad application. To meet its objectives, the FSRP is involved in the following activities (Binswanger et al. 1975):

- The assembly and interpretation of existing baseline data in several research areas relevant to agricultural development in the SAT.
- The communication to cooperators of basic and applied research results relating to improved farming systems in the SAT.
- The analysis of farming systems and the execution of simulation and modeling studies based on climatic, soil, and cropping systems information to identify regional research priorities.
- The organization and coordination of international cooperative trials to rapidly gain information about the performance of a practice, technique, or approach over time at one location and/or across locations.
- The provision of support and expertise for those ICRISAT training programs related to farming systems research.
- The conduct of basic and supportive research in several disciplines and the development of systems research methodology.
- The performance of interdisciplinary research on resource development and management, crop production, and resource conservation at selected, representative benchmark locations.

In addition to the seven subprograms administratively part of FSRP, ICRISAT scientists from other disciplines participate in farming systems research and cooperate closely in many research projects. The FSRP is also linked to other ICRISAT programs and national research organizations; this is illustrated in the organizational chart (Fig. 3). All subprograms are involved in the operational-scale systems research and in the on-farm cooperative studies with national programs.

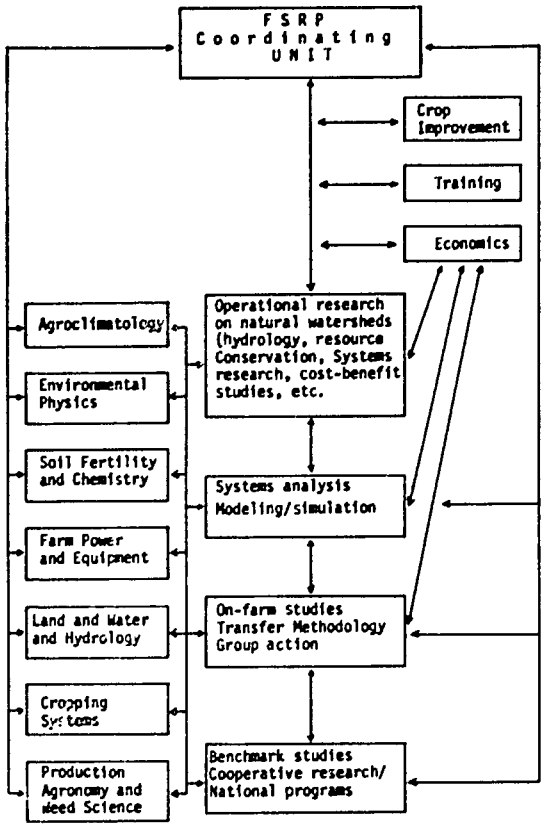

Figure 3. Organizational chart of the Farming Systems Research Program.

Concepts, Selected Problems, and Hypotheses

To those involved in farming systems research at ICRISAT, it was clear from the beginning that a holistic, interdisciplinary approach to research on soil, water, and crop management and the integrated application of new technology would be essential to successful agricultural development in the SAT. Single-component approaches were not expected to solve the complex problems encountered in the SAT. Undependability of the crop-water environment is the most limiting factor to crop production; therefore, earlier approaches consisting of only varietal improvement, crop and fertility management, fallowing, or bunding, etc., could not result in substantial effects. Emergency relief remained common in many areas. Even conventional irrigation projects were considered inadequate to meet the real needs of agriculture in the SAT (Kampen et al. 1974).

To develop relevant approaches and to mold the FSRP, attention was focused on some major problem areas that were not intensively researched by national programs and the solution of which appeared to have great potential impact.

These were:

- About 18 million hectares of deep Vertisols in India and millions of hectares in Africa are being fallowed during the rainy season. The low productivity of postrainy season crops grown on residual moisture seemed to indicate inefficient use of available water. The exposure of uncropped soils to intense rains appeared to result in serious runoff and erosion in spite of the presence of soil conservation structures.
- Alfisol areas in India and many similar soils in other regions of the SAT lose large quantities of water as runoff; however, rainy season crops frequently suffer from moisture stress. In India, water from wells and that stored in small reservoirs is being used mainly on such crops as rice and sugarcane. Few research efforts have been made to explore how limited water resources can be used to back up, rather than to replace, rainfed agriculture.

In researching these problems, important hypotheses, considered basic to ICRISAT's farming systems research strategy, were developed:

- In the SAT, water is most limiting and the entire farming system must be geared to its optimum use.
- Intercropping is practiced widely in existing farming systems and its improvement and development is a crucial step in generating more productive, resource-conserving, and reliable systems.
- Soil erosion is serious and new soil- and water-conservation methods that simultaneously increase yields are urgently needed.
- Most soils are low in fertility; although the only short-term solution is increased chemical fertilizer use, research on lower

cost inputs, nitrogen fixation, and nutrient cycling is essential.

- Rainfall is the only source of water, thus the watershed (catchment) is the logical framework to investigate water as a manageable input and also for resource development.
- Agroclimatological analysis, based on existing data and a quantitative understanding of the processes involved in the soil-plant-atmosphere continuum, can assist in priority research problem identification and in the extrapolation of research results.
- Runoff, erosion, drainage, infiltration, groundwater recharge, etc., do not express themselves in relevant terms on small plots; such hydrologic factors are best studied on watersheds.
- Efficient and appropriate farm equipment of low cost is essential to implement more efficient soil-, water-, and crop-management systems and to attain adequate weed control.
- Most farmers depend upon animals and their own labor for power. Rapid access to mechanical power is neither probable nor desirable. Thus, in developing viable technologies, the use of available energy resources must be optimized.
- Many of the gaps between results derived at research stations and the farmers' real needs can be bridged by operational-scale systems research.
- Improved varieties, cropping systems, fertilization, and crop-management practices to better utilize the available natural and human resources are essential ingredients to help increase and stabilize production to improve the quality of life of the people of the SAT.

Research on Vertisols and Alfisols at ICRISAT

The mean monthly values for rainfall and potential evapotranspiration of many areas indicate that, on average, sufficient moisture is available to grow at least one, and sometimes two, crops per year. However, studies of the probabilities of dependable (> 70%) rainfall on a weekly basis in relation to crop moisture demands have shown that frequently the water requirements of crops may not be met (Figs. 4–5). Thus yields are very low and the risk to crop production is great.

Resource-management approaches and cropping systems principles developed and applied at ICRISAT led to promising results on the Alfisols and the deep Vertisols (Kampen and Burford 1979). The attributes of these soils at ICRISAT have been listed earlier (Krantz et al. 1978).

A Watershed-based System for Resource Conservation, Management, and Use

Watershed-based resource utilization involves the optimum use of the watershed[5] precipitation through improved water, soil, and crop management for the improvement and stabilization of agriculture on the watershed. Better utilization of water can be facilitated by one or more of the following means: (1) by improving infiltration of rainfall into the soil; (2) through runoff collection, storage, and use; and/or (3) by recovery from wells after deep percolation.

To improve resource utilization, management, and agricultural productivity, the following factors were studied (ICRISAT 1974, 1975, 1976, 1978, 1979).

Precipitation and Cropping Systems

Weekly rainfall records were used to develop probabilities of soil-moisture availability related to the water-holding capacity of soils and these were then matched with the requirements of widely different systems of cropping. The use of monthly data is not satisfactory because of the importance of variability over shorter time periods. These analyses resulted in the selection of cropping systems especially suited to

5. "Watershed," strictly defined, refers to the divide separating one drainage basin from another. However, the use of the term to signify a drainage basin or catchment area has now become predominant. In this context the terms watershed, catchment, and drainage basin are considered synonymous.

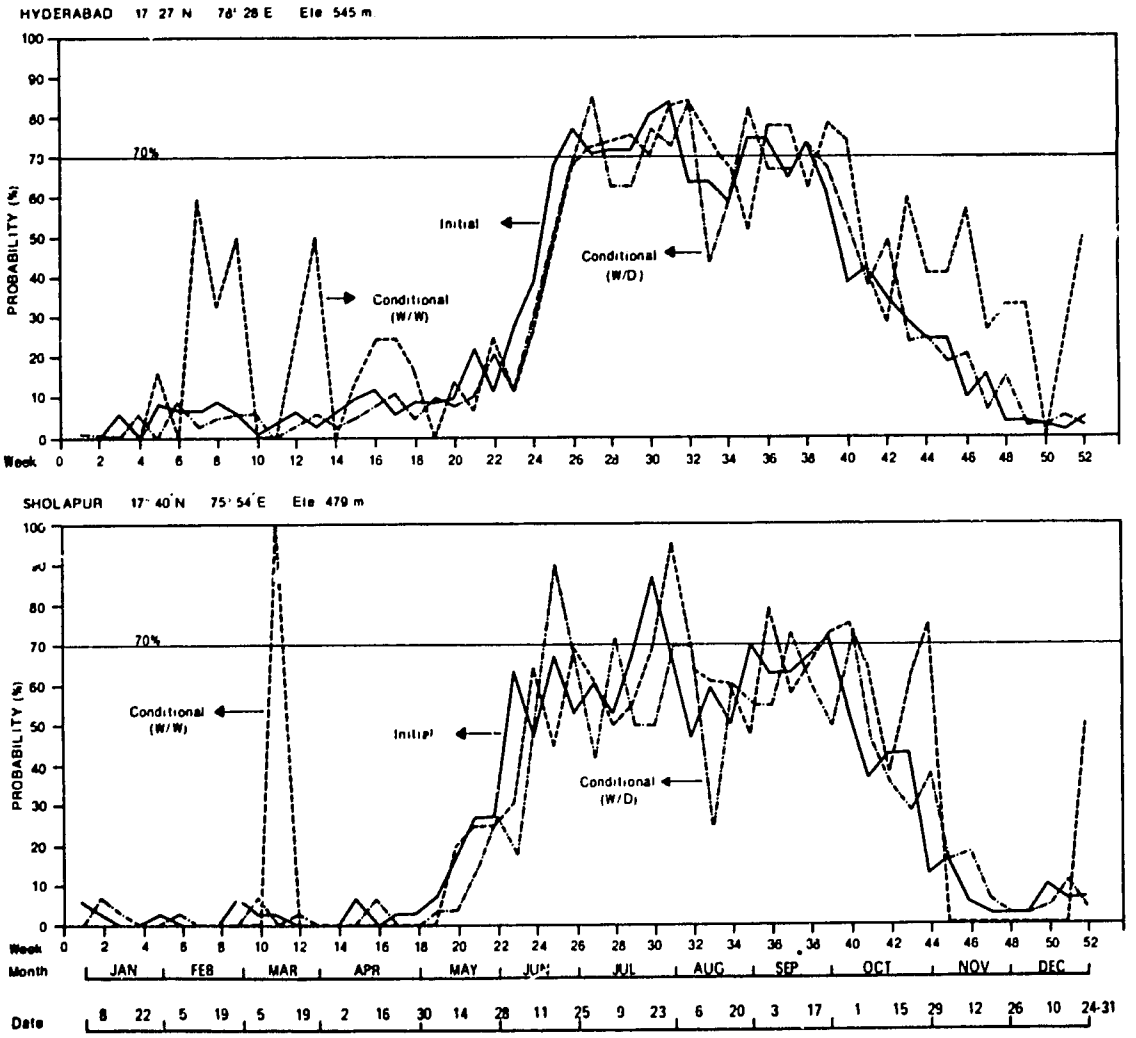

Figure 4. Initial and conditional rainfall probabilities[a] of R/PE[b] ≥0.33 at two selected semi-arid locations. Initial as well as conditional rainfall probabilities are below the generally accepted dependability level of 70% during substantial periods of the rainy season at Hyderabad; the situation is even more serious at Sholapur (Source: Virmani et al. 1978).

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a. The probability of receiving certain amounts of rainfall during a given week is indicated by the initial probabilities P(W); the probability of rain next week, if rain was received this week by the conditional probability P(W/W); and the probability of rain next week if the current week has been dry, by the conditional probability P(W/D).

b. R = Rainfall;
PE = Potential evapotranspiration.

different soil situations. These studies also pointed out the problems involved in double cropping under many soil and climatic conditions in the SAT and the potential advantage of intercropping systems. This type of analysis has great potential for use in priority settings for agricultural research in new areas (Virmani et al. 1979).

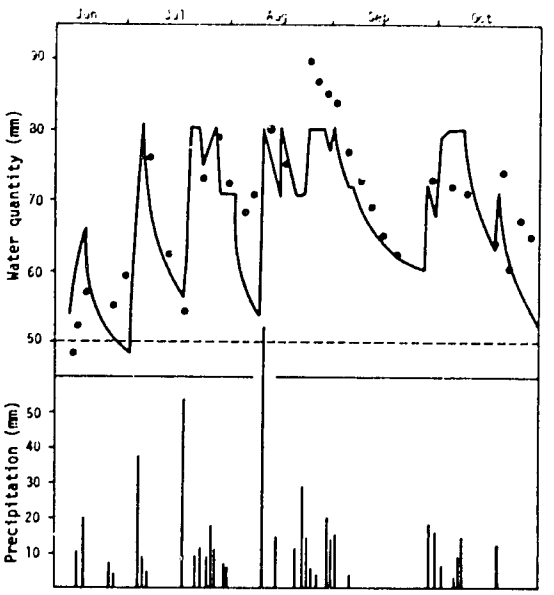

Figure 5. Computed (^) and measured (•) water quantities in the surface 20 cm of a rainy season fallow Vertisol at ICRISAT in 1977. The approximate level of water present in that layer when seedlings would be seriously stressed is given by (----); the rainfall distribution is also indicated. Note the risky situation that would have occurred thrice during the early growing season if a crop had been planted (Adapted from Russell 1979).

Infiltration

Provided storage capacity is available in the root profile, maximizing infiltration is of the highest importance so that water is located where it is required. This is especially relevant to the deep Vertisols, whose capacity to store up to 250 mm of available moisture makes it feasible to support plants through mid- or late-season spells of drought. Improved infiltration is also needed on Alfisols, where the infiltration rate may be 75 mm/hr shortly after cultivation; however, this can diminish to less than 10 mm/hr due to the surface sealing created by high-intensity rainfall.

Erosion and Control of Excess Water

Moisture in excess of available storage or in excess of the infiltration rate must be directed away from the land to prevent waterlogging and the attendant difficulties in agricultural operations, particularly on Vertisols. A major problem on all soils is the removal of excess water without allowing the development of high-velocity, high-volume streams that are a severe erosion hazard.

Reuse of Excess Water

The collection of runoff water is required so that it can be used for supplemental irrigation during drought periods. This would be particularly important on Alfisols and shallow Vertisols because of their limited water-retention capacity. Severe mid-season droughts can be expected at least once every 4 or 5 years in many areas of the SAT. If a water-storage facility is developed, the early runoff can be collected, stored, and used later as a supplemental "life-saving" irrigation until further rain comes.

Based on these studies of the characteristics of existing farming systems, several components were researched and adapted or changed.

Reappraisal of the Cropping Season

Only a small portion (20%) of the deep Vertisols in India are cropped during the rainy season, in contrast to the common practice of rainy-season cropping on Alfisols and shallow and medium-deep Vertisols (Krantz et al. 1974). The reason is largely the poor workability of these heavy soils once the rainy season starts, thus preventing land preparation and adequate weed control. Therefore, these soils are usually fallowed; the profile becomes saturated by July or August, and considerable runoff and erosion

Figure 6. An intercrop of maize and pigeonpea on a Vertisol watershed; this combination was found particularly advantageous on deep Vertisols because of continuous crop cover; no land preparation for the second crop is required and continuity in crop canopy aids in erosion control.

Figure 7. A sequentially sown chickpea crop after maize on a Vertisol watershed; the stubble of the previous crop is left to minimize land preparation. The pigeonpea of a maize pigeonpea intercrop can be seen in the background.

occurs during the remaining part of the rainy season (Fig. 1).

However, if a crop can be established on these soils during the early rains, the whole profile is usually near saturation only for short periods during the latter half of the season; water is more efficiently utilized, and there is less need for runoff collection and storage. A possibility is also created for double cropping by means of intercropping or sequential cropping (Figs. 6–7); the large water-storage capacity of these soils supports growth more easily during the subsequent dry (but cooler) post-rainy season. In small-scale experiments it was found that intercropping systems can increase yields per hectare very substantially compared with sole cropping (Krantz et al. 1976, Stoop 1977, Willey et al. 1979). For many combinations, these advantages are most evident at high plant population densities. Since intercropping is very important to small farmers, improvements will benefit ICRISAT's main target group.

Dry Sowing

An important factor that has facilitated cropping the deep Vertisols during the rainy season has been the realization that crops can be sown dry (shortly ahead of the rains) in areas where the precipitation commences fairly reliably and where there is a good probability of follow-up rains to ensure establishment of the germinating crop. One problem was the difficulty of preparing a seedbed during the dry season, when tillage on these hard, clayey soils is difficult. However, in most years, one or two preseason rains occur to moisten the surface soil, and the development of new tillage techniques and suitable equipment make adequate land preparation ahead of the rainy season feasible.

Animal-drawn Precision Equipment

Operations research in 1973 and in 1974 clearly indicated that in order to provide the required precision and to improve the efficiency of draft-animal use, improved animal-drawn equipment was necessary (Thierstein 1979). Accordingly, a tool carrier was adapted to provide the same vertical and horizontal precision as tractor-mounted equipment at lower speed but at only a fraction of the cost. This tool carrier consists of a frame on two rubber-tired or steel wheels with a toolbar to which various implements (moldboard and disc plows, harrows,

planters, cultivators, fertilizer applicators, scraper, cart body) can be attached. The use of animal-drawn wheeled tool carriers and modified equipment has resulted in considerable improvements of this segment of farming systems.

The animal-drawn tool carriers have been successfully used for land smoothing and drainageway construction (Fig. 8). Since 1973, four fully equipped tool carriers and eight pairs of bullocks have been sufficient to grow two crops each growing season on about 60 ha of Vertisol watersheds, conducting all operations of tillage, planting, and interrow cultivation (Fig. 9). Several lower cost units are presently being investigated (Thierstein 1979).

Year-round Weed Management

The feasibility of dry season primary tillage has facilitated the development of the year-round weed management concept. This approach is especially suited to the SAT where a warm humid season, a cool dry postrainy season, and a hot dry season can be distinguished. Weed control during the two growing seasons can be accomplished (in intercropping systems) through a combination of mechanical and biological control. On soils such as Vertisols, where weeds are a serious problem, particularly in the rainy season, some herbicide use may be required. However, the hot dry season lends itself best to thorough tillage to reduce perennial weeds and weed seeds (Shetty and Krantz 1979).

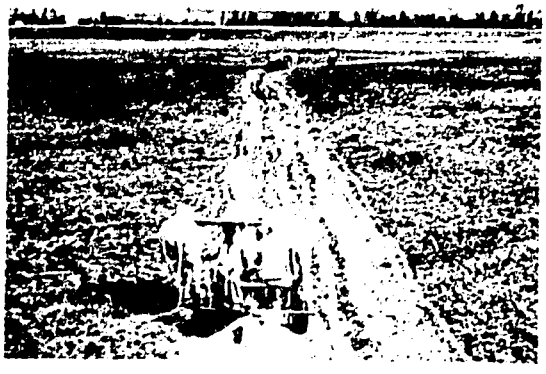

Figure 8. Tool carrier with scraper constructing drains on an Alfisol.

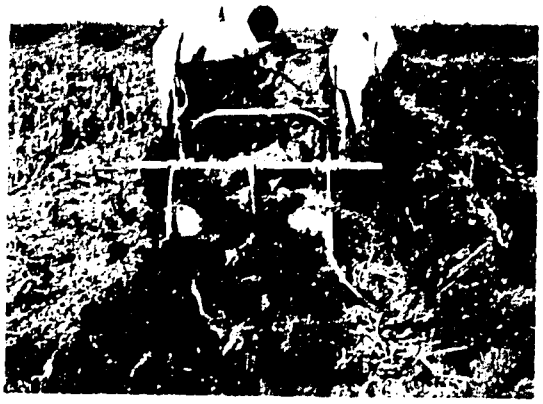

Figure 9. Tool carrier used for dry season primary tillage on a Vertisol.

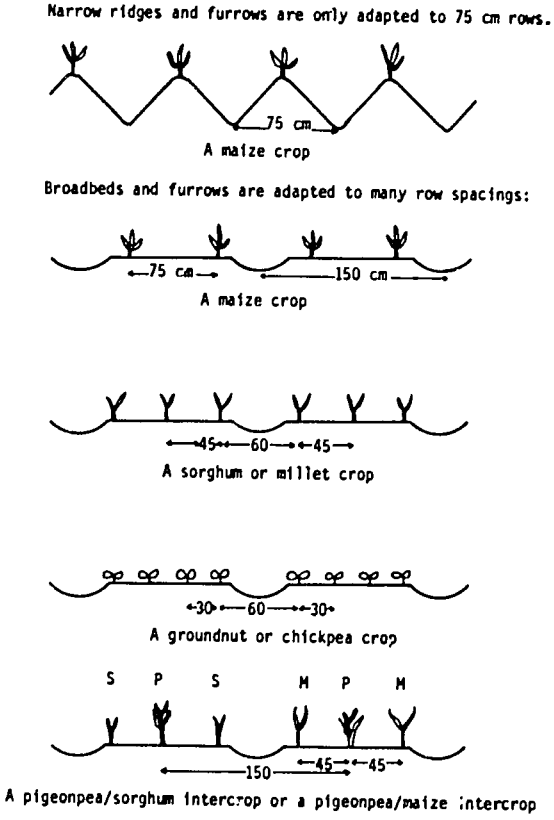

Figure 10. Alternative cropping systems and row arrangements on broadbeds (150 cm). All dimensions in cm.

Broadbed-and-Furrow System

The system found to be most successful, both to facilitate cultural operations and to control excess water, is a broadbed-and-furrow system with an amplitude of 150 cm (Fig. 10). The broadbed is about 100 cm wide and the sunken furrow about 50 cm. Initial experience with narrow graded ridges of 75-cm amplitudes at ICRISAT indicated instability of this system, particularly on Alfisols. The ridges were not wide enough to prevent "breaching," which can be catastrophic for soil conservation (ICRISAT 1978); they also had too limited a flexibility to accommodate the wide range of crops grown in the SAT. With the broadbeds, it is possible to plant two, three, or four rows at 75-, 45-, and 30-cm row spacings, respectively. Comparisons of flat planting with cultivation on broadbeds indicate substantial yield advantages of the graded broadbed system on deep Vertisols (Table 1). In 1976, values of crop yields in field-scale experiments were about Rs. 800/ha higher on broadbeds at a 0.4 to 0.6% slope than under flat cultivation at that slope (Kampen and Krishna 1978).

Erosion and runoff are relatively low in the broadbed system on deep Vertisols, because the excess water is led off the land at a controlled velocity in many furrows rather than in concentrated streams down the steepest slope. Drainage during wet periods is also facilitated. The preliminary data obtained at ICRISAT indicate that the optimum slopes along the furrows on Vertisols are in the range of 0.4 to 0.8%.

The furrows are graded so that water discharges into grassed waterways, which may lead to a runoff-collection facility consisting of a dug tank or earth dam (Figs. 11–12). Research on watershed-based resource utilization is conducted on natural watersheds of a size similar to farm holdings in the SAT. Alternative resource-management methods and cropping systems are simulated on these watersheds, under conditions similar to those on real farms in terms of available labor and draft animals.

Investigations on runoff and soil loss during high-intensity, long-duration storms on operational-scale research watersheds show that total runoff and peak runoff rates on Vertisols are much lower with broadbeds than with other treatments. This is particularly true in comparison with the fallow treatment with repeated cultivations presently practiced on almost 20 million ha in India (Fig. 1, Table 2).

In brief, operational-scale research on watersheds has shown that the broadbed-and-furrow system:

- Reduces soil erosion.
- Provides surface drainage.
- Concentrates organic matter and fertilizer in the plant zone.
- Reduces soil compaction in the plant zone.
- Is adaptable to supplemental water application.
- Can be laid out on a permanent basis.
- Is easily maintained with minimum tillage.
- Facilitates land preparation during the dry season.

Table 1. Mean monetary values of flat vs semipermanent broadbed-and-furrow system on Vertisol watersheds using improved technology in 1976 and 1977 (ICRISAT 1979).

			Intercrop			Sequential crop			Means	
Watershed No.	Land mgt.	Year	Maize (Rs/ha)	Pigeonpea (Rs/ha)	Total (Rs/ha)	Maize (Rs/ha)	Chickpea (Rs/ha)	Total (Rs/ha)	Both systems (Rs/ha)	Both years (Rs/ha)
1, 2, 3A	Beds	1976	2840	2080	4920	2730	950	3680	4300	
1, 2, 3A	Beds	1977	2270	2770	5040	2880	2400	5280	5160	
Means										4730
3B, 4B	Flat	1976	2530	1680	4210	2300	570	2870	3540	
3B, 4B	Flat	1977	2450	1810	4260	2790	2200	4980	4620	
Means										4080
LSD. (.05)										280
CV (%)										9.2

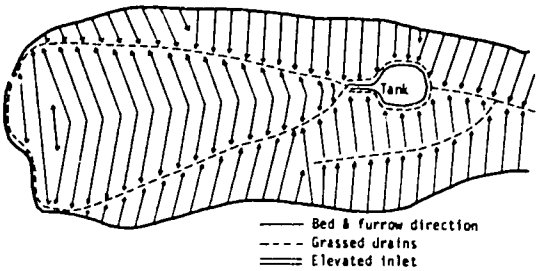

Figure 11. The watershed concept of soil and water conservation and utilization. The key elements are: the formation of a graded broadbed-and-furrow system to increase infiltration, to control excess water, and to facilitate timely soil-management practices; the development of a drainage system to convey excess water; and, where desirable, the introduction of water collection facilities.

- Reduces the power and time requirements of agricultural operations.
- Provides furrows for animals to follow.
- Is adaptable to many row spacings.

Water Balances

Studies of the water balance of alternative farming systems on Alfisols and Vertisols using broadbeds indicate that the relative quantity of runoff is still considerable on both soils. The seasonal runoff on Vertisols exceeds 10% of the rainfall in many years. On Alfisols 20% runoff is not unusual due to the surface-sealing character of these soils (Table 2); also large quantities of the rainfall percolate beyond the root zone. Thus, effectively used rainfall on Alfisols may remain relatively low, often in the range of 50 to 60% of the seasonal precipitation (ICRISAT 1975, 1976).

Figure 12. An airphoto of the BW5 Vertisol watershed at ICRISAT.

Runoff Collection and Supplemental Irrigation

The collection of surface runoff during periods of excess rainfall, and its subsequent use during dry periods in the rainy season or early in the dry season, markedly decreases the risks involved in rainfed agriculture. A particular example is the response observed in the rainy

Table 2. Rainfall and runoff on a cropped Alfisol (RW2B) and a cropped deep Vertisol (BW1) watershed with broadbed-and-furrow systems at 0.6% slope and a rainy season fallowed watershed (BW4C) (ICRISAT 1976).

		Runoff		
		Alfisol	Deep Vertisol	
Date	Rainfall[a] (mm)	Cropped (mm)	Cropped (mm)	Fallow (mm)
23 June	23	1.8	.0	0.5
2 July	24	3.0	1.7	0.2
21 July	89	25.2	16.9	49.4
3 Aug	26	0.8	0.2	1.6
4 Aug	32	8.5	2.3	21.4
19 Aug	105	77.5	27.0	95.4
20 Aug	39	16.5	19.5	37.1
21 Aug	10		4.2	8.5
26 Aug	8	0.5	0.1	3.2
3 Sept	8	0.2	0.0	2.9
4 Sept	20	2.3	0.4	11.1
Total of eight small storms	115	4.3	0.7	6.9
Total	499	140.6	73.0	238.2

a. Includes only rainfall from the 19 runoff-producing storms. The total rainfall for the rainy season (June–Oct) was 679 mm.

season of 1974, when a 30-day dry period coincided with the grain-formation stage (ICRISAT 1975). A supplemental irrigation of only 5 cm to sorghum and maize in operational-scale research watersheds maintained yields near optimum levels, while yields of rainfed crops decreased by about 50%. The gross values of the increases due to this water application in two watersheds were (in Rs/ha) 3120 for maize, 2780 for sorghum, 1085 for pearl millet, and 650 for sunflower.

The deep Vertisols rarely require supplemental irrigation for the rainy season crop. However, supplemental water can always be used on a postrainy-season crop, and growing a second crop can sometimes be facilitated by a small initial quantity of water (Kampen and Krishna 1978).

Thus, the potentials for use of collected surface or ground water as a backup resource need to be further explored. The direct effect of improved water-utilization technology appears substantial in years of ill-distributed rainfall.A similar effect may be expected in producing a second crop in the dry season. However, another consequence of decreased risk of production may be of even greater importance: reduced uncertainty will provide the basis for more assured profitability and also greater assured responses to other inputs such as improved seeds and fertilizers. This means greatly increased yields during years of adequate and well-distributed rainfall and thus better opportunities to "harvest the good years."

Crop Production and Rainfall Productivity

Data collected on Vertisol watersheds indicate that broadbed cultivation — even without runoff collection — has the potential to use a much higher proportion of the rainfall for crop production than most present systems. The effectively used rainfall on double-cropped Vertisol watersheds, cultivated to graded broadbeds, was about 75, 65, and 65% in 1974, 1975, and 1976, respectively; this was two to three times the effective rainfall utilized by existing rainy season fallow systems (ICRISAT 1975, 1976, 1978). Intercropping systems on broadbeds usually resulted in a somewhat greater rainfall utilization than sequential cropping systems, due to the temporary absence of canopy in the latter sequence. However, the total returns per hectare from sequential cropping systems exceeded those from intercrops (ICRISAT 1976, 1978).

The effectively used rainfall on Alfisols under improved systems of farming was found to be only about 55% in 1975 and 1976. Without technically appropriate and economically viable systems for runoff collection and use, large increases in effectively used rainfall appear difficult to achieve on these soils.

An attempt has been made to obtain preliminary estimates of the "rainfall productivity" achieved by alternative systems of farming (Kampen and Krishna 1978). The RP values in 1975-77 showed wide differences among various farming systems. In 1975, sequential cropping of rainy season maize and supplementally irrigated postrainy season sorghum resulted in the highest RP value on deep Vertisols. Rainfall productivity increased from Rs. 12/cm per ha in a traditional farming system of single postrainy season cropping on rainy season fallowed land to Rs. 58/cm per ha on double-cropped Vertisols cultivated to graded ridges (ICRISAT 1976). A very high RP value of Rs. 133/cm per ha was obtained on an Alfisol watershed where pearl millet grown on graded ridges in the rainy season was followed by supplementally irrigated tomato in the postrainy season.

The range of RP values obtained on deep Vertisols illustrates the production potential of this environment in the SAT if an improved system of farming can be developed and implemented. Such systems are now being further adapted and tested in on-farm research, conducted cooperatively with national programs in India.

Synergistic Effects

The development and implementation of improved technology involves many facets or steps. Researching the effects of each individual facet independently would make the total number of experiments unmanageably large. Moreover, the yield-increasing effects of many of these single steps (fertilizer type, placement, quantity, timing, etc.) have already been established in small-scale, controlled experiments, often under otherwise optimum conditions. Therefore, in one set of experiments these

many facets were grouped into four phases: variety, fertilization, soil and crop management, and supplemental water. To determine the effects of these four phases, at alternative levels of technology, the studies were executed on a field scale using exclusively animal-drawn equipment for all cultural operations. In 1976, this "steps in technology" experiment was conducted with sorghum, involving a comparison of "traditional" versus "improved" technology on an Alfisol (Fig. 13). During the rainy season, the rainfall was adequate and the distribution reasonably uniform so that no supplemental water was required. Thus, only the first three phases are considered.

There was a significant response to improved fertilization in traditonal systems; unfortunately chemical fertilizers are an expensive input and therefore the risk of applying these in the rainfed setting is great. Improved variety and improved management as single factors showed an upward trend but this effect was not significant. Improvement of either one of these two factors alone did not result in substantial net benefits (ICRISAT 1978). However, treatments involving two or three steps in combination resulted in large yield increases. The yield increase of "improved" over "traditional" technology from the three steps combined was double that of the sum of the increases from the same three steps applied singly (Fig. 13). This illustrates that large benefits can be gained from the synergistic effects obtained when different steps are applied together in a system. Similar results were obtained with sorghum on the same soil in 1975 and with maize on a Vertisol in 1976 (ICRISAT 1976, 1978). The ratoon crop resulted in low yields. This was due to serious shoot-fly damage and illustrates the devastating effect that one missing facet may have on yields of an improved technology system. Unpredictability of yields, due to weather uncertainty or to missing elements in an improved farming system that requires more expensive inputs, will be a serious barrier to implementation on small subsistence farms.

A Look Ahead

From 1974 onwards, several international conferences, workshops, and reviews have aided in shaping the orientation and major thrusts of the FSRP (TAC 1978, Krantz et al. 1977). None of these resulted in fundamental changes in the objectives of the FSRP. However, it has been repeatedly recommended that greater emphasis be placed on: meaningful agroclimatic classifications of the widely diverse SAT, research methodology development, cooperative research with national programs, in-depth analysis of farming systems and simulation studies, farming systems research at ben-

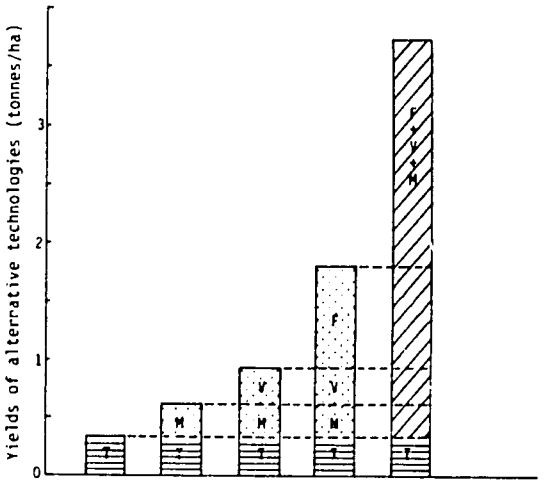

Figure 13. Sorghum grain yields (tonnes per hectare) from traditional[a] (T) technology ▤ from the single ⊡ application of improved[b] management (M), variety (V) or fertilizer (F) and from the application of these three factors in combination ▨ on an Alfisol in 1976 (ICRISAT 1978).

a. Traditional technology: Variety-PJ8K; Fertilization — 50 cartloads farmyard manure in 1975, none in 1976; soil and crop management simulates present farmers' practice with fertilizer broadcast, sowing done with a local seeder and minimum insect control if required.

b. Improved technology: Variety-CSH6; Fertilization — 75 kg/ha of 18-46-0 and 67 kg/ha of nitrogen top-dressed; Crop and soil management — all operations executed with improved implements, fertilizer banded and seed planted on graded broadbeds, atrazine applied at 75 kg/ha, minimum insect control if required.

chmark locations, and studies of improved farming systems under on-farm conditions. These are expected to be the areas of primary focus in the years ahead.

Major Research Areas in the Next Five Years

Classification

In order to serve the farmers of the SAT, we must know more precisely the characteristics, resources, and constraints in different regions. The initially accepted definition of the SAT emphasizes the length of the wet season, is ecological, and is based on readily available data (Virmani et al. 1979). However, more detailed work on the identification of isoclimes based on climatic and soils data is now required to assist in the transfer of suitable crop improvement and farming systems technology developed at ICRISAT, its benchmark locations, and by national programs. It is also important to provide indices of moisture availability for successful crop production in seasonally dry areas. Risk is an important factor governing present and potential farming systems; it is therefore necessary to quantify the risk levels associated with agriculture in diverse regions and to identify basic climatic constraints (Virmani et al. 1979).

Research Methodology

Farming systems research must be concerned with the development and dissemination of principles and results that are transferable and capable of speeding up the development and implementation of specific farming systems by national research centers and action agencies. Work on the development of research methodology, basic principles, and the conceptualization of research approaches will therefore be strengthened. Thus, in the future, substantial emphasis will remain directed toward developing a better understanding of the processes involved in water and nitrogen dynamics, competitive claims for resources in intercropping systems, factors influencing weed susceptibility, etc. These studies will stimulate interdisciplinary approaches and facilitate model development.

The Environmental Physics subprogram is leading an effort to develop accurate, reasonably simple, and reliable techniques for field studies of the dynamics of water as it moves through the soil-plant-atmosphere continuum. The scientists concerned seek to understand the physical processes operating and to measure in situ the quantities of water involved and the quantitative effects of the properties of the system that controls them. The ultimate aim is to contribute to the modeling of transpiration and crop yields to facilitate the extrapolation of research results (ICRISAT 1978, Russell and Singh 1979).

The Cropping Systems subprogram is spearheading an effort to discover the fundamental relationships that will provide a scientific basis for intercropping improvement. Central to this effort is a set of research projects examining the efficiencies with which the resources of light, water, and nutrients are utilized and identifying the agronomic practices leading to greater yield advantages. Particular attention is also directed to experimental design development (Willey et al. 1979).

Modeling

ICRISAT is one base where new concepts, approaches, and methods to arrive at improved farming systems are generated. However, these principles have to be integrated, tested, and adapted into viable systems before their application in the diverse regions of the SAT. Modeling and simulation can effectively contribute to this process. Where areas characterized by varying conditions are to be served, the first step is to collect detailed information on the physical and biological settings in the different regions. Climate, soils, crops, and cropping systems are the building blocks for improved farming systems. The FSRP will not be pioneering in model development; available models will be tested and adapted to the requirements of different agroclimatic regions.

Two objectives of modeling at ICRISAT can be distinguished: (1) a greater understanding of the physical processes involved and at the identification of gaps in knowledge, which can assist in the setting of research priorities, and (2) the generation of predictive models that can be used to evaluate the relative potentials for various prospective technologies under a wide range of crop-resource situations. Although

most early results will relate to the first objective, long-term efforts are aimed at the generation of predictive models to better fulfill ICRISAT's objectives across varying resource environments.

It is our hope that such process-based, weather-driven soil and crop modulated models will be useful in: (1) explaining and generalizing the results of site- and season-specific field experiments, (2) identifying agroclimatic analogues, (3) analyzing the likely consequences of alternative systems of soil, water, and crop management under different sets of soil and climatic conditions, (4) quantifying the risks associated with alternative farming systems, (5) assisting national programs in setting research priorities.

Benchmark Research

To make simulation techniques effective, it will be necessary to identify a limited number of benchmark locations in Asia, Africa, and Latin America. The diversity of the resource base encountered in the SAT dictates the need for associated research efforts at such sites. These locations will be carefully chosen in cooperation with national programs to represent distinctly different clirnatic, soil, and topographic conditions, and to cover the spectrum of environments with a minimum of locations. Research at these benchmarks will be developed in cooperation with the national and state institutions; it is expected that in many cases, ICRISAT's Crop Improvement cooperative programs may also be located at or in close proximity to these sites.

Experimental results from the past few years justify the assumption that the farming systems presently found in much of the SAT cannot be significantly improved by introducing better technology for any single production factor alone. The climate and soils environment, the traditional cropping systems, and the behavior of farmers in the face of risk create a situation in which improvement of one component of the production system rarely results in adequate returns for the long run. The implications for farming systems research are clear: several components of new technology must be identified and integrated in operational-scale research. This should be done in such a manner that the synergistic effects of these components make their concurrent introduction feasible and rewarding, while conserving the resource base to assure long-term stability. Once technically and economically viable farming systems have been developed for different areas of the SAT, further research on successful implementation in the setting of existing farming systems must be pursued.

Cooperative Research

Preliminary results from research by national programs in the SAT and by ICRISAT indicate that improved resource conservation and utilization, along with improved technology applied to all phases of crop production, has great potential for generating economically and technically viable farming systems capable of increased and more stable agricultural production (Kampen 1979, Krishnamoorthy 1977, Krantz et al. 1978, Spratt and Chowdhury 1978). However, the resource base (climate, soil, people, crops and cropping systems, livestock, capital, etc.) is characterized by great diversity. Even at a given location, the environment for crop growth will differ from year to year due to the variability in rainfall. Therefore, appropriate farming systems technology will have to be flexible to perform well under a range of conditions.

Two major questions must be answered by cooperative farming systems research:

1. Through studies of the existing resources and management techniques as well as the requirements of new cropping systems, a clear answer must be obtained to "what" is to be done to improve the crop growth environment and to maintain productivity; investigations with these objectives and the determination of the relative probability of success for alternative approaches are primarily conducted at research centers, and past research has almost exclusively focused on these questions.
2. Knowledge gained on the first set of questions must be translated into "how" this new information is to be fitted into existing farming systems. Site-specific, applicable resource management and utilization technology must be generated under diverse agroclimatologic and socioeconomic conditions. Such problem-

solving investigations are most effectively carried out through farming systems studies on an operational scale at research stations and on farms (Kampen 1979). Cooperative research programs aimed at these goals are presently being initiated in the seasonally dry regions of southern and southeastern Asia, West Africa, and northeastern Brazil.

On-farm Research

In its cooperative research programs on real farms. ICRISAT's FSRP does not envisage the demonstration effect or the implementation of new technology as a major goal. Those activities are the exclusive responsibility of national organizations for research and extension. However, it is expected that the results of such cooperative research projects will greatly facilitate later implementation of new technology across large regions of the SAT by adapting that technology to what farmers require, by identifying bottlenecks, and by developing guidelines for appropriate village- and farmer-level organizational structures (Kampen 1979).

In view of the more limited resources of farmers, the performance of technology in farmers' fields may differ from what has been observed at research stations. Testing under real world conditions can provide information on the actual economic viability of watershed-based technology. It is therefore important that the technology be studied in farmers' field situations so that constraints to adoption can be identified and specifically addressed by further research to improve the technology (Kampen and Doherty 1979).

On-farm research provides for participation of farmers in the development of technology. Ideally, agricultural research does not start at research stations; it starts on farms. Only in this setting will feedback to the research programs be generated. Such feedback is considered essential to assure the continuing relevance of technological solutions to the problems of farmers.

Research on watershed-based systems in on-farm situations also has an advantage in that ciritical questions can be addressed regarding the initiation of group action among farmers who operate plots on a watershed area. Indeed, these issues only express themselves in an on-farm situation. With farm sizes in the Indian SAT averaging around 1 to 2 ha, and with farmers having several plots comprising this area (often in locations that are spatially separated), and with watershed sizes generally many times larger than individual farms, it is imperative that operational guidelines for eliciting group action be defined.

We envisage that the information generated from these cooperative research projects will have impact far beyond the actual locations of project execution. Improved understanding of the technology-generating process — and of effective organizational structures identified as prerequisites to the effective implementation of new farming systems — may facilitate agricultural development not only in the regions concerned but in the entire SAT.

Participation in Training Programs

Training programs are an essential part of farming systems research. The concepts and approaches for farming systems research are new, and guidelines are not as well developed as in more established research activities. Farming systems research is also highly interdisciplinary, involving integration of many disciplines to develop efficient resource use and productive cropping systems technology. The FSRP staff has been active in ICRISAT training programs and expects to greatly expand this activity by providing special courses in farming systems research. In the early stages, this effort will be oriented primarily toward cooperating scientists. Later, training of those charged with teaching technical officers involved in development projects will be emphasized.

Conclusions

Over the past 6 years, ICRISAT's FSRP developed a research strategy which consists of: (1) identification of major problems in a representative ecological zone and the focus of interdisciplinary research on the solution thereof; (2) development, investigation, and testing of hypotheses and the generation of approaches and methodologies that can be used by national programs to tailor solutions to specific conditions; (3) the simultaneous investigation in depth of single production com-

ponents and the integration of new technology into improved farming systems through operations research; (4) the development of models to extrapolate results; and (5) the study of implementation methods on real farms.

In the process of developing a research strategy, several important factors have been recognized. Some of these are:

- Recognition of the small agricultural watershed as a focus of research and a framework for development.
- Reevaluation of animal power as a major resource in farming systems in the SAT if appropriate machines and tools can be developed.
- Demonstration of the value of agroclimatic quantification in research priority-setting, in the selection of improved soil-, water-, and crop-management systems, and in extrapolation of research results.
- Understanding of the advantages to farmers in the SAT of intercropping systems under high levels of management and inputs.
- Appreciation of the critical importance of model development to extrapolate research results in time and space.
- Advantages of year-round tillage and weed-management approaches, especially on Vertisols.
- Potentials of operational-scale systems research to partially overcome gaps between research results and farmers' requirements.
- Substantial synergistic effects that can be obtained by combining important production factors.
- Utility of on-farm research to involve farmers in technology development and as a feedback mechanism for identification of priority research needs.

There are no shortcuts to development in the SAT. Sustained increased production, employment, and income will result only if improvement can be effected simultaneously in several production factors. The soil and the water that falls on it are precious resources that require careful husbandry. Soil and crop management, as implemented by farmers, appears to be the most critical of the factors now limiting production. The research results obtained show potential and justify hope that problem-focused farming systems research can effectively contribute to the realization of ICRISAT's goals.

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Socioeconomic Constraints to Agricultural Development in the Semi-Arid Tropics and ICRISAT's Approach

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Abstract

This paper discusses how socioeconomic constraints to agricultural development are evaluated at ICRISAT in order to better formulate research priorities in an ex ante sense as well as to improve the efficiency with which new technologies, once they are developed, are "marketed" to farmers. The constraints discussed include variations in population densities, the heterogeneity of the resource endowments in the SAT, the role of risk in farmers' decision making, marketing institutions, human institutional requirements, and, finally, efficiency and equity concerns in research resource allocation.

One of the important mandates of ICRISAT is to help identify socioeconomic and other constraints to agricultural development in the SAT, and to evaluate alternative technological and institutional means of alleviating them. This is a recognition that agricultural research must be designed and implemented keeping the socioeconomic environment of target and client groups clearly in view; agricultural research investments that consider only the potentialities and constraints of the agrobiological environment do not lead to the highest possible returns. Viewing agricultural research as a multidisciplinary exercise can enhance the returns, not only in terms of efficiency but also in terms of human welfare and equity.

The importance of carefully targeting research allocations cannot be overstressed in view of the extremely limited amount of research expenditures in the SAT. They amount to only 0.008 U.S. cents per hectare of geographic area and only 0.14 cents per hectare of the five ICRISAT crops — sorghum, pearl millet, pigeonpea, chickpea, and groundnut. Total research expenditure in the SAT amounts to $14 million, of which over 50% is ICRISAT's. The low level of national research expenditures for SAT agriculture is in itself an important socioeconomic constraint that needs to be emphasized at the outset of this paper.

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Socioeconomic Constraints

Population Densities

The 48 less developed countries with semi-arid tropical climates had an estimated population of around 600 million in 1975. These are supported on a SAT geographical land area of approximately 17.6 million km² representing a population density of 0.34 people/ha.[1] Or, to put it another way, there are about 3 ha of geographic land available per person in the SAT to provide food, clothing, shelter, and the wherewithal to invest for the future, as well as to augment the necessities of life at the present population level. In some SAT countries, the population/land equation is far in excess of the 0.34 average. For example, in India the density is almost five times the SAT average, while in Nigeria it is twice. This means in SAT India there is only 0.6 ha of land for each person, while in Nigeria there is 1.5 ha Since not all this land is arable, the picture is even more serious than these figures indicate.

It is the generally high population/land pressure in the SAT — along with the primary dependence on uncertain rainfall and nutrient-deficient and often eroded soils — that poses the most significant physical constraint to de-

1. Land areas are on a geographical basis. The source for most of these data are Ryan (1974, 1978), with appropriate updating.

velopment. When this is combined with the high population growth rates, the problems for agricultural research become urgent. These population growth rates are as follows:

SAT region	*Population growth*[2] (% p.a.)
Asia	2.45
Africa south of Sahara	2.50
South and Central America	2.70
Near East and North West Africa	2.90
Total SAT	2.50

More than 75% of the population of these countries depend on agriculture for their livelihood, particularly the people who reside in the SAT regions.

These statistics reveal to some a gloomy prospect for the SAT. However, at the same time there are some hopeful signs. First, more recent population growth rate calculations suggest that in many of the less developed SAT countries the rates of increase have begun to slow down (World Bank 1974). The reasons seem to be that the rapid increases in life expectancies since World War II — resulting from substantial public health programs aimed at controlling malaria, tuberculosis, smallpox, cholera, etc. — have begun to taper off. Also, birth rates have been declining as people incorporate this information about increased life expectancies into their decisions on family size. To have one's children alive when one reaches old age is now much more probable than it was 25 years ago. Since 1950, the life expectancy at birth in many low-income countries has increased 40% or more (Ram and Schultz 1977). For India, male life expectancy at birth between 1951 and 1971 rose from 32.4 to 47.1 years, an increase of 45%; for females, the increase was 44% — from 31.7 to 45.6 years. To the extent that part of the demand for children in less developed countries is to provide social security for old age (Mamdani 1972), these increased life expectancies must further reduce the demand for children.

2. These are simple averages of individual country growth rates as reported in Ryan (1974). Data cover the period prior to 1971.

The increase in life expectancy, resulting primarily from improved health and/or nutrition, also implies an increase in the quality of labor — or enhanced *human capital*. These improvements have positive impacts on production (Ram and Schultz 1977). Increased investments in schooling, which are also occurring in low-income countries, further augment their stocks of human capital. Preston (1976) suggests that the decline in mortality leads to increased incentives for people to invest in schooling.

Hence, while demographic events in less developed countries on the surface have resulted in what many would call physical constraints on development, a more informed view suggests that these same events have also led to an increased investment in humans; this, in turn, is expected to lead to a greater potential for populations to deal with the economic disequilibria that characterize economic modernization (Schultz 1975).[3] Viewed in this perspective, the high population/land ratios of much of the SAT need not be a negative factor in the prospects for growth of food production and enhanced development in these countries.

The predominance of subsistence-oriented farming in SAT countries is a current fact; ICRISAT is designing its technologies to explicitly recognize this, especially in the short run. However, we are not restricting ourselves to this concept in the long run. There is evidence (Doherty 1978) that in commercialized agriculture, where reliance on unskilled and family labor is less than in subsistence-oriented agricultural sectors, birth rates are also considerably less. Planning agricultural technology that allows or even encourages commercialization itself can have a restraining influence on population growth.

Heterogeneity of Resource Endowments

The heterogeneity of the SAT is a factor which makes technology design a difficult exercise for an international center. This is why we have

3. We do not have precise information on health and schooling in countries other than India at this time. However, similar trends in life expectancies and fertility are occurring in many developing countries (World Bank 1974).

devoted considerable effort to characterizing the SAT, to ensure that our research is focused on the priority problems and regions. In India the SAT population/land ratio is about 1.7 persons/ha, while in SAT Africa it averages only 0.14; this means that technology design in these two regions must embody different characteristics.[4] In SAT India, with its abundance of animal draft power, ICRISAT has opted for technologies that use labor and animals but save scarce land. On the other hand, in SAT Africa the emphasis may be more toward labor-saving and land-using technologies, with the possibility of mechanical innovations also (Ryan 1974, Subrahmanyam and Ryan 1975). In SAT India, it seems from the work of Binswanger (1978a) that, except in special circumstances, tractors may not be a desirable component of new technologies. Therefore, our primary focus at ICRISAT — particularly in farming systems research for India — has been on developing improved soil, water, and cropping systems that can be implemented with animal-powered implements supported by human labor, resources that are relatively abundant.

The heterogeneity in the resource endowments of the SAT regions of the world has led ICRISAT to use the concepts of induced innovation espoused by Hayami and Ruttan (1971) in their now-famous book *Agricultural Development: An International Perspective*, and subsequently elaborated by Boyce and Evenson (1975) and Binswanger et al. (1979). This has helped guide research resource allocation decisions and the search for new techniques of production. Although this has often been more at the macro end of the spectrum (Ryan 1974, 1978, Doherty 1978), these concepts are increasingly being applied at the micro or farm level (Binswanger et al. 1976, Binswanger and Ryan 1977, Ryan and Rathore 1978, Jodha 1978, Doherty 1979).

Infrastructure

There are substantial differences in the infrastructural support systems in the 48 less developed SAT countries. India has a well-developed marketing system for crops (von Oppen 1978a); a widespread road, rail, electricity, and communications network; rural credit facilities that are improving each year; large-scale fertilizer and pesticide manufacturing and distribution facilities; and a sophisticated agricultural research and training network. Other SAT countries such as Brazil, Mexico, Thailand, Nigeria, Senegal, Rhodesia, and Argentina are also relatively well-endowed with infrastructural facilities of this type. Even in these countries, however, there is an imbalance in the regional distribution of facilities, with the urban areas and the non-SAT agricultural regions with higher and more assured rainfall generally receiving a disproportionate share of infrastructural investments. Nevertheless, these countries are in a far better position than such SAT countries as Mali, Chad, Sudan, Ethiopia, Niger, and Upper Volta.

In the short run, infrastructural constraints will mean that all SAT farmers will not be able to fully adopt technologies that offer high payoffs to investments in purchased inputs such as fertilizers, pesticides, and improved implements; rather, adoption will be a sequential process. ICRISAT must therefore evolve technological options that will fit the varying infrastructural support systems prevailing in different SAT countries. At the same time, it should be recognized that a prerequisite for infrastructure improvement in these countries is a demand for improvements such as fertilizers, credit, roads, markets, and communications, resulting from development of technologies that make profitable use of these inputs. We believe this demand must be there in order to convince governments and international donor and aid agencies of the need to supply improved infrastructural facilities. These are the precursors of development and growth. Research in the Economics Program by von Oppen and his colleagues (1979) has demonstrated the gains in productivity that can be achieved from investments in establishing markets, in improving roads and communications, and in enhancing interregional trade opportunities. Gains from improvements in interregional trade flows were shown to be substantially greater under circumstances where technological change is occurring differentially in the regions concerned.

4. The differences are even more extreme between countries: the lowest ratio is in Botswana, with 0.02 people/ha, or 1% that of India.

International and national agricultural research institutions must not focus solely on input and management-intensive technology; other technological options, which make better use of the extremely limited infrastructural facilities found at present in many SAT countries, must also be a part of the portfolio.[5] As Ryan and Subrahmanyam (1975) have shown, there seems to be a real scope for development of technological options that offer substantial payoffs to farmers with limited access to infrastructural facilities while at the same time allowing those with better access to reap additional benefits. There need be no trade-off made here in designing technologies that offer improved productivity and income to farmers regardless of where they are located on the infrastructural spectrum; a single package-of-practices approach will not be the correct philosophy in this context.

At ICRISAT we have adopted an approach to research that embraces the concept of technological options. In the Farming Systems Research Program, for example, a series of experiments has been under way for several years to evaluate the individual and complementary effects on yields and yield stability of various levels of fertilization, soil and water management, and crop varieties. These are termed "steps in improved technology" experiments.

The watershed-based research of the FSRP has aimed at development of soil- and water-management technologies that make use of the natural drainage unit. In this, we have examined the differential effects of various sized watersheds, with particular emphasis on the scope for group action among farmers (Doherty and Jodha 1977). Are there benefits to be gained by individual farmers from adoption of parts of the complete watershed-management technology, such as the broadbed-and-furrow method of cultivation? Or will several farmers with contiguous land parcels on a watershed have to agree to manage their parcels jointly in order to reap significant gains?[6] In addition to being examined on research stations at ICRISAT and in cooperating national programs, these issues are being taken to carefully selected villages in the SAT. It is only at the village and farm levels that such questions can be satisfactorily answered, through cooperative experiments with farmers, national program scientists, and ICRISAT scientists working together to identify the viable elements of prospective technologies and to learn from each other. (See Binswanger and Ryan, this symposium.)

In the crop improvement program of ICRISAT, the advanced cultivars and lines are being selected under high and low levels of fertility and management. Before elite lines are released to national programs, they are tested to ensure that they are not only superior to existing cultivars at the higher fertility management levels, but also that they are clearly superior at very low levels.

Risk

The SAT environment is a risky one. The risks derive from various sources. Weather is often thought of as the most significant factor influencing the riskiness of farming in the SAT; however, weed, pest, and disease incidence — along with fluctuations in market prices — are among some of the other major contributors. Studies conducted by Barah at ICRISAT and reported in Binswanger et al. (1979) have shown that in the regions of SAT India where there is little irrigation and low average rainfall, the largest component of overall risk is crop-yield variability rather than price variability.[7] In the higher rainfall regions and/or those with a substantial proportion of irrigated land, the contribution of price risk is higher than that of yield risk.

Ryan (1974) calculated the coefficient of variation (CV) of yield for the two major SAT

5. There is increasing evidence that the national and international community is recognizing the key role of agriculture and its associated infrastructure in the economic growth of less developed countries. For example, after the Sahelian drought of the early 1970s, substantial funds were made available to the Sahelian countries to develop their agricultural sectors.

6. In India there are almost five parcels of spatially separated land comprising the average holding (Ryan 1974).

7. Risk was measured as the variance of gross returns over time from the cropping patterns of the districts comprising each region.

cereals as follows:

SAT region	Coefficient of variation of yields (%)	
	Sorghum	Millets
India	9.4	22.2
Other Asia	9.8	14.1
Africa south of Sahara	11.5	14.9
South and Central America	17.0	12.4
Near East and North west Africa	2.3	11.6
Average SAT	11.7	14.4

Generally the CV of annual rainfall in the SAT regions rises as the average annual rainfall decreases; that is, those regions where rainfall is generally lowest are also those where fluctuations in annual rainfall are larger. This is reflected in the above table, where the variabilities in millet yields are greater than those in sorghum. Millets are primarily grown in the regions where rainfall is lower and more highly variable. In eastern Rajasthan, India, for example, where millets are mainly grown, the probability of a drought of moderate or worse severity is almost one in three. In the sorghum-growing areas such as Andhra Pradesh, Madhya Pradesh, Karnataka, and Maharashtra, the probabilities are less than one in four (Ryan 1974).

Research at ICRISAT explicitly recognizes the nature and significance of risk facing farmers of the SAT. In the Farming Systems Research Program, much of the research is predicated on the notion that water is the most limiting natural factor in SAT crop production. Research in soil and water management, agroclimatology, environmental physics, and cropping systems is aimed at making more effective and economic use of rainfall, soil moisture, runoff, and groundwater for increasing and stabilizing crop production. In crop improvement, entomologists, pathologists, physiologists, and microbiologists are working with plant breeders to develop cultivars resistant or tolerant to such "yield reducers" as insects, pests, pathogens, drought, and soil nutrient deficiencies. Success in these programs would mean less risk of crop failures.

The field-scale research in development of improved soil, water, crop, and implement management technologies at ICRISAT is carefully monitored by the agronomists, engineers, economists, and anthropologists in a multidisciplinary team approach extending beyond the research station into the villages. Not only is the technical, economic, and social viability of prospective technologies analyzed, but their effects on risk are also gauged. For example, such analyses have confirmed that intercropping is not only more profitable than double cropping but also less risky (Ryan et al. 1979).

Economists have researched the extent and determinants of risk in the SAT and of the attitudes of farmers to these risks. In a study of 330 ruralists in Andhra Pradesh and Maharashtra, Binswanger (1978) found all farmers moderately risk averse when faced with choices of varying profits and risks. If this reflects risk attitudes of SAT farmers in general, it suggests that separate technologies with different risk characteristics for small and large farmers are not required. Farmers will invest in technologies that have some risk, provided the profits are attractive. The fact that small farmers often may not have participated as much as large farmers in previous technological innovations may have been due more to unequal access to infrastructural support facilities than to any great aversion to taking risks. This research therefore suggests that institutional policies are required to give small farmers equal access with large farmers to credit and modern inputs.

Market Parameters and Preferences

The two cereals of ICRISAT's mandate, sorghum and pearl millet, and to a lesser extent the two pulses, chickpea and pigeonpea, are what may be termed staple food in the SAT. As such we *expect* them to be faced with relatively small price and income elasticities of demand. That is to say, if their prices fall by 10%, we expect consumer demand to increase far less than that. If income increases by 10%, we expect consumption of these staples to increase only marginally and possibly even to decrease.

Very little precise information is available on demand elasticities. What is available is at an

aggregative level, often not suitable for the type of policy analyses to be undertaken.

The picture with respect to market information on groundnut is similar to that of the four foodgrain staples, except that this is a commodity that enters commercial market channels to a much greater extent. Raju (1976) estimated that in India around 60% of total groundnut production reaches markets. The figure for sorghum and millets is 15 to 20%; for chickpea and pigeonpea, 35 to 40%. With groundnuts, where national and international trade occurs in three components — hps (hand-picked selection) kernels, oil, and oilcake — the parameters of demand for the various countries are much more complex, but still are as necessary to know as are the parameters of staple foodgrain demand.

If staple foodgrain demand is as inelastic as expected, then technological change that shifts supply functions will generate substantial price declines. Hence, the market demand for them could place constraints on sustained increases in foodgrain supplies, as farmers subsequently react to their depressed relative prices. By how much will farmers' supply respond to changes in these prices? Again, we know very little about farmers' supply response to market price changes and to other variables for these four foodgrain staples and for groundnuts. ICRISAT has been undertaking research into these questions to help fill the void (Bapna 1976, von Oppen et al. 1979). With the aid of these market parameters, price and trade policy questions can be more adequately addressed by policymakers in SAT countries, especially those where supplies of these commodities become more abundant following technological advances. Policies designed to enhance technology adoption and increase welfare can also be formulated with these more precisely estimated parameters.

Consumer preferences for evident and cryptic quality characteristics in foodgrains are often well defined and are reflected in differential prices in the market (von Oppen 1978b, 1978c). Failure of researchers to develop new cultivars with characteristics acceptable to consumers can adversely affect adoption and relative prices. Past experience with some of the new wheat and rice cultivars testifies to this. In SAT India, for sorghum and pearl millet, we need to consider factors such as seed size, color mix, swelling capacity in water, cooking time, chapati-making quality, and protein and calorie content. For the pulses, instead of chapati quality, we need to consider dhal-making qualities. In the African SAT, other preparations such as cous-cous, beer, and gruel are considered for the two cereals.

ICRISAT breeders, biochemists, and economists are working together to determine more precisely what characteristics consumers prefer, by how much, and whether there is genetic scope for breeders to manipulate these various attributes into viable grain types that lose none of the other important characteristics we are breeding for, such as high and stable yields (von Oppen and Jambunathan 1978).

Human Nutrition

One might say that the problems of inelastic demands and consumer preferences for the staple foodgrain crops of the SAT are concerns for ICRISAT in the short to medium term only. To an extent, this is true, as in the longer run population and income growth are projected by many agencies to place excessive strains on food supplies, particularly in SAT countries. In the less developed countries, demand for coarse grains is expected to triple by the year 2000. Some 60% will be for human consumption and the rest for animals (Kanwar and Ryan 1976). Demand for coarse grains in all less developed countries is estimated to grow by 3.23% per year in the future. In the decade from 1964 to 1974, the SAT production of sorghum and millets together rose at a compound rate of only 2.11% per year, made up of 2.81% for sorghum and 1.24% for millets (Table 1). If this continues into the future, serious imbalances in supply and demand will occur in the less developed countries of the SAT. Studies reviewed by Ryan (1978) suggest these cereal deficits could be between 17 and 37% by 2000 A.D. If not corrected by trade flows from developed countries, which are projected to have a demand growth of only 2.14% per year with recent production trends of 3.48%, the nutritional welfare of some of the poorest people in the world — those of the SAT — will be severely reduced. This will be especially true in Africa, where cereal deficits are expected to be worse than in Asia.

A more adverse long-run supply/demand

Table 1. Annual compound growth rates of five major crops in the less developed countries of the SAT during 1964–74.

Crop	Area (%)	Yield (%)	Production (%)
Sorghum	0.71	2.08	2.81
Millets [a]	0.04	1.20	1.24
Chickpea	−1.29	1.46	0.15
Pigeonpea	−0.08	0.83	0.75
Groundnut	−0.40	0.02	−0.38

a. Includes pearl millet (*Pennisetum americanum*), as well as the minor millets such as *Setaria*, *Panicum*, and *Eleusines*.
Source: Ryan (1978).

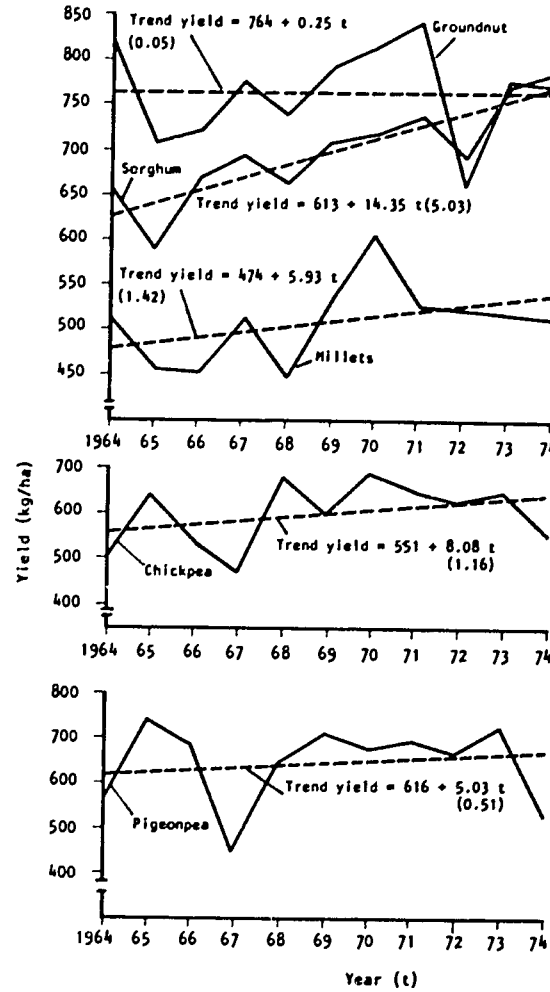

Figure 1. Yield of five crops grown in less developed countries of the SAT from 1964 to 1974. (Figures in parentheses are t-values.)

balance is projected for the pulses than for the cereals. Here the deficit in the less developed countries is estimated to be around 50%. For oilseeds, it will be closer to 40%. India and Africa are likely to have equally large deficits of pulses and oilseeds.

The long-run answer to alleviating these projected food deficits is increased crop yields. As Table 1 and Figure 1 indicate, yields have been virtually stagnant for groundnuts and pigeonpeas in less developed countries of the SAT. They have been moderately better for chickpea, millets, and sorghum. In view of the increasing pressure on arable land, particularly in SAT Asia, the long-run need is for land-augmenting and capital-saving technological change that will have the effect of increasing yields per unit of land and capital. In SAT Africa and South America, where land constraints are not as immediately binding, emphasis should also be given to labor-augmenting technological innovations.

Emphasis on technologies that increase food production per unit of the scarcest resources will also directly contribute to the alleviation of the major nutritional constraint in the SAT — energy. Studies by Ryan, Yadav, and Sheldrake (reported in Ryan 1977) showed that calories, vitamin A, vitamin B complex, and selected minerals were the primary nutritional deficiencies in diets of the people in the SAT, even those with low incomes (proteins and amino acids were not found to be as deficient as was earlier believed). Breeding strategies that emphasize yield and yield stability offer the best prospects for improving the nutritional well-being of the least nutritionally and economically affluent groups in the SAT. This is the primary strategy of ICRISAT, and it finds more support from an analysis of the net nutritional impact of the new dwarf cultivars of wheat introduced into India in the mid-1960s. Ryan and Asokan (1977) found that, even allowing for the reductions in pulse production to which the new wheats contributed, the net production of energy, proteins, and amino acids was substantially higher with

the new wheats than it would have been without them.

Increased yields and production of foodgrains have a direct impact on prices and real incomes of the least affluent groups, who spend a large amount of their incomes on these foodgrains. Increased real income will enable them to purchase additional foodgrains and improve their nutrition. If yield potentials of cereals, pulses, and oilseeds could all be increased, nutritional improvements would follow, as these crops have complementary nutritional compositions. ICRISAT will continue to search for cultivars with better nutrient compositions also, as long as this does not unacceptably affect the attainment of increased yield and yield stability.

Efficiency and Equity Concerns

As a whole, the SAT region is probably the poorest in the world, with an average gross domestic product of about $160/yr per capita (Ryan 1974). The fact that ICRISAT was established to undertake research for the benefit of the SAT signifies that any productivity gains that might result from its efforts will directly benefit the poorest sector of humanity. The initial choice of the SAT region and its staple foodgrain and oilseed crops as the mandates of ICRISAT ensures that efficiency and equity considerations at the macro-level are not in conflict. However, there are potential conflicts between efficiency and equity concerns as we move to the regional, village, and farm levels within the SAT.

The first of these relates to the allocation of research resources amongst regions and countries within the SAT, and also among the various research programs. Research resources should be allocated to achieve maximum productivity gains consistent with interests of the various potential beneficiaries. This is not an easy task in an ex ante framework (Binswanger and Ryan 1977). It is one where techniques such as Boyce and Evenson's (1975) congruence technique can be helpful, as indeed it has been at ICRISAT (Ryan 1978).

A second concern is the effect of the unequal distribution of land on the allocation of research resources. Biological innovations are usually divisible and hence scale-neutral. Scale economies generally arise with mechanical innovations. A strategy favoring small farmers should thus discourage research resource allocation to techniques requiring large-scale or expensive machines. In this context, little conflict between efficiency and equity should arise, since most mechanical innovations are labor-saving and unlikely to result in large efficiency gains in low-wage countries. This has guided ICRISAT in its strategies regarding tractors, as mentioned earlier.

There is evidence that large and small farmers in SAT India do not fit uniformly into two distinct factor endowment ratio groups. Although Ryan and Rathore (1978) found significant differences in mean levels of factor *endowment* ratios, these differences were reduced when factor *use* ratios were considered. The operation of factor markets in the villages was such as to tend to equalize factor *use* ratios, although not completely. Even more relevant was the fact that variability of factor ratios within farm size groups was so large that it was impossible to delineate small from large farms. It would seem from this that at the micro-level, the type of technology relevant for large farmers will not be basically different from that for small farmers in factor saving/using characteristics. There need not necessarily be a search for substantially different technologies for small and large farmers. Improving factor market access and providing for technology options should be all that is required, as was mentioned earlier in this paper.

There may be research activities that might favor particular socioeconomic groups and that can be identified after careful study of farming systems at the village level. For example, Jodha (1977) found from ICRISAT's Village-Level Studies that the practices of intercropping and rainy-season fallowing/postrainy-season cropping of deeper Vertisols were more prevalent on the smaller farms in SAT peninsular India. This suggests that successful research on new intercropping technologies and on technologies that allow a rainy season crop to be grown on deeper Vertisols will not only have large productivity effects but will also be of relatively large benefit to smaller farmers. These two problems are receiving major attention in ICRISAT's Farming Systems Research Program.

In the Asian SAT, there is a large population of landless agricultural laborers. There are signs

in some of the more densely populated African SAT countries, such as Nigeria, of an emerging landless labor class. In designing agricultural technology, the interests of this group must not be forgotten. Labor-using technology will always be in the interests of landless labor; labor-saving technology will not, as Binswanger and Shetty (1977) point out is the case with herbicide technology.[8]

Hired females are a major source of labor in SAT agriculture, especially in India. They are generally the most disadvantaged in terms of wage rates and employment probabilities. This seems especially true for those from the landless households (Ryan and Ghodake 1979). For this reason, and because of the negative effect of work participation on female fertility, their role must be explicitly considered in the design of new technology. ICRISAT has recognized this from the outset.

Conclusions

The SAT being the poorest region in the world, ICRISAT is committed to strategies that will help alleviate constraints on its food production and development. Indeed, it seems clear that the major factor involved in enhancing SAT development is improving the productivity and stability of food production, thereby allowing the release of necessary resources for other developmental activities. The source of much of these gains will be agricultural research, to which national and international programs in the SAT and other countries are contributing, frequently in cooperation.

In attempting to make these contributions, it is our contention that socioeconomic factors or constraints must be explicitly considered. This is true both in the ex ante framework of research resource allocation questions and when technology is being "marketed." This is a continuing process requiring close collaboration among scientists of many disciplines. New socioeconomic constraints arise almost weekly; research institutions must be able to evaluate the likely effect of these on agriculture and design appropriate strategic responses.

A good example of this was the substantial oil and fertilizer price rise in the early 1970s. Many inferred that the oil price rise caused the fertilizer price rise; therefore, as oil prices were likely to rise further in future, new cultivars that could yield well with zero fertilizers should be the major focus of plant breeders. The answer was not as simple as that. Fertilizer prices are indeed affected by oil prices, but not proportionately; oil is a small component of fertilizer costs. Fertilizer prices are now almost at their lowest ebb (in real terms), whereas oil prices are at their highest — a complete reversal of the implied relationship after the early 1970s oil crisis! Other factors, such as fertilizer plant capacity, growth, and demand, are more important in determining fertilizer prices. The problem of how to respond to the likely future fertilizer situation still confronts research institutes such as ICRISAT. It involves questions such as the likelihood of future relative price changes, the scope for developing fertilizer-saving technologies, and their gestation periods. Scientists of many disciplines are required to sit down and assess these types of issues together. The stakes are high.

The SAT farmers may be poor in resources but are certainly economically rational agents willing to take some risk on attractive rewards.

Given appropriate incentives from superior technologies and appropriate economic policies, farmers can be expected to innovate in their production and marketing practices. If we better understand their aspirations and the constraints under which they operate, technology design and economic policies are more likely to fit their needs.

8. As the landless also are at the low end of the income spectrum, ICRISAT's research on the staple foodgrains will further benefit the landless via reduced relative prices of these major items in their consumer budgets.

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Summary of Discussion — Session 2

Dr. Govindaswamy asked what the incentives are for farmers to adopt innovations. Dr. Ryan replied that the availability of technological options would be one of the primary incentives. Sometimes these must be accompanied by institutional incentives, such as the provision of infrastructure support, to enable effective use of the technology. Thus, technology and institutional policy would provide the major incentives for innovation.

Dr. Daulat Singh asked how one deals with social and economic stratification in providing incentives for the farmer who has no surplus produce to market. Dr. Ryan said that this was in the realm of governmental policy and thus outside the proper scope of ICRISAT research. However, ICRISAT is aware of and sensitive to the implications of these socioeconomic realities. Operationally, the Institute addresses the issue by developing technological options rather than a single package of practices that might be at variance with the resources available to farmers in this stratum. But it must also be recognized that there is a limit to how much technological change can do to redress social biases.

Dr. Cummings observed that although solving some of these problems was outside the realm of research in an international institute, identifying the problems might well be within its scope.

Dr. Ryan was asked what strategy ICRISAT was adopting to cover or reduce risk in SAT farming. He said the strategy is definitely directed at the risk question and cited four instances:

1. As the papers on crop improvement indicated, research is aimed at alleviating the adverse effects of diseases, pests, drought, and other yield reducers on the main SAT crops. This will automatically increase yields. This strategy of attacking the yield reducers will probably be a major contribution to reducing or diffusing risks of farming in the semi-arid tropics.
2. The performance of new technology — whether involved in crop improvement or farming systems — is assessed not only in terms of the average rate of profitability but also of the variability of those profits and the probability with which they can be achieved.
3. It is important to understand the farmer's attitudes towards risk. Thus ICRISAT is studying the attitudes of SAT Indian farmers to different options that generate different types of risks and payoffs. Though this needs further study, the findings thus far indicate that it may not be necessary to develop one type of technology (in terms of risk) for the small farmer and another for the large farmer.
4. ICRISAT is studying the institutional or policy mechanisms — crop insurance, for example — that also help diffuse risk. Dr. Cummings added that the institutional factors to be considered would include price support and price stabilization policies, storage facilities, and availability of markets and of input supplies.

The three papers on crop improvement identified a number of the risks — such as diseases, pests, parasites, weeds, and the technology for overcoming these. One of the major risks is the uncertainty of moisture supply. Intercropping, intercepting water, and improving infiltration to get through dry periods more effectively are technological means of overcoming at least some of the risks involved. If these risks and the extent to which technology can reduce them can be identified and quantified, this might give the farmer a better chance to make choices.

Dr. Kampen was asked whether it would be possible for a research program such as ICRISAT's to indicate the kinds and magnitude of assistance that might be given to rainfed agriculture in comparison with the subsidies and assistance given to irrigated agriculture.

He said that, while it was not the task of ICRISAT to develop any prescriptions in this regard, it could indicate what the alternatives are. Today traditional large-scale irrigation projects are implemented at costs ranging from Rs. 15 000 to Rs. 30 000 ($1875 to $3750)/ha in the developing world. Region-specific and location-specific research that closely examines

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how to make the best use of available resources could lead to substantially decreased risk and increased security at a fraction of the cost of large-scale irrigation.

Dr. Cummings commented that governments invest large sums in drought relief and public works in times of stress. If quantitative parameters could be worked out around the costs and benefits of some of these programs, governments might have better guidelines for making investment decisions.

It was suggested that construction of large reservoirs continue to be needed as they serve many other purposes — electricity generation, flood control, etc. — besides irrigation. However, small farm ponds have been used over the ages to store excess rainwater in South India and this practice could be extended to other SAT regions. The government could undertake to desilt existing tanks and expand them, on a watershed basis. Relative costs of such operations should be worked out.

Dr. Ryan was asked to what extent ICRISAT programs — herbicide research or nutritional studies, for instance — are assessed before they are undertaken, for the possible or probable benefits that would accrue to the target group.

He stated that economists at ICRISAT are encouraged to look closely at the value and desirability of programs from this perspective. Herbicide research in the Indian context, for instance, is unlikely to form a desirable component of improved farming systems unless herbicides can give substantial yield advantages over conventional weed control methods. Herbicide use might displace large numbers of female hired laborers, the most disadvantaged group in SAT India. In the SAT African context, the picture is quite different, because labor constraints loom large there; any herbicide research, therefore, must focus on SAT Africa.

Regarding nutritional priorities in the breeding program, nutritional status and needs in the SAT have been closely examined; this has generated much basic research on questions of protein and lysine content, for instance. Scientists are always on the lookout for a something-for-nothing in this area, but other priorities will not be sacrificed for this.

Dr. Patil observed that the development of weed-resistant varieties would be a welcome aid to small and marginal farmers, who work for wages on large farms and are seldom able to attend closely to their own crops during the critical first 30 or 40 days when weed competition is strongest.

In answer to a question on the interaction between desirable rates of fertilization and water management and water supply, Dr. Kampen stated that this was extremely important in terms of model development aimed at extrapolating results. Substantially improved water conservation and water use would go hand in hand with increased use of other inputs, including fertilizer. Dr. Cummings added that while this had been an important philosophic consideration in planning the research program, quantitative evaluation has not yet taken a prominent place in the program.

Dr. Blumenschein asked whether, in terms of technology transfer, ICRISAT built up a farming system from its components or attempted to transfer the entire system. Dr. Kampen stated that ICRISAT's objective was to identify viable systems and critical components in these systems, at different levels of sophistication. Dr. Ryan added that hardly any farmer would adopt the entire package at one time. Depending on managerial capabilities, he might adopt one component or another; however, he might take the package sequentially.

Session 3

Transfer of Agricultural Technology

Chairman: K. M. Badruddoza
Co-Chairman: A. R. Melville

Rapporteurs: R. J. Williams
R. P. Thakur
F. R. Bidinger
G. Alagarswamy

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Problems and Concepts of Agrotechnology Transfer Within the Tropics

L. D. Swindale*

Abstract

Agrotechnology transfer among countries or between regions within countries has constraints and problems additional to those associated with the diffusion of innovations. Site-factor constraints, the appropriateness of the transferred technology, social, economic, and institutional constraints must all be recognized and conceptualized.

Seed-centered technology has the fewest constraints and has been a major means for agrotechnology transfer. New soil management or cropping systems technology is more difficult to transfer. Stratification of the environment either through soil or climate classification is an essential element.

A national capacity for agricultural research is also essential. The international agricultural research centers assist in the research needed for transfer and in the creation of awareness of the existence of technology and its acceptance.

Over the last 7 years on the research farm at ICRISAT, Dr. Bert Krantz (now retired) and his colleagues in the ICRISAT Farming Systems Research Program developed a new technology that could enable rainy-season use of the deep black Vertisols of the semi-arid tropics. We estimate that 15 million hectares of these soils lie fallow at the time of the year when water is most available — in the rainy season — for want of a technology suited to the needs of the generally poorly endowed farmers who live in these areas. Dr. Krantz and his colleagues at ICRISAT chose a small number of alternative combinations incorporating all the many components required for testing in complete watersheds at a near-operational scale, on the research farm of ICRISAT. Their choices proved to be wise and effective, and over the last 7 years, making minor modifications as they went along, they have developed a technology that we believe is scientifically sound and operationally feasible. It offers a hope for substantially increased food production from these soils and substantially improved incomes and standards of living for the small farmers and their families.

The technology is complex and complete, involving many factors and many new practices; however, as scientists have shown, it can be adopted piecemeal, although none of the pieces bring the advantages that the entire technology does. How, now, do we transfer this agricultural technology?

There are many examples that can be given, such as the one cited, of biological and physical research in agriculture that is specific to the location in which it was conducted. Its value in other areas can only be proven by adaptive research that may take as long to complete as the initial research did. Many people concerned to help the farmer or busy with development projects decry this fact. But little effort has been made in the past to overcome it. The action people are eager to proceed and the researchers cautious to recommend.

Let me give you another example in farming systems technology. The soils on the central plateaus of West Africa are typically of low fertility, highly erodible, and shallow. Vertisols, inherently more fertile and deeper, occur in the river valleys. Because of the danger of river blindness, there are few people in the valleys and many people on the poorer soils of the plateaus. Money is being spent to bring river blindness under control and resettle the people from the plateaus, and the action agencies involved have recommended that ICRISAT test its new technology in pilot projects on the Vertisols in the valleys. Recently a panel of

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scientists with considerable knowledge of conditions in Africa came to ICRISAT to review our programs. They looked at our farming systems research and, after careful consideration, recommended that ICRISAT should conduct more research in African conditions before making recommendations there for development projects. This is the quandary. The panel is undoubtedly correct in saying that ICRISAT must help with farming systems research in Africa, and the development agencies are undoubtedly correct in pointing out that people need help.

I believe that the solution to this problem lies in the development of concepts and methods of agrotechnology transfer that will allow us to determine, with reasonable accuracy and for practical purposes, where new research findings can be implemented in pilot-scale demonstrations and where they cannot. In relation to the example I have given, I am sure that there are locations in Africa that could benefit from the immediate implementation of pilot projects utilizing the farming systems technology developed for the deep Vertisols at ICRISAT.

I must make it clear that the emphasis in this paper is on transfer of technology among countries or between regions within countries. I will make passing reference to the acceptance of new ideas and technologies by farmers, but this is essentially another subject, closely interrelated and certainly of great importance and interest, but outside my purpose.

A second point of clarification is to emphasize that this paper limits itself to considerations of tropical environments. Although concepts should apply generally, we know full well that there are serious limitations to the transfer of agricultural technology between temperate and tropical environments, and I will not address them. There are enough problems and constraints within the tropics.

Technology with Low Site-Factor Constraints

The problems involved in transferring technology are different for technologies that are highly site-specific and those that are not. Seed is an example of technology with low site-factor constraints. The value of the international agricultural research centers so far has been mainly in the transfer of technology through seed.

Seed is easily transported — with due allowance for quarantine — and purchase prices are comparatively low. The widespread adoption of improved varieties and hybrids throughout the world is clear evidence that seed is an effective vehicle for agrotechnology transfer. But there are difficulties that cannot be overlooked.

Environmental Differences

Within the tropics, there are differences in soils and climates. The more similar the environments, including the spectrum of diseases and pests, the more likely that successful cultivars can be selected for local use from introductions. In other localities, introductions may contribute nothing of immediate value.

In areas where local farmers' varieties are widely grown, usually with minimum inputs, there is often a balance between the crop and its diseases and pests. The balance is precarious. The introduction of new varieties or hybrids may disturb the balance, with disastrous effects upon production. Cultivars with single-gene resistance to disease are examples.

In response to these problems, the international agricultural research centers have avoided narrowly adapted hybrids; they seek out cultivars with wide adaptability, and stability, insensitive to photoperiod and with polygenetic resistance to diseases and pests.

Limitations of Plant Breeding

The number of characteristics considered desirable in a plant and its seed exceeds the number of criteria a plant breeder can handle in his research And different crops have different linkages between characteristics and different degrees of difficulty in breeding. For many tree crops, for example, local selection for a few major criteria and asexual propagation of selected cultivars are the only techniques possible, and transferability is very limited. Even where large population breeding programs with cross-pollinated crops are possible, the number of criteria incorporable are limited, and compromises must be made by the breeder. Every compromise limits the transferability of the resulting seed.

Particularly difficult to match are the criteria for consumer preference, especially for staple

cereals and particularly where improved cultivars are required to replace traditional varieties. Not only are these criteria difficult to measure, they are also variable over short distances. Much seed is needed in tests for acceptability, and the tests can be carried out only after harvest. While these problems limit the ability to breed for quality, they do not reduce the necessity of doing so.

Surprising as it may seem, there are still examples of substantial resources being spent on breeding for the wrong criteria. International cooperative networks may be particularly susceptible to this problem. Breeders' or planning agencies' preferences are substituted for farmers' needs or consumers' preferences. Breeding for the wrong maturity or for nutritional criteria or for high levels of management are examples. In each case the value of the seed is lowered to the extent that it attempts to transfer inappropriate technology.

Transfer of Unfinished Technology

The clients of the international agricultural research centers are the scientists of the nations of the developing world. It is their responsibility to produce the agricultural technologies and new cultivars for their nations. The centers' roles are to undertake research that contributes to that goal. The stronger the national research programs, the less need there is for direct transfer of technology. Such national programs can best use unfinished technology and scientific knowledge.

For seed-centered technology, the centers must aim at increasing the genetic diversity available to national scientists, provide early-generation breeding material, and develop information about the most efficient breeding methodologies for different purposes in the various commodities. They must emphasize breeding for broad adaptability to ensure that site-factor constraints remain low.

The International Federation for Agricultural Research and Development (IFARD), an organization of national administrators of agricultural research programs in developing countries, has recommended that in the long run the international agricultural research centers should concentrate in their crop improvement work upon the transfer of unfinished technology and scientific principles, that is:

- the collection and maintenance of genetic resources
- the production of advanced breeding material
- basic research on the mandate crops
- the organization of symposia
- the dissemination of information

Technologies with High Site-Factor Constraints

Farming systems involving new soil-management practices are examples of technologies with high site-factor constraints. A soil is part of the landscape. Unlike a seed, it cannot be moved physically from place to place. Soils are variable and tropical soils are more variable than temperate soils (Moorman 1972). Transference of such technology must take into account the differences in environmental and socioeconomic conditions. Local efforts in adaptive research will always be needed, but these can be significantly reduced if the environmental differences between the experimental location and the transfer location are not too marked.

Concepts of Transfer

Nix (1968) has suggested that there are three different, but not mutually exclusive, approaches to predicting the success of the transfer of site-specific agricultural technology.

Analogue Transfer

Areas analogous to the experimental site are identified by soil and/or climatic classification. The attempt is to stratify the environment sufficiently precisely to ensure successful transfer. Three papers in this symposium, by Nix, Virmani, and Gill, will deal in detail with this approach. To my knowledge, however, only analogue methods using soil classification have been experimentally tested.

The Benchmark Soils Project of the Universities of Hawaii and Puerto Rico in cooperation with USAID (Swindale 1978, Gill, this symposium) provides a successful approach to the transfer of agricultural technology with high site-factor constraints. It combines use of the new Soil Taxonomy with the methods of soil

survey interpretations, the benchmark soils concept, and a systematic, sequential approach to agronomic research.

Site-factor Methods

Site-factor methods seek to relate key parameters to biological productivity within a given environment (Nix 1968). The most widely used method for this purpose is multiple linear regression. An example of such methods is the work of Voss et al. (1970), who used a regression equation involving variables of N, P, and K levels applied and occurring naturally in the soils; soil pH; previous soil use; and an index of soil type and erodibility to explain and predict maize yields in a large area of western Iowa. Earlier, Laird and Cady (1969) had produced regression equations relating soils, soil management, and fertilizer applications to maize yields in Mexico. More recently, Heady (1974) has produced equations for cotton and corn production under irrigation in the western United States and Culot (1974) for wheat production in Chile. In these examples and others in the literature, site-factor variables are included in the regression equations, thereby allowing them to be applied over a wide area. To use these methods, experiments are necessary in a range of site and environmental conditions to ensure that the final equations have validity over the full range of sites.

Simulation

Simulation models attempt to develop, combine, and utilize the physical laws that govern biological processes, and inherently they should be the most efficient methods for overcoming high site-factor constraints. However, the incompleteness of scientific knowledge and the complexity of the models are barriers to their use, and there are few examples of their successful application outside the immediate environments in which they were developed.

The dynamic grain sorghum growth model developed by Arkin et al. (1976) has been used successfully at Manhattan, Kansas, USA, in a temperate semi-arid climate and is now being tested in the semi-arid tropics at ICRISAT by the agroclimatology research group. Some interesting early results suggest that optimum yields of short-duration sorghum may be obtained in soils with 150-mm water-holding capacity, and optimum yields of long-duration sorghum may be obtained in soils with 200-mm water-holding capacity. The tests indicate that adaptive research on the model is necessary.

Transfer of Concepts and Methods

The work of any research center is necessarily confined to a small number of specific locations. The highly site-specific technology it develops is not transferable to any significant extent. The center must concentrate instead on extracting concepts or principles from this type of technology, and explaining and refining the methods used to develop and monitor the effects. This is more easily said than done. Research to elucidate principles and cause-and-effect relationships requires good understanding of theory, careful design of experiments, and the use of the scientific method. Furthermore, where indigenous research institutions are not strong, the principles and methods may need to be applied by the center to one or two locations in cooperation with national scientists to overcome the complexity barriers between scientific knowledge and the technologies that can be developed from it.

Intercropping research has high site-factor constraints. ICRISAT's intercropping program has concentrated on concept and method development while at the same time it is succeeding in developing new information usable in adjacent farming systems (Willey 1979, Natarajan and Willey 1979). The crop combinations possible in intercropping are numerous, and the number of experiments that can be devised are more numerous still. Careful consideration of the objectives of intercropping, the minimum number of crop combinations necessary to investigate, the measurements to be used to determine advance, and the measurements and experiments needed to understand what physical, chemical, and biological phenomena are involved, provide a conceptual and methodological framework that is transferable.

The Need for On-site Testing

At present, the transfer of technology with high site-factor constraints can best be made by analogue methods using soil and climatic-

criteria, both from the point of view of precision and of distance.

Regardless of the methods used for transferring technology, and regardless of the magnitude of site-factor constraints, new agricultural technology must be subjected to on-site testing. Differences in relative endowments, environments, cultures, and institutions ensure that no two regions, indeed no two farms, are alike.

Testing technology with few components is not difficult using conventional field plot techniques, but several years of testing are necessary. More complex technology will take longer to test and will require operational-scale research and even pilot-scale testing before successful adoption.

Appropriate Technology

The need to develop technologies appropriate to conditions in developing countries is the subject of much controversy. Inappropriate technologies, it is said, lead to unemployment, the waste of scarce resources, destruction of the environment and the disturbance of socio-cultural equilibria. The other side of the debate claims that emphasis on appropriate technologies will retard development, perpetuate poverty, and shore up degenerate cultures. For the international agricultural research centers, there is the additional problem of determining whether the technology must be appropriate to client groups of scientists or target groups of farmers and consumers.

Induced Innovations

The theory that technical innovations are partly or largely induced by prevailing economic conditions was first explored in agriculture by Hayami and Ruttan (1971). According to this theory, the needs of farmers stimulate lagging technical changes, including those produced by research in public-sponsored institutions. Researchers respond to information on farm profitability, pressure from farmer organizations and agricultural supply firms, and the incentives for professional recognition to develop technologies appropriate to needs.

In developing countries, research may be necessary to collect this type of information. For the last 4 years, ICRISAT has been carrying out a series of studies in villages at six locations in semi-arid India for such a purpose (Binswanger and Ryan, this symposium). The results have had profound influences on the direction of ICRISAT's research and the nature of technology that has been devised. The ecological/environmental area defined by these villages will determine the boundaries within which the biological and physical technologies developed are appropriate. Similar information must be collected elsewhere in India, from Africa, and Latin America, or research must be done to obtain it if it is not yet available.

Perceived Risk

Agriculture is a risky business. Farmers underinvest if the risks of crop loss or catastrophe are, or seem, too high (Binswanger et al. 1979). We need, therefore, an accurate idea of farmers' attitudes to risk in different areas, and the riskiness of different technologies. Risk aversion is associated with climatic variation, prices and factor costs, sociocultural conditions, and government famine-prevention policies. The results achieved so far in the study mentioned above are that (a) levels of income risk in the Indian SAT are high and are related more to loss of yield than to loss of price, (b) virtually all farmers are moderately or slightly risk averse, and (c) they do not have access to cheap self-insurance or effective risk diffusion techniques.

In view of these results, it is appropriate in seed-centered research to emphasize yields as high as are consistent with yield stability. In resource-centered research, it is appropriate to discount adverse biological events with relatively low probabilities of occurrence — say 1 year in 10 or less — and to give research priorities to farming systems that farmers use naturally to diffuse risk, such as intercropping, postrainy-season production, and the provision of life-saving water where necessary.

Inapplicable or Inappropriate Technology

Appropriate technology may prove inappropriate if the information gathered about farmers' needs and resource endowments is inapplicable or inaccurate. A case in point is the

use of bullocks versus tractors in farming systems technology. We are proud of our bullock-powered technology at ICRISAT. To many visitors, it is proof of the relevance and applied nature of ICRISAT research. But to some, it is inapplicable to the socioeconomic conditions in which they are working; tractor power may be for them the appropriate answer, and the important question becomes what size of tractor to use. It is necessary for our researchers to concentrate not on the bullocks themselves, but on the power requirements and efficiencies of various cultural operations. The choice of power source is thus released from the technology to be transferred.

Even in semi-arid India, the information on bullocks versus tractors may be inaccurate. Our research gives us many of the reasons why farmers decide the way they do, but not all the reasons and perhaps not the significant reasons. If that is so, our technology based on bullocks may yet prove to be inappropriate.

What is essential and possible in agriculture to partly offset the problems of appropriate or inappropriate technology is to provide a range of technological options, for example, a number of alternative cropping patterns for use within a single overall farming system. There is some evidence to suggest that in developing-country agriculture, there is a range of potentially economic input choices for important types of output (Hayami and Ruttan 1971). Furthermore, the process of decision-making on small family farms is not well understood, and it is surely wrong to assume that maximization of profits in the customary sense is the main objective on subsistence farms in which most of the labor is supplied from within the family.

Socioeconomic and Institutional Issues

There are institutional and social issues and costs involved in the transfer of technology, as there are in the diffusion of innovations. The issues are often the same and many are covered in the copious literature on innovation diffusion (see, for example, Beal and Bohlen 1957, Rogers 1962). There are, however, some unique issues involved. The largest of these is national planning for development. Centralized planning and the issuance of regular multi-year plans are normal procedures in most developing countries. Much of the planning deals with agriculture, because in these countries about 65% of the people are directly involved with agricultural production. National planning objectives include (Eckhaus 1977):

1. Maximizing of net national output and income
2. Maximizing of availability of consumer goods
3. Maximizing of the rate of economic growth
4. Reduction of unemployment
5. Redistribution of income and wealth
6. Regional development
7. Balance of payments relief
8. Promotion of political development and national political goals
9. Improvement in the quality of life
10. Self-reliance

The mix of these objectives will influence the transfer of agricultural technology, particularly from other lands, and transferred technology will induce changes in the mix of objectives.

Socioeconomic Constraints

Ryan and Binswanger at this symposium have discussed the socioeconomic constraints to the transfer of technology. Population increase and its attendant effects on the allocation of resources, factor endowments and use, and differences in market parameters are described as major issues. Information about these constraints is used at ICRISAT in the design of technology appropriate for transfer.

Transfer of technology is not without its costs. There are the costs of adaptive research and the costs of inadequate understanding or appreciation of the limitations of conditions. New technology may cause equipment to become obsolete before the end of its useful life.

The input requirements of one technology are usually different from those of another. This can be a major constraint in the adoption of technology. Much of the recent literature on the economics of technology transfer (for example, Hayami and Ruttan 1971; Evenson and Binswanger 1978) has dealt with this subject and its relevance to the ex ante analysis of agrotechnology transfer.

National Agricultural Research

A technological society must be dynamic. To use an agricultural illustration, the successful introduction of the first hybrid seed for any crop requires automatically that further hybrids be developed. No amount of successful transfer of agricultural technology from outside can replace the need for an adequate national research program.

Hayami and Ruttan (1971) theorize that the most serious constraint to agrotechnology transfer is the lack of national research capacity. Evenson and Binswanger (1978) have shown by empirical analysis of the transfer of wheat and rice varieties around the world that no transfer of improved technology occurs in the absence of indigenous agricultural research. Some adaptive research is always necessary. A small national research effort on a particular commodity will screen and transfer only relatively simple technology with low site-factor constraints. A large, mature national research effort will have many more options. It will be more capable of transferring technology with high site-factor constraints but will tend to be most interested in transferring principles and methods and advanced scientific knowledge.

The International Agricultural Research Centers

The international agricultural research centers (IARCs) were created specifically to assist in the transfer of agricultural technology. Long before any of the centers were established, the colonial powers were conducting agricultural research in the developing world. The research concentrated on cash crops of export value. The centers were established for a different purpose: to increase production of major food crops.

The earliest centers, CIMMYT and IRRI, were given the objectives of improving production of the major commercial food crops. ICRISAT, on the other hand — the first center actually created by the CGIAR after its formation in 1971 — was given the objectives of improving production of major subsistence food crops and the way of life in the tropics.

The work of the centers is well enough understood to need no further explanation at this symposium. Several activities of the centers have been described in this paper, particularly those designed to assist easier transfer of technology through the development of appropriate technology, conducting multilocational trials, and training. Conferences such as this are another important aspect of the work of the centers. They help create awareness of new technology and provide information to the centers for planning future activities.

Training in the International Centers

Training contributes directly to technology transfer. It helps create awareness of the existence of the technology. Training is necessary for transfer of complex technology and technology with high site-factor constraints, to provide insight into the underlying principles and inherent limitations. The international agricultural research centers conduct regular training programs.

Probably the training program with which the IARCs are best identified is the short-term (one cropping season) in-service development of practical research skills. Although the program includes other aspects of research and some exposure to issues of research management, it is strongly oriented to improving technical skills for production technology and particularly plant-breeding technology. Implicit in the program, according to Swanson (1977), is the judgment that the institutions from which the trainees come have not themselves developed these skills well enough, and are therefore not fully effective in producing the new biological technologies needed for their countries.

Of equal importance in terms of numbers and emphasis in some centers are the programs involving research scholars and young scientists. The programs also involve the development of technical skills, but give larger emphasis to the development of professional skills in research design and analysis. These programs make no judgment on the abilities of national programs to organize effective agricultural research.

Trainees, after they return to their countries, often participate directly in the international multilocational trials conducted by centers. They contribute to making the trials more uniform and more meaningful. For both of these reasons, training reduces some of the costs of technology transfer.

Creating Awareness and Acceptance of Technology

As mentioned above, training serves the purpose of creating awareness of the existence of technology. So too do scientific visits and conferences and communications and information services. Surveying the opportunities to gain knowledge about new technologies gives one the impression that there should be no difficulty in creating awareness. In fact there is, because these services are not always effective. The reasons lie in certain complexity barriers to the acceptance of new knowledge.

Technology that is both transferable and appropriate may not be acceptable because it is not understood. This will be particularly true for complex technology evolved from multidisciplinary efforts and technology sublimed into principles and methods. Scientists generally are better at analysis than synthesis, and the job of recapturing technology from its principles is beyond many of them.

A valuable approach to overcoming barriers to acceptance is the creation of networks for multilocational testing and research. Most of the international agricultural research centers have developed such networks with cooperating national institutions.

There is always the possibility of discordant goal systems between institutions. Where the mix of governmental policies requires national scientists to work on different priorities towards different goals than those of the centers, there will be barriers to the acceptance of IARC-generated technology. This is a particular possibility for ICRISAT, with its goals towards the poorest farmers and agricultural workers. The technology developed by ICRISAT would not fit perfectly, for example, into a national program oriented towards maximizing food production or reducing balance-of-payment problems.

Is New Technology Needed?

Development aid programs in the 1950s and 1960s worked on the theory that sufficient agricultural technology existed for development purposes. Efficient diffusion of extant innovations was all that was required. The theory proved incorrect. Transfer of technology was needed and indigenous agricultural research capacity had to be created for the adaptive research that was required (Moseman 1970).

The transfer of technology through adaptive research is also not sufficient. Social science research repeatedly confirms the need for new technologies. In the West African semi-arid tropics, for example (Newman et al. 1979), there is need for improved varieties of sorghum and millet, new technologies for soil and water management, and whole new farming systems. Many of the principles of these technologies may exist, but the technologies do not. Much research must be done, mostly by the national agricultural research institutions. ICRISAT and other external research institutions can only help.

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Agroclimatic Analogues in Transfer of Technology

Henry Nix*

Abstract

Basic concepts and methods of agroclimatic classification and homoclime analysis are reviewed and discussed. Reasons for the tardy progress in development, testing, and application of methods of agroclimatic analysis are explored and possible alternative approaches examined. These include concepts of minimum data sets, definition of optimum experimental networks, and development of dynamic interactive systems of crop-climate and crop-weather analysis and synthesis.

This symposium focuses on the *general* problem of development and transfer of technology but in *specific* relation to the farmer of the semi-arid tropics. What are the goals of the SAT farmer? For many, it may be simply survival and the emphasis will be on minimizing year-to-year variation in food production. For some, more fortunate, the emphasis will be on maximizing expectation of profit. For all, maintenance of longer-term stability of the system is vital, although population and/or economic pressures may subvert this requirement. Whatever the goals, they must be clearly identified if we are to develop and transfer technologies that are appropriate and relevant to the SAT farmer.

Since each farmer and his farm is unique, and since there are some hundreds of millions of SAT farmers, how do we prescribe a technology that is relevant to the land, labor, capital, and management resources of each individual? If it were possible to predict the performance of any crop-production system at any location given a specified minimum set of soil, crop, weather, and management data, then it would be possible to prescribe an appropriate technology. I have argued elsewhere (Nix 1968, 1976) that this is an attainable objective, but it does require some major shifts in the prevailing logic and method of agricultural research, of which agroclimatic analysis is but a part.

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Methods of Agroclimatic Analysis

Climate and weather condition physical and biological processes and determine much of the strategy and tactics of crop production. It is difficult to conceive of any component of a farming system that is not influenced by climate and weather. Yet, the development, testing, and practical application of methods of agroclimatic analysis do not receive a very high priority in most agricultural research programs. The reasons for this situation are many, but some of the more important are:

- basic climatic data are inadequate or unavailable
- understanding of crop-climate and crop-weather interactions is limited
- available methods lack generality and tend to be descriptive rather than prescriptive, static rather than dynamic
- truly interdisciplinary research programs are the exception rather than the rule.

These limitations tend to compound, i.e., they have a synergistic effect. Thus, data limitations may restrict the choice and scope of method and hence the relevance and utility of the resulting analysis. Because adequate methods are not available or not accessible to research and extension workers at the district level, climatic data collected at great cost remain unused. Understandably, it then becomes difficult to justify arguments for upgrading networks. Only by a convincing demonstration of the utility of climatic data in general and of agroclimatic analysis in particular and at scales ranging from the continental to the local will

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this particular nexus be broken.

Hopefully, methods and techniques now available and under active development will aid in eliminating these limitations. Computer technology has provided a basis for efficient storage and retrieval of climatic data. Satellite technology holds promise of much finer spatial resolution of key components in the energy and water balances. Systems analysis and simulation techniques permit a much closer coupling of climatic data and the agricultural or biological system being studied and offer prospects of quantitative prediction. Adoption of a systems approach reinforces the need for interdisciplinary research.

Progress towards an ultimate goal of prediction of probable outcomes (ecological and economic) of any crop-production system at any location has followed an evolutionary path from simple trial and error, transfer by analogy, correlation and regression, and multivariate analysis to systems analysis and simulation techniques (Nix 1968). These methods are not mutually exclusive, and various combinations are normally in use in any given situation.

Trial and Error

Attempts to relate climatic and weather phenomena to observed biological and physical phenomena have roots in antiquity. Given time, stable and successful farming systems have evolved through keen observation coupled with generations of trial-and-error experiment. Farmer innovation has been, and still is, a major source of new technology, and as scientists and technicians we should not underestimate it. However, the social cost of the farmer's experimentation can be considerable, since for every success there are many thousands of failures. It can be and has been argued that a major task of agricultural research is to reduce the social cost of such experiments.

In long-established farming systems, the complex timing required to fit farm operations into the climatic cycle has been codified by ritual and custom. Climatic information thus becomes an integral part of the total system. Careful analysis of such traditional systems can yield much valuable information about climatic hazards and constraints. Before confronting the problem of transferring a "new" or "improved" technology, we need a thorough understanding of the existing crop-production systems.

Farmer trial-and-error experiments could provide a valuable additional source of information if a basic minimum set of soil-crop-weather data could be obtained. Regular monitoring of selected farm areas on such a basis can provide the necessary data base for yield predictions at the regional and national level. However, usual "ground-truth" procedures concentrate solely on final yield, and this does not permit anything but a superficial analysis of crop-climate and crop-weather interactions.

Transfer by Analogy

Most agricultural research is firmly based on the concept of information by analogy. Since it is impossible to replicate every experiment on every farm, a "representative" site is chosen, and results are extrapolated to other sites that share similar properties. The central hypothesis is that all occurrences of a defined class should respond in a similar way to management. Soil, vegetation, and climatic classifications exemplify this approach. Although the analogue approach does not require any detailed understanding of functional relationships between selected site attributes and crop response, the better such understanding and the more relevant the attributes, the better will be the classification.

The more rational and systematic of the general climatic classifications, such as Köppen (1931) and Thornthwaite (1931, 1948), have played an important role in codifying and communicating climatic information at global and continental scales. Thus, for example, Köppen's *Aw* class and Thornthwaite's *CA'w* class broadly define ICRISAT's sphere of responsibility. This is greatly expanded in area if a probabilistic approach is used and year climate is based on a series of years rather than on long-term means. Using an extensive network of stations, Mizukoshi (1971) calculated relative frequencies of Köppen climatic classes for South and Southeast Asia. The resultant pattern of dominant year climates places a much higher proportion of Thailand, Indochina, and Indonesia in the *Aw* class.

In an extensive review of methods of agroclimatic classification, Burgos (1968) concluded that general, multi-attribute schemes of classification were of limited value in the transfer of

technology. The most useful agroclimatic classifications are those developed for a specific purpose but, until recently, the sheer volume of data processing required in each case made such an approach impractical. Now, with computer-based storage and retrieval of climatic data and ready availability of numerical taxonomic programs, it is easy to generate any number of classifications. However, problems remain in the choice of attributes, weighting of attributes, choice of classificatory strategy, and, most importantly, interpretation of results. It is not intended here to review these aspects of numerical taxonomy since they are adequately detailed in basic texts (Sneath and Sokal 1974, Williams 1976).

The techniques of numerical taxonomy or pattern analysis are objective and repeatable and have been used successfully in a number of examples of agroclimatic classification and homoclime analysis. Plant introduction has played a very prominent role in the development of agriculture on all continents, but particularly in Australia, where no cultivated plants existed before European settlement in 1788. In recent years, active plant exploration has been reinitiated, and identification of homoclimes on other continents has received attention. Thus, Russell and Moore (1970) used selected climatic parameters and numerical taxonomic techniques in detecting homoclimes of a developing region in Queensland and, more recently (Russell and Moore 1976), in a comparative study of the climates of Australia and southern Africa.

In any agroclimatic classification, the choice of attributes is critical. In the simplest case, it is a matter of selection from available raw climatic data. Usually there will be a conflict between the density of geographic network and the range of climatic data available. Commonly, only monthly or, at best, weekly mean data for precipitation and temperature are readily available for an extensive network of stations. Wherever possible, probability values are to be preferred over mean values. Thus, Nix (1978) in an agroclimatic classification of east-central Queensland used median, upper, and lower quartile values for summer (November – April) and winter (May – October) seasonal rainfall derived from a standard 50-year period (1915–1965). The resultant regions were used as a basis for selection of representative locations that had more extensive climatic data for more detailed crop simulation studies.

Because each crop — indeed each cultivar — has a specific genotype-environment response, it is logical to consider crop-specific and even cultivar-specific classifications as an ultimate objective. Advances in our understanding of ecophysiological response, coupled with advances in computer technology, now make such an approach entirely feasible. The beginnings of such a crop-specific approach are evident in the works of Papadakis (1938, 1965, 1970), who recognized broad climatic constraints for a comprehensive array of cultivated crop species and developed climatic indices that reflect important processes in the crop environment.

Following from this approach, a more direct coupling of climate and ecophysiological response offers even better prospects of more relevant bioclimatic analysis and classification. Thus, for example, Fitzpatrick and Nix (1970) developed a simple growth-estimation model, using separate functions for light, temperature, and moisture response for each of three major plant groups (temperate C^3, tropical C^3, tropical C^4). The model was coupled to a data base of weekly mean climatic data for some 300 locations and was used to analyze the climatic factor in the grassland ecology of Australia. Subsequently, the model has been developed and used to derive selected attributes in a numerical taxonomic classification of arid-zone mulga (*Acacia aneura*) environments (Nix and Austin 1973). In a further study (Austin and Nix 1978), the objective was to define bioclimatic zones for rangelands research. Edwards and Johnston (1978) used a similar approach in a study of the agricultural climatology of the Upper Murrumbidgee River Valley, N.S.W.

Given that present agricultural research strategy is based on the analogue approach, a network of research and experimental sites is a necessity. But can we define an optimum network? Field-based research is expensive but essential. Any rationalization and streamlining of research, extension, and development strategies could have tremendous benefits both in terms of reduction in expenditure and cost effectiveness. Thus, for instance, we might wish to define the most efficient network of experimental sites for the semi-arid tropics in general, or for a selected target crop or crops within that

zone. (Separate analyses for individual crops might indicate sites of general acceptability.) Such an analysis is being undertaken by the author, but the results are not yet fully analyzed.

An example of this approach is provided in an analysis of dryland wheat environments in Australia (Nix 1975). A simulation model of wheat was used to derive measures of the light, thermal, and moisture regimes during the vegetative, reproductive, and grain-filling phases of a standard cultivar. Numerical taxonomic techniques were used and the resultant classification suggested that existing research centers were by no means equitably distributed. In contrast, the study of rangeland environments reported earlier (Austin and Nix 1978) found that existing research centers were most economically distributed.

Correlation and Regression

Simple and more complex correlations have been sought between practically every primary and derived climatic parameter and every aspect of crop growth, development, and yield. The classical example is provided by Fisher (1924) who analyzed wheat yields at Rothamsted in relation to 6-day rainfall periods. In environments where a single factor, such as the water regime, dominates crop performance, such correlations may have useful predictive value. The use of more refined indices of the crop's climatic environment, coupled with a phenological rather than a calendar time-scale, usually in more general and more robust predictive equations (Stanhill 1970).

The deficiencies in this approach are due primarily to explicit assumptions of linearity of response, implicit assumptions that correlation implies causation, and the normally location-specific and season-specific nature of the relationship. Despite these criticisms, correlation and regression methods remain a valuable tool in fitting functions used in more complex modes of analysis.

Systoms Analysis and Simulation

Very simply, systems analysis is concerned with the resolution of any complex system into a number of simpler components and identification of the important linkages between them. A graphical presentation (flowchart) may precede a formalized set of logical statements and mathematical formulae (program). This, then, is a model of the real system, and when it is developed to the stage when it can mimic the behavior of the complex system, then experiments can be performed using the model. This is simulation.

Adoption of a systems approach immediately emphasizes the need for interdisciplinary teamwork, since knowledge and insight gained from biological, physical, social, and economic disciplines are required. It formalizes what is already known about the crop-production system, identifies the more important components and processes, and helps to identify significant constraints to performance. It is only at this level that the real significance of climate and weather becomes apparent. These are primary inputs that drive the biophysical processes of the crop system and as such are an integral part of the whole.

A research strategy based on the systems approach would center around development of working models of crop-production systems. These models would need to be structured so that they are capable of continuous improvement in logical structure and function. It would be advantageous to have a range of models capable of application at a range of levels of scales and a range of levels of precision and accuracy.

Only by development of such crop models is it possible to begin identification of *minimum data sets* that are needed for adequate interpretation and extrapolation of experimental results. It is essential that *balanced* sets of soil-crop-weather-management data be collected. Very few agronomic experiments meet this criterion. Often, very detailed measurements and observations are made on one component or process in the system, while others are ignored.

Recognizing the different objectives of field experiments and the different scale of facilities available, one can conceive of a series or hierarchy of minimum data sets with increasing range, precision, accuracy, and frequency of measurement and observation. However, at all levels the emphasis remains on maintaining a balanced monitoring of the whole crop system. Thus, for example, consider a three-level system:

1. Level generally applicable to field trials

remote from laboratory facilities. Data collected are the absolute minimum required for relating crop performance to the environment and for comparative analysis of crop performance at widely spaced sites and/or seasons. Precipitation must be measured at the site, but temperature, evaporation, and solar radiation data can be obtained from a meteorological station within the general region. Soil data may be restricted to gravimetric soil water content at or near sowing and at harvest. Crop data are limited to phenological observations (dates of emergence, floral initiation, flowering, physiological maturity, harvest) and components of final yield. These data are just sufficient for calculation of empirical biophysical indices and for verification of the simpler predictive models.

2. Level generally applicable to field experiments conducted at or near regional research station. A combination of more frequent and more comprehensive soil, crop, weather measurements and observations permits analysis of crop performance on a physiological or process basis. This provides a much sounder basis for analysis of major environmental constraints and permits the development and testing of process-based models of growth, development, and yield.
3. Level applicable only where major data-logging and data-processing facilities are available. Greatly increased frequency of sampling permits a detailed analysis of component subsystems and component processes. This provides the necessary data for development and testing of general crop models that incorporate explicit representation of major processes in the whole crop system.

The emphasis throughout must be on identifying the absolute minimum data set at each level of complexity. Standardized data collection sheets and crop phenological charts would ensure comparability of data and permit much more comprehensive analyses of crop experiments at widely spaced locations. Such developments would benefit agricultural research and aid in transfer of technology, whatever the research methodology adopted, but they are an essential prerequisite for the systems approach.

Conclusions

The systems approach has much to offer in devising new technologies. It formalizes what is known about existing crop systems, their more important components, processes, and feedback mechanisms, and helps identify significant constraints that are often subtle and not immediately obvious. The possible consequences (ecological, agronomic, economic) of introducing a new technology can be examined using simulation techniques and appropriate field experiments designed to test the model predictions.

In the systems approach, climate and weather occupy a primary position in the whole hierarchy of data acquisition, processing, and analysis and become an integral part of the whole system. The full flowering of the techniques of systems analysis and simulation will not occur until they can be placed in the hands of the agronomist, soil scientist, plant physiologist, plant breeder, and other subject specialists. The development of microprocessors and small, relatively inexpensive, programmable hand calculators should soon make this a reality.

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Organizations in Technology Transfer and Research

Frederick E. Hutchinson*

Abstract

Research designed to develop technology that can be appropriately transferred to small landholders in the developing world is essential for successful agricultural development. The United States Congress has mandated that future agricultural development programs financed through U.S. foreign assistance emphasize transfer of technology appropriate to small landowners. In the past, U.S. organizations working in development found it difficult to coordinate their efforts to maximize their effectiveness; but now must do so under Title XII of the Foreign Assistance Act of 1975. This act links agricultural universities, federal agencies, and private organizations in research programs tied to agricultural development strategies. Key elements in forming and maintaining this cooperative effort are discussed.

There are several organizations in the world that are presently involved in facilitating or conducting research for appropriate technology transfer in agricultural development.[1] I will not attempt to name them all because that is not the theme of my presentation. Instead, I would like to focus on the issues involved in maximizing the opportunities presented by these organizations to improve the production and utilization of major food materials. Opportunities to improve upon the present situation will be the primary thrust of my remarks, and I shall use an example from the U.S — Title XII of the Foreign Assistance Act of 1975, since that is a recent experiment with which I am very familiar. However, I feel the principal issues identified in that example are reasonably appropriate to other organizations working in the same field of agricultural development worldwide.

It is important to begin such a discussion with a clear understanding of the necessity of research as the undergirding for a successful agricultural development program. This means research designed to develop technology that can be appropriately transferred to small landholders in the developing world. If one begins with the premise that little research has been conducted that was designed for that specific purpose, the need for a new research program is evident. Although the U.S. agricultural research organizations cannot be expected to attack this problem single-handed, it is logical to expect the tremendous capability that has been built in that country over the past 100 years to make a strong commitment in this direction.

I also wish to acknowledge the fact that a large amount of agricultural technology transfer to LDCs from the U.S. has been attempted in the past 25 years by universities, federal agencies, and private corporations. The success record is spotty, mainly in relation to the degree the technology implanted was appropriate to the local conditions — in other words, the degree to which the research upon which the technology was based happened to coincide with conditions where it was transferred.

It is also clear from past experience that the "trickle down" theory — which holds that agricultural technology transferred to large land-

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1. The term Appropriate Technology is defined as "A technology which is most suitably adapted to the conditions of a given situation. It must be compatible with the human, financial, and material resources which surround its application." A. E. Perez, 1978. The Role of U.S. Universities in International Agricultural Development (Washington University), p. 9

holders will eventually be adopted by small landholders as well — has not worked in most LDCs. Thus, the U.S. Congress has mandated that future agricultural development programs financed through foreign assistance must emphasize transfer of technology specifically appropriate to small landholders.

In the past, U.S. organizations that were interested in development and transfer of technology appropriate to agricultural production in LDCs as well as in the U.S. have found it difficult to coordinate and/or combine their efforts in order to maximize their effectiveness. Experience with agricultural research in this country shows us the importance of coordinated programs on commodities such as corn or wheat, whereby the research conducted in each state also contributes to a major national effort. A recent opportunity for such a coordinated U.S. research effort directed toward worldwide agricultural development was the passage of Title XII of the Foreign Assistance Act of 1975.

Under the Title XII legislation, U.S. agricultural universities, federal agencies, and private organizations can become linked in large-scale agricultural research programs tied to agricultural development strategies in the developing world. The Board for International Food and Agricultural Development (BIFAD) sits with the Administrator of AID in setting priorities for the food and nutrition programs funded by the Agency, a funding that presently approximates $600 million per year. The Joint Research Committee (JRC) created by the BIFAD has worked hard for the past year to identify and prioritize the major opportunities for U.S. agricultural research organizations to intermesh their capabilities and interests with the needs in the developing world. (A prioritized list of 24 suggested programs is available from BIFAD.) In the process of establishing such a list and initiating the first four programs, the JRC has identified some of the key elements in forming and maintaining involvement of U.S. organizations, especially universities, in such programs. These key elements are as follows:

1. long-term commitment by all parties,
2. true joint interest in collaboration,
3. maximum possible program flexibility for all participants,
4. appropriate balance of the research program in U.S. to that in LDCs, and
5. an agreement that research is essential to agricultural development.

I will now discuss each of the above points in some detail, because the experience of the JRC indicates that each one is important enough in its own right to essentially defeat any attempt to mount a successful program if it is not properly dealt with in the planning phase.

First, long-term commitment by all parties: It is clear to me that many past attempts to develop and transfer technology appropriate to specific commodities in LDCs have failed because the program was restricted to an unreasonable time frame, such as 2 or 3 years. Research is by its very nature long-term, requiring methodology, design, implementation, and evaluation phases. Consider the time frame over which the agricultural technology in the U.S. has been developed. It is encouraging that Title XII legislation recognizes the need for long-term research and development programs.

Second, a true joint interest in collaboration: It is not easy to develop among 10 or 12 universities and/or other organizations a genuine desire to collaborate in a formally designed agricultural research program that also involves institutions in developing countries. Participants must be assured of their function in the total program and they must be convinced it will be structured in such a manner that the credibility of all participants will be maintained. In other words, who is prepared to deal with the possible situation where one participant is not getting the job done? The JRC has discussed several models for structuring these entities, and it appears the problem can be solved.

Third, maximum program flexibility: Many of the U.S. research organizations that have conducted international agricultural development projects in the past agree that funding agencies have been excessively restrictive in the manner in which they allowed them to administer the project. This type of restriction kills initiative and tends to limit the chance for maximum productivity by the scientists. Title XII offers an opportunity for much more flexibility in project administration once a well-designed project has been approved.

Fourth, a balance in research effort: It is obvious that effective research on agricultural technology appropriate to other parts of the world requires involvement in the entire process of planning and implementation by scien-

tists from the appropriate LDCs. Also, some of the research will need to be conducted on location in those countries, even though a significant part can be conducted in the U.S., where major research facilities and highly trained staff are available. These foreign linkages take time to develop, but they are absolutely essential to the process.

Fifth, the commitment to research: To those of you who are scientists, this seems so obvious that it does not require further elaboration. However, please realize there are many, both within the U.S. Congress and within the worldwide funding agencies, who do not believe further research is needed for agricultural development to occur. It is their assumption that the past agricultural research we so loudly proclaim has answered nearly all of the important questions or constraints to be encountered in food production. We must keep stressing the need for continuing research designed to develop technology appropriate to specific LDC commodities and conditions, social as well as agronomic.

In summary, I believe there are several substantial obstacles to effective research and technology transfer programs. These obstacles are common to most of the organizations that are active on the world scene today, and they should be carefully considered by all who attempt to plan, implement, and evaluate such programs. Much has been learned in recent years concerning the best means to surmount these obstacles; the experience from Title XII of the U.S. Foreign Assistance Program is one contribution.

Climatic Approach to Transfer of Farming Systems Technology in the Semi-Arid Tropics

S. M. Virmani*

Abstract

The crop yields in the dry semi-arid tropics are low due to the temporal and spatial variations in rainfall. These areas are characterized by high climatic water demand, and the rainfall exceeds evapotranspiration only from 2 to 4½ months in a year. Due to the wide spatial distribution of the natural endowments, there exists a strong element of location specificity in terms of moisture environment during the crop growing season. Some techniques employed for quantification of rainfall distribution and soil-moisture availability in relation to crop water needs have been described. Examples of the relevance of agroclimatological analysis for the translocation of farming systems technology are discussed.

The tropical semi-arid regions lie to each side of the tropical rain forest climates and at higher latitudes in both hemispheres. Rainfed agriculture, laden with uncertainty and instability in its precipitation patterns, has failed to provide even the minimum food requirements for the rapidly increasing populations of many developing countries in the semi-arid tropics (SAT). The mean annual temperature of the SAT exceeds 18°C. The rainfall exceeds potential evapotranspiration for 2 to 4½ months in the dry SAT and 4½ to 7 months in the wet-dry SAT (Troll 1965). These areas are characterized by a high climatic water demand and by variable and erratic rainfall. It is imperative that any technology for land and water management and crop production in the SAT areas must be aimed at improved resource management that conserves and utilizes rainfall and soil more efficiently and at new crop production systems that maintain productivity and assure dependable harvests (Kampen 1979).

The intimate relationship between the weather and agricultural production systems, especially the complexities associated with vagaries of weather in terms of yield fluctuations, has been a subject of wide concern in national and international crop production planning. In this context, the situation in the SAT areas is even more complex because of the large variations in the weather parameters that affect agricultural production. A proper description and analysis of these weather parameters is an essential element in the application of agrometeorological knowledge for the generation and transfer of farming systems technology in the SAT areas.

Climatic Approach in Farming Systems Technology

Over the past 6 years, a considerable amount of farming systems research at ICRISAT has concentrated on analysis of the agricultural process for identifying the constraints to agricultural production and for evolving suitable production practices in the removal of these constraints. As a useful corollary to this exercise, efforts in the agroclimatology subprogram are aimed at analyzing the meteorological conditions of a region in order to characterize its agricultural potential and identify suitable crops/cropping systems to reap the full benefit of this potential. A systematic climatological approach in this context comprises the following steps:

1. Description of the rainfall regime in a particular area, including studies on the total rainfall, rainfall intensities, and rainfall probabilities.
2. Calculations of potential evapotranspir-

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ation and its relationships with rainfall regimes to identify the water surplus and deficit periods.

3. Evaluation of the soil water-holding capacity and other soil physical characteristics such as texture, structure, infiltration rates.
4. Water-balance calculations using the rainfall and potential evaporation data in conjunction with soil water storage.

Description of Rainfall Regime

Rainfall in the SAT mostly occurs April to October in the Northern Hemisphere and October to April in the Southern Hemisphere; the percentage of seasonal rainfall to annual total often exceeds 90%. Data pertaining to the monthly rainfall, annual total, and seasonal rainfall percentage for six selected locations in the SAT are shown in Table 1. For all the locations the strong seasonality in the rainfall is evident.

Hyderabad, located somewhat in the center of the "heartland" of the SAT, has annual precipitation concentrated in 4 rainy months from mid-June to mid-October. The rainfall is highly erratic; data for the last 78 years show that it may vary from 320 mm (1972) to 1400 mm (1971) with a CV of 26%. Variability is by years as well as by seasons. Rainfall distribution during the last 6 years at ICRISAT Center and the normals (1940–70) for Hyderabad are shown in Table 2. During 1972–73, June was the wettest month, with 107 mm, whereas in 1974–75, October recorded the highest monthly total of 279 mm. In 1978, August received a record amount of rainfall (516 mm), while in 1975 August was the driest of the last 6 years. The reliability of the seasonal rainfall from April to October is indicated by the mean amounts as well as by the low CV.

The marked seasonality of the rainfall in the SAT exerts an overall control on the water availability and agricultural systems. The characteristics of individual rainstorms are also of importance, particularly their intensity and duration. In the SAT, a high proportion of rainfall occurs in large storms of high intensity. Hudson (1971) concluded that 40% of the rainfall in the tropics occurs at intensities of at least 25 mm/hr, a figure considered as a threshold value at which rainfall becomes erosive. The highest rainfall intensity observed at ICRISAT Center was 88 mm/hr recorded on 24 September 1975. On 18 August 1976, a rainfall intensity of 60 mm/hr was experienced. These characteristics are of great importance to both soil erosion and the effectiveness of rainfall to agriculture; large storms of high intensity result in considerable loss as surface runoff and as drainage beyond the root zone.

Despite the complexity of the moisture supply, certain generalizations can be made. Use of monthly average to describe seasonal rainfall

Table 1. Average monthly rainfall (mm) for selected SAT locations.

Location	Lat ° ′	Long ° ′	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual*
1. Hyderabad (India)	17 27N	78 28E	2	10	13	23	30	107	165	147	163	71	25	5	761 (93)
2. Dakar (Senegal)	14 44N	17 30W	0	2	0	0	1	15	88	243	163	49	5	6	578 (98)
3. Bamako (Mali)	12 38N	08 02W	1	0	3	15	60	145	251	334	220	58	12	0	1099 (99)
4. Maradi (Niger)	13 28N	07 05E	0	0	0	4	32	60	164	260	110	12	0	0	642 (100)
5. Sokoto (Nigeria)	13 01N	05 15E	0	0	0	13	53	89	165	252	147	15	0	0	734 (100)
6. Ouagadougou (Upper Volta)	12 21N	01 31W	0	3	8	19	84	118	193	265	153	37	2	0	882 (99)

* Percentage of seasonal rainfall (April to October) to annual total is shown in parentheses.

Table 2. Rainfall at ICRISAT Center during 1973–78 and normals (1940–70) for Hyderabad.

Month	Normal Mean (mm)	Normal CV (%)	1973	1974	1975	1976	1977	1978
Jan	5.5	319	0.0	0.0	35.0	0.0	0.0	17.2
Feb	11.0	204	0.0	0.0	0.0	0.0	0.0	20.5
Mar	12.5	199	0.0	0.0	23.9	0.5	0.0	3.8
Apr	24.0	122	0.0	14.8	0.0	91.0	7.5	56.4
May	26.5	95	3.0	15.0	1.7	22.4	26.0	15.0
June	115.5	57	59.8	119.8	98.4	86.0	66.5	181.4
July	171.5	45	161.0	89.3	195.2	219.3	183.5	228.2
Aug	156.0	52	230.8	160.2	139.4	298.7	196.4	515.8
Sept	181.0	57	68.9	185.5	422.3	74.0	40.0	81.5
Oct	67.0	94	216.4	278.6	173.5	0.6	48.9	70.5
Nov	23.5	167	10.6	4.5	15.0	29.7	27.8	10.4
Dec	6.0	254	1.3	0.0	0.0	0.0	2.0	0.9
Annual	800.0		751.8	867.7	1104.4	822.2	608.6	1201.6

regimes is often not sufficiently accurate; at certain times in the crop growing season, the presence or absence of water is not critical, and indications of variability over shorter time periods are of great importance. Many agricultural operations revolve around the probability of receiving given amounts of rainfall. Farm-scale operational planning often requires decision-making with respect to resources, manpower needs, available work days, cropping schemes, and several other factors. A comprehensive idea regarding the probability of rainfall is essential in view of the economic implications of certain weather-sensitive operations — dry seeding, harvesting, etc.

In agronomic terms, once a seed is planted, water is required on a continual basis until the crop matures. We therefore utilized the concept of the Markov Chain to define the probability of rainfall of a given amount during a given week: initial probabilities or P(W); the probability of rain next week if rain was received this week P(W/W); and the probability of next week being wet if the current week has been dry P(W/D). These are called conditional probabilities.

Potential Evapotranspiration or Evaporative Demand

Another significant feature of the tropical environment is the high climatic water demand. The meteorological factors affecting evaporation include solar radiation, temperature of the evaporating surface, vapor pressure gradient, and wind and air turbulence. Solar radiation is the dominant source of energy and sets the broad limits of evaporation. Values of solar radiation tend to be high in the tropics, modified by cloud cover, making the evaporative demand of the atmosphere considerable (Jackson 1977). The annual values of potential evapotranspiration (PE) often exceed 1750 mm. During the growing season these values are of the order of 8 to 10 mm/day on clear nonrainy days and usually are around 3 mm/day on cloudy or rainy days.

When rainfall exceeds PE, soil moisture reserves are recharged. When rainfall is less than PE, soil moisture reserves are utilized. Most of the time in the SAT areas, rainfall is less than PE and actual evapotranspiration (AE) may equal rainfall. As shown in Figure 1, all six selected locations show only 2 to 3 months when rainfall exceeds PE, allowing some soil moisture recharge followed by utilization in the succeeding months.

Denmead and Shaw (1962), working with corn in Iowa, reported that on a clear day, when the potential transpiration was as high as 6 to 7 mm/day, the decline in the transpiration rate occurred at a very low moisture tension, close to field capacity (Fig. 2). On a heavily overcast

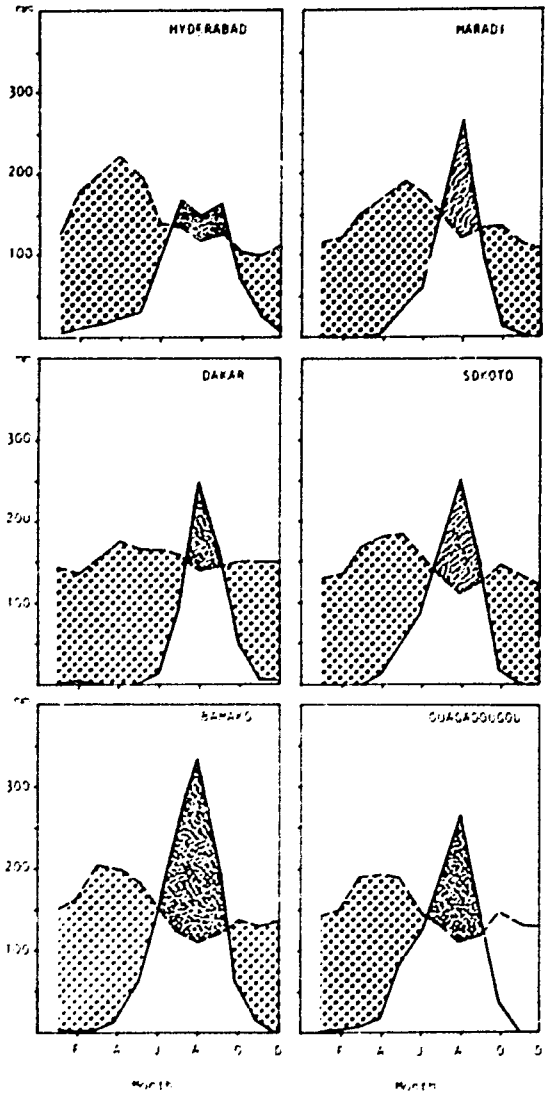

Figure 1. Monthly variation in rainfall (——) and potential evapotranspiration (----) at six selected locations in the SAT. [• • •] Water deficiency [▨] soil moisture recharge.

day, when the potential transpiration rate was only 1 to 4 mm/day, the transpiration rate did not decline until the soil moisture reached 12 bars, not much above the permanent wilting point. Since the rainfall distribution in the SAT is highly erratic, and rainy spells are interspersed with unpredictable droughts, the crops are exposed to considerable stress at different stages

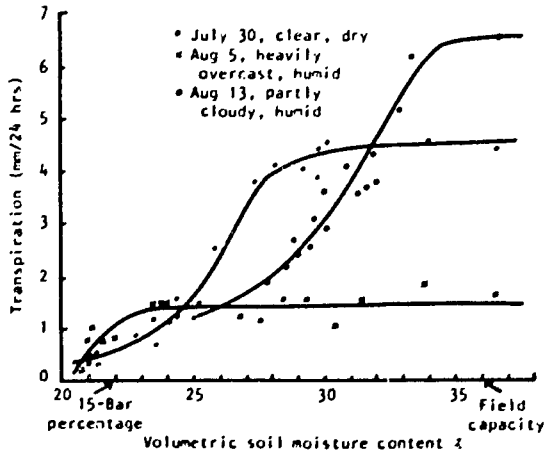

Figure 2. Actual transpiration rate as a function of soil moisture content (Source: Denmead and Shaw 1962).

of growth. Since the crop yields are proportional to moisture availability, the semi-arid tropical environment introduces a strong element of risk to high and stable crop yields.

Soil Moisture Storage

The soils of the SAT show great diversity in texture, structure, type of clay, organic matter content, and depth. Among other things, the precipitation actually entering the soil depends upon the type, surface conditions, and moisture status of the soil.

As shown in Figure 3, the moisture depletion from a given soil varies with the soil type (Holmes 1961). The idealized curves show that in the case of sandy soils, the low moisture-holding capacity and the low colloid content permit a rapid removal of much of the soil moisture. The depletion rate remains at a high level almost to the wilting point. For a heavy clay soil, on the other hand, the moisture cannot be removed rapidly.

The average values of changes in the profile moisture on the weekly basis in three typical soils of the Hyderabad region are plotted in Figure 4. These curves are based on the 1901–70 rainfall records. It is apparent that in the shallow Alfisols there is very little soil moisture storage for use over extended drought periods. In deep

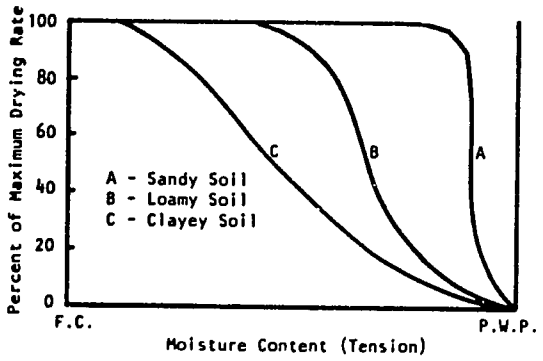

Figure 3. Drying rates of three types of soils as a function of soil moisture content (Source: Holmes 1961).

Alfisols, medium deep Vertisols, and in deep Vertisols, there is a fair degree of moisture storage for a substantially longer time during the growing season compared with shallow Alfisols. Thus, under identical rainfall conditions, the effects of short-term intraseasonal droughts on crop moisture status will differ in different soil types. The amounts of water lost by runoff would be much higher in the shallow Alfisols compared with the other two soil types, and the potential benefits derived from supplemental applications of water would vary with the soil type. Our experience has shown

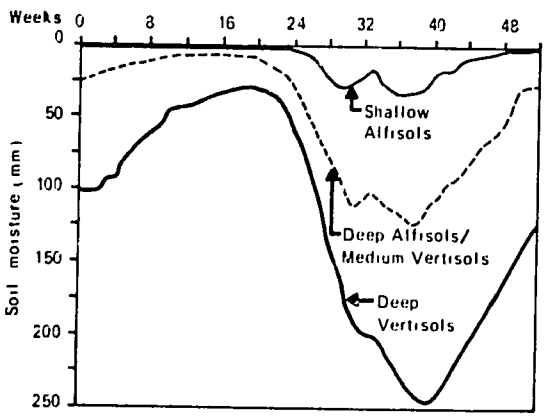

Figure 4. Weekly soil-moisture storage in three soils (based on Hyderabad data, 1901–1970).

that it is on the shallow Alfisols that reuse of runoff is usually profitable under Hyderabad conditions.

Water Balance Calculations

It is possible to calculate the water balance for a given region for any given crop from the actual rainfall evapotranspiration and soil moisture characteristics over a series of years. The use of computers for fast and accurate calculation of water balance using various simulation models has made this task relatively easy. Water-balance results find useful application in the determination of the length of the growing season and the optimum sowing date; maximum water use of a crop and maximum water availability can be matched for optimal use of available resources.

Transfer of Farming Systems Technology: Some Case Studies

For over 2 decades agricultural research has focused its major attention on improved crop yields under irrigated agricultural systems. Recent crop failures and widespread famines in the arid and semi-arid areas have brought to the attention of researchers the need for improved technologies for greater yields and production stability in these areas. The geographical diversity and the distance between SAT locations impose definite limitations on the technical and financial resources for intensive investigations over large areas in the SAT. Hence, research conducted at a few important locations for the generation of improved technology will have to find application over large areas.

The climatic approaches for the transfer of agrotechnology have been described earlier. A few case studies are presented here to show the application of these approaches for some practical problems. These case studies are by no means exhaustive but can serve as useful examples to illustrate the idea behind these exercises.

Location Specificity of Moisture Environment

The distinctive characteristics of the SAT

influence the distribution of natural endowments — soils, rainfall, and climate — introducing a strong element of location specificity in terms of the agricultural environment. This is exemplified by a comparison of two locations — Hyderabad and Sholapur, India — situated about 500 km apart at similar latitude and altitude. They seem agroclimatologically, ecologically, and edaphically similar (Virmani et al. 1978). At both locations, soils are deep to medium deep Vertisols. The mean annual rainfall at both the locations is about the same (764 mm at Hyderabad and 742 mm at Sholapur) and, on an average, more than 75% of their precipitation is received between June and September. Krishnan (1974) computed the annual PE at 1757 and 1802 mm, respectively, for Hyderabad and Sholapur; the actual length of the growing season was estimated to be 130 and 148 days, respectively. The CV of the annual rainfall is 26.1% for Hyderabad and 28.6% for Sholapur. Rao et al. (1971) computed Thornthwaite's moisture index at −56.4 and −58.7, respectively.

With this information, one could expect similar agricultural potentials at these two locations. However, research has shown that this is not true. At Hyderabad, on Vertisols, yields in excess of 5000 kg/ha are common in pigeonpea/maize intercropping and in maize/chickpea sequential cropping; rainfall-use efficiencies of the order of 6 to 10 kg/mm can be obtained regularly. However, at Sholapur, rainy-season cropping is undependable with sorghum or maize; a short-duration crop of pearl millet or a grain legume followed by sorghum grown on conserved moisture is somewhat successful. Furthermore, yields from year to year are highly variable, ranging from 1000 to 2000 kg/ha; the rainfall-use efficiencies are quite low.

Hargreaves (1975) reported extensive rainfall analyses for defining the agricultural potentialities for rainfed agriculture of semi-arid tropical northeastern Brazil. He found that if the amount of rainfall was sufficient to meet one-third of the potential demand (R/PE = 0.33), it was sufficient to meet water requirements of dryland crops in soils with a fair amount of available water-holding capacity. The rainfall is defined as "dependable precipitation" when the probability of its receipt is at least 75%. In such a scheme of evaluation, consideration is given both to the adequacy of rainfall in relation to crop water needs and the dependability of its occurrence.

An analysis for initial and conditional probabilities of R/PE$\geq$0.33 explains most of the differences between Hyderabad and Sholapur (Fig. 5). The rainfall distribution is highly erratic; few of the initial probabilities P(W) exceed the 70% threshold level and the (P(W/W) follows a similar pattern. In comparison, the rainfall analysis for Hyderabad shows that rainfall is dependable (as defined at 70% probability) between 18 June and the end of July, and from about mid-August to mid-September. Thus, rainfall characterization based on short-term periods can be particularly effective in explaining differences in agricultural climate and crop yield potentialities.

The illustration of location specificity, as exemplified by the rainfall analysis of Hyderabad and Sholapur, clearly brings out that quantification of the moisture environment would be essential for identifying isoclimes and for the transfer of different elements of the farming systems technology.

Possibilities of Dry Seeding on Vertisols in India

The methodology of rainfall probabilities could be used for assessing the risk associated with dry seeding of rainy-season crops in the SAT. From our experience, we have observed that the dry seeding period of the crops will be a couple of weeks ahead of the onset of the rainy season. At Hyderabad, the onset of seasonal rainfall is abrupt at the commencement of the rainy season and the probabilities of continuance of rain are fairly dependable. Therefore, this location offers an excellent scope for dry seeding. At Sholapur, on the contrary, the onset of rains at the commencement of the season is not abrupt and the probabilities of the continuity of rainfall after onset are not high; such locations are prone to considerable risk in dry seeding. Based on rainfall probabilities of more than 90 locations in India, the areas offering possibilities of dry seeding on Vertisols are mapped in Figure 6. The technology for dry seeding of crops generated at ICRISAT Center could be translated with a fair degree of success to Akola, Jabalpur, Indore, and Udaipur; whereas at Sholapur, Dharwar, Jalgaon, and Ahmedabad the likely success of dry seeding is

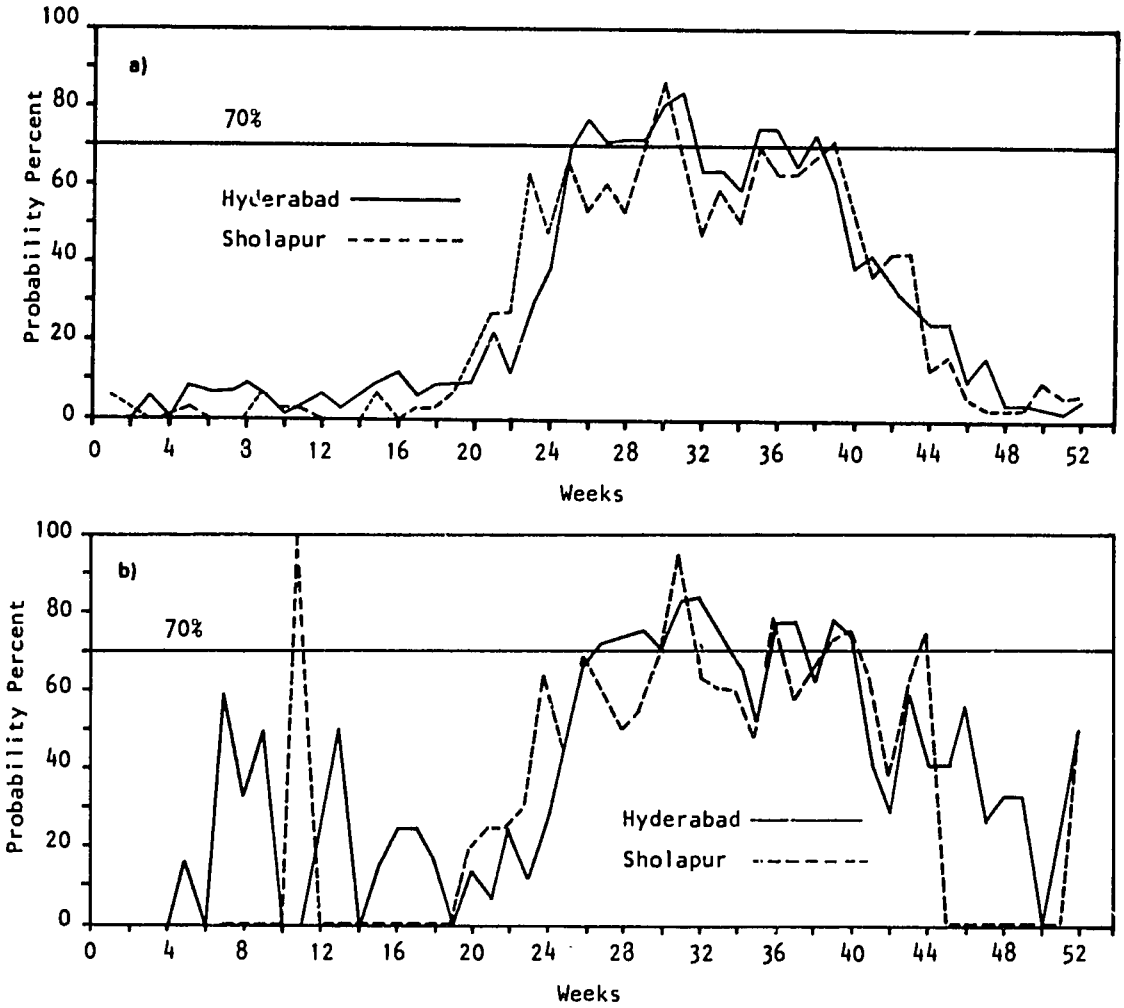

Figure 5. Comparison of probabilities of R/PE≥0.33 at Hyderabad and Sholapur.
a. Initial probabilities (P[W])
b. Conditional probabilities (P[W/W])

low due to the high risk associated with this practice. In such cases it would probably be best to build up some moisture in the upper horizons of the soil profile prior to seeding.

Length and Characteristics of the Growing Season

Thus far our discussion has been mainly on the probabilities of rainfall and the methodologies that may be used to employ this information in the planning of agricultural strategies/operations. The length of the growing season depends upon the pattern of rainfall and also upon the type of the soil, particularly its moisture-holding characteristics.

The soil-moisture availability characterization could have implications in crop planning and selection of crop cultivars, at least as a first approximation. The length of the growing season in the three soils is shown in Table 3. At the

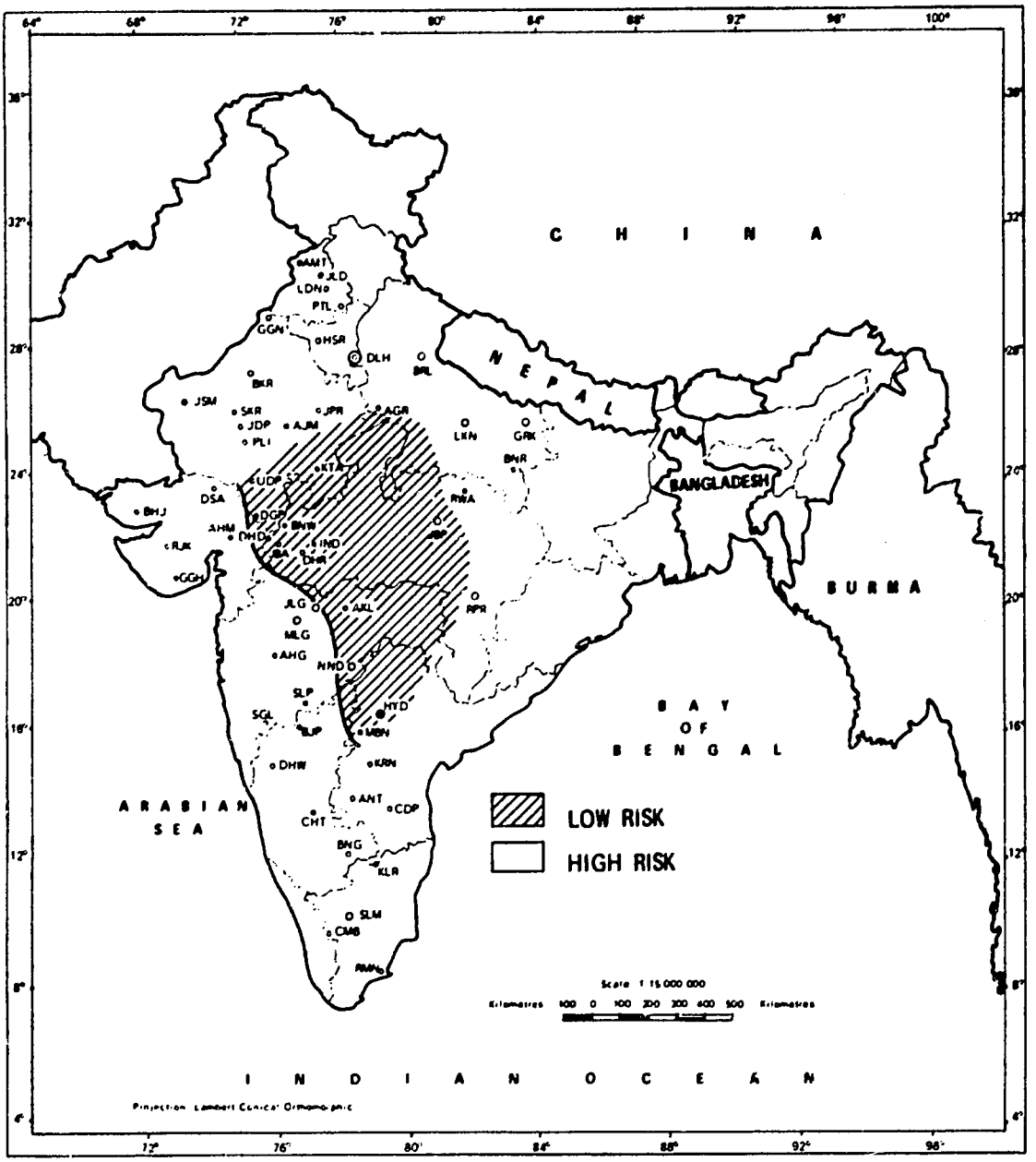

Figure 6. Possibilities of dry seeding on Vertisol.

75% probability level, the length of the growing season in shallow Alfisols would be about 15 weeks, while in the Vertisols it extends to about 23 weeks. This would mean that — depending upon the soil water-storage capacity — one could grow a medium- to long-duration crop at the Hyderabad location on a deeper soil, as opposed to a short-duration crop on a low water-holding capacity soil. Since soil types and rainfall patterns in the SAT show considerable variations over short distances, such analyses will assist considerably in deriving estimates of

Table 3. Length of the growing season (in weeks)[a] for three soil conditions.[b]

Rainfall probability	Available water-storage capacity		
	Low (50 mm)	Medium (150 mm)	High (300 mm)
Mean	18	21	26
75%	15	19	23
25%	20	24	30

a. From seed-germinating rains (25 June) to end of season (time when profile moisture reduces EA/PE to 0.5).
b. Low: shallow Alfisol; medium: shallow to medium-deep Vertisols; high: deep Vertisol.

the crop growing periods and suitable crops, and in delineating isoclimes for the transfer of technology.

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Benchmark Soil Studies: A Means for Transfer of Agrotechnology

Tejpal S. Gill*

Abstract

A benchmark soil study is a cooperative effort of people dealing with standardized agronomic research on well-defined soils that belong to the same taxa. It is, by design, a network. Research done on a benchmark soil produces data to be shared among test sites and extended to agriculturists managing the same soils. Experimental results obtained in one country can be applied to sites on the same soil family in another country. As the information base increases, it will enhance a model of agrotechnology transfer based on soil interpretation and classification. An international benchmark soil network is already in operation in Hawaii, Puerto Rico, Brazil, and the Philippines; it can be expanded into a worldwide network to enhance food production with the help of the international research centers and their outreach programs and the agronomic research projects conducted by national programs at numerous in-country locations.

Many specialists combine their talents and knowledge in agronomic research to develop improved soil management practices for increased economic food production and resource conservation. Technology in disciplines related to food production changes so rapidly and at so many different places that it is becoming impractical for all political subdivisions to undertake experiments to solve each problem as it arises. The strain on available resources — people, time, land, and money — too often overcomes the ability to respond effectively; thus, shortcuts are needed in the struggle to alleviate food crises and future famines.

An obvious shortcut is a sharing of knowledge of demonstrated agronomic responses. A major difficulty is sorting out which information can be transferred to which location. There are many options to try, numerous criteria to propose, and millions of previous trials and errors. The fragmented bits of information accumulated by generations of agriculturists throughout the world are seldom known by others beyond the limits of their restricted communication networks.

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Sharing is a fundamental attribute of human well-being, and is akin to love. One person, group, institution, or agency cannot share. Sharing is an active process that involves giving and receiving. Nothing is shared that is not received, thus mutual agreement is essential for a meaningful sharing of agronomic knowledge. A benchmark soil study is an efficient way to improve tha certainty and momentum of the process of agrotechnology transfer. This process of transfer is one of sharing.

An Overview

A benchmark soil study is a cooperative effort of people dealing with standardized agronomic research on well-defined soils that belong to the same taxa. Soil sites are carefully selected to provide homogeneity of soil properties and local landscape features that modify interactions with external climatic conditions. The soils for the study are classified according to soil taxonomy, and similar slope and landscape positions are located for each site.

The agronomic research is carefully designed and standardized for all sites to assure comparability of results. That is, the same land preparation techniques; varieties; insect, disease, and other management practices; input variables; methods of harvest; and methods of

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analysis are used. Site variables, mainly climatic, are also measured at each location. These cooperative research experiments are called transfer experiments because the results are evaluated to test the hypothesis of agrotechnology similarity among the sites. Additional soil management experiments are conducted to expand the kind of information that can be linked among the locations.

A benchmark soil study is, by design, a network. The experimental sites may be only a few miles apart, tens or hundreds of miles apart, or even thousands of miles apart. The crucial criterion is that the soils at the selected sites belong to the same soil family in soil taxonomy and that the phase conditions (slope, landscape position, erosion, etc.) are very similar.

There are many benefits from a benchmark soil study. The nature and degree of transferability of soil and crop behavior is quantified; consequently, economic returns can be determined relative to the local economies of the sites. The significance of site variables are better understood and the exchange of such information improves predictions of soil-crop-climate interactions. Basic information of soil properties at the research sites can be evaluated and suggestions made for updating and improving soil classification. A final yield of a crop depends on so many factors that when a response surface of one site can reasonably be predicted from others, there will be lots of additional information that can be transferred. The esprit de corps among the experimenters involved in the network is high. The anticipation of providing data relevant to a distant location and of obtaining meaningful results from experiments conducted by others, prevails throughout the system. There is heightened excitement and satisfaction resulting from sharing among equal partners in the challenge of food production.

Concept of a Benchmark Soil

Soils are fixed in space; consequently, crops have to be grown at specific locations. Some properties of soils can be modified easily if the resources are available. Nutrients can be added to soils deficient in nutrients, water can be supplied to some and drainage provided for others, and surface soil structure can be altered by mechanical disturbance to improve aeration and moisture relationships for germination and early growth of plants. Subsoil properties and landscape features, such as slope and aspect, are more difficult and costly to modify; thus many of these characteristics are used to classify and describe soils. Combinations of physical, chemical, and biological properties of soils provide meaningful subdivisions of the earth's unconsolidated upper mantle. Dynamic patterns of internal soil temperature and soil moisture commonly relate to landscape influences on external climatic conditions; they are important attributes of soils that can be measured and used in classification schemes.

A benchmark soil is similar to other kinds of benchmarks in that it is a major reference point that facilitates comparisons in uncharted areas and also ensures that the current results are accurate for the intended purpose. A benchmark soil in agriculture is a well-defined, properly characterized, and correctly classified soil, whose extent, or uniqueness, is significant in the planning, development, and maintenance of the agricultural economy of a particular region.

Recognition of benchmark soils depends on a classification system that is comprehensive, can be adapted universally, and has criteria that are related to soil behavior when used for crop production. The soil family category in the hierarchal soil taxonomy stratifies the soils of the world into relatively homogeneous grouns. A soil family integrates climatic information important to plant growth with physical and chemical features that affect soil response to management. Soil families are subdivided in the lowest category into soil series that are restricted locally and in many parts of the world are not mapped and classified. By using appropriate phases at the family level of classification, soils with very similar landscape conditions can be identified, mapped, and compared.

A link exists among all soils of the same benchmark class wherever they occur in the world. They have a limited range of measured physical and chemical properties, as well as similar characteristics of temperature and moisture regimes. The strength of the linkages depends on the consistent application of the criteria that provide the taxa of interest.

What soils should be considered as benchmark soils? Collective judgment of planners and scientists is needed to select those soils whose

present and/or potential use contributes significantly to the welfare of people through improved food crop production and resource conservation. Some soils are selected because they are extensive and can be used to increase the amount of land under cultivation. Other soils may be selected because they respond favorably to intensive management practices. Where the soils are, and what kind they are, is based on reliable soil resource inventories that provide information about land qualities. The selection process continues as long as there is need for refinements in developing and utilizing agronomic research results.

A Benchmark Soil Study

Research done on a benchmark soil produces data to be shared among the test sites and extended to agriculturists managing the same soils. Some minimum number of locations or sites is needed so that an important segment of the range of conditions for a soil family can be evaluated. Weather patterns often vary over short distances and yet may be similar at widely scattered locations; thus, weather is the most interesting influence at sites on similar soils.

The present international benchmark soil studies consist of one primary and two secondary sites in each country on each benchmark soil being evaluated. As with other agronomic research, it is necessary to have enough experimental sites to obtain sufficient data for statistically valid estimates of the effects of uncontrolled variables on crop yields. It appears that five locations are the minimum; the optimum number of sites has not yet been determined.

The underlying principle of a benchmark soil study is that experimental results obtained in one country can be applied to sites on the same soil family in another country. Some experiments are conducted to continually test the degree of transferability of results. Other experiments evaluate soil and crop management practices and crop varieties. As more sites are added to a benchmark soil study, the so-called "transfer experiments" may some day become the "control or check" plots in an array of internationally coordinated experimental designs.

At all locations, the field operations, data collection, and data processing follow standardized procedures and guidelines to assure compatibility of results among the sites. Guidelines deal with land preparation, pest and disease control, field plot design, water management, harvesting, and data collection of controlled and uncontrolled variables.

As the information base increases from benchmark soil studies, it will enhance a model of agrotechnology transfer based on soil interpretation and land classification. The details of the experiments that should be tried and the complexities of multidisciplinary aspects of agronomic research can confidently be handled by the scientists associated with benchmark soil studies. Being personally involved in sharing is a phenomenal inspiration and reward system that scientists readily respond to.

An International Benchmark Soil Network

A major goal of a benchmark soil network is increased agronomic crop production consistent with growth and development of overall economic and environmental well-being of society.

Increased production refers to more kinds of crop production, larger amounts of foodstuffs, and quicker availability. The crops of immediate concern are those food and feed crops that sustain and nurture humans. Consistency with economic development implies that food and feed production is a subset of agricultural production and services, which in turn are one sector of importance in national and world economics. Environmental well-being refers to the urgent need to develop and maintain long-term sustainable agricultural production, not in any one location, but in a perspective of a worldwide network whose interactions affect everyone.

An international benchmark soil network is not just a concept or a dream; it is becoming a working reality and will probably expand as the results of the current soil studies become more widely known. Sharing finances, sharing competent research scientists, and sharing responsibilities for a needy world is as appealing as it is just good common sense.

The ingredients for an agronomic crop production network founded on well-defined benchmark soils exist throughout the world.

How best to measure and blend these ingredients needs the immediate attention of dedicated people who want to be active partners in sharing. The raw materials need to be refined to achieve better and quicker results.

The important scientific ingredients include:

1. A universally recognized system of classification to identify soils having similar characteristics. Soil taxonomy is a workable scheme that is widely accepted. The refinements needed to satisfactorily identify and consistently classify soils in the tropics are receiving careful attention, and testable recommendations will soon be made. This system is sufficiently comprehensive, quantitative, and flexible to accommodate new research results.
2. Adequate soil resource inventories, soil analysis, and soil interpretation programs within countries. Sharing experiences of operations and quality control of these programs needs to be expanded. Helping each other in training and evaluation procedures will help ensure consistent use of soil taxonomy and its application to soil survey activities.
3. A workable international soil correlation network, including a manageable soil data bank. High-quality agronomic research is very expensive and if the soils are improperly identified the extent of transfer is poorly known. A computerized scheme of data handling will let soil scientists adequately backstop the efforts of other scientists involved in agronomic research.
4. A sound, reliable program for standardizing agronomic research that evaluates transferability and pinpoints site-specific conditions. Science provides predictions based on measured relationships. Techniques and procedures that are not compatible produce results that cannot easily be used to test predictions, and progress in increasing crop production is hindered. Ideas and working concepts from many disciplines are desperately needed to make this program viable. Pathologists, entomologists, agronomists, hydrologists, economists, pedologists, conservationists, and others can contribute to the scientific soundness of meaningful research.
5. Competent crop and soil scientists guiding the work at research sites that are linked together in a global network. Isolation is no excuse for incompetence in this plan because isolation is only physical location. Equal partners in a sharing of knowledge implies that communications must be easy and mutual respect is maintained. This is critical for planning, implementing, and evaluating the research activities agreed on.
6. Information systems capable of processing, evaluating, and disseminating agronomic research results. Horizontal transfer links research sites around the world, but vertical transfer directs attention to the country or locale where adoption is intended to occur. The skills and techniques of vertical transfer are as varied as the dialects and traditions of the agriculturists whose privations prompt our desire to share. We must receive in order to be able to give if we want to share.

Scientifically, the capabilities exist to refine and extend the above considerations into a viable agronomic research network. The rate of expansion of the network, the scope of the various research activities, and the interactions both horizontally and vertically depend more on political decisions than on scientific know-how. The shortcut of effective and efficient transfer of agrotechnology based on soil interpretation and land classification is scientifically feasible.

A Potential Framework

The United States Agency for International Development has supported the concept of a soil-based network of agronomic crop research. Research projects on agrotechnology transfer in the tropics based on the soil family continue to develop and test the hypothesis of soil management and crop yield transfers from site to site. In addition to these projects in Hawaii, Puerto Rico, Brazil, the Philippines, Indonesia, and Cameroon, there are the international centers and their outreach programs. National research centers also conduct agronomic crop research at numerous in-country locations.

The basic infrastructure is in place. For example, the far-reaching implications of the research here at ICRISAT can be offered to areas of the semi-arid tropics having the same soil families. The black soils (Vertisols) are domin-

antly fine, montmorillinitic, isohyperthermic Udorthentic Chromusterts and the red soils (Alfisols) are dominantly clayey, mixed, isohyperthermic Rhodic Paleustalfs. Three other soil families also occur at ICRISAT, and crop response information can be provided for testing transferability. Standardized agronomic research on these same soil families by cooperating scientists will form the links of other benchmark soil studies.

Joining the present family links among the Hydric Dystrandepts, Tropeptic Eutrustox, and Typic Paleudults will be family tie-ins with the Typic Rhodustalfs on the Malia Illuppallana Agricultural Research Institute in Sri Lanka, and others with the Oxic Paleustalfs at IITA in Nigeria.

Soil data banks are receiving soil information from experiment stations in many countries. Cooperation in analyzing and identifying soils of unsure placement strengthens the communications among scientists in far-off places. New experiment stations are being set up, more outreach programs are under way, and the exchange of information that leads to effective transfer increases daily.

Eventually the experiences of hundreds of researchers will be able to be utilized by hundreds more. The scientific ingredients exist; they need additional refinement; they require the cooperative endeavors of many to bring about a global network of agronomic crop production based on well-defined soils into a truly international sharing of agrotechnology transfer.

A Network Vision

The initial hypothesis testing of transferability is being done with the following soil families: (1) thixotropic, isothermic Hydric Dystrandepts, (2) clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox, (3) clayey, kaolinitic, isohyperthermic Typic Paleudults.

The soil families that occur at the international centers — IRRI, IITA, ICRISAT, CIAT, CIMMYT, WARDA, CIP, and ICARDA — need to be matched with areas having the same soil families. Cooperative standardized crop experiments can be established and results shared.

The soil families at existing regional and national agricultural research locations can also be identified, and corresponding areas of the same soil families can be located.

Using this information as a nucleus, it will be possible to consider where and how to join additional benchmark soil studies into an international network. Preliminary strategies likely will be based on agroclimatic regions or zones and on known or expected areas of similar soil potentials.

Agroclimatic regions outline areas within which climatic variations are less than the whole. The range of uncertainty is limited. Soil taxonomy acknowledges soil climate as an interaction between external climate and landscape features that may be measured in the soils. Thus, classifying soils in the family category identifies groups that also have a limited range of climatic variability. Major permanent modifications of climate or of soil on a large scale is not feasible and probably is not environmentally wise; therefore, climate and soil are the main resources that must be understood to provide the basis for efficiently and effectively increasing food production of adapted crops and systems of management.

Agroclimates and soil families are seldom ideal. However, to the extent that their properties are adequately described, so are the major limitations that must be managed to strive toward the ideal. Benchmark soil studies attempt to resolve the soil management practices needed to permit the climate and crop to respond favorably in the specified soil. Economic evaluation of the results suggests whether successful farmers are likely to choose the practices recommended as being transferable.

Benchmark soil studies do not work with ideal soils or climates, but they are designed to provide guidance on how to maximize effort in approaching the ideal.

If we assume for a moment that 80 to 100 agroclimatic zones significant for most food production can be adequately described and located, and the three soil families in each zone bracket most of the important soil conditions, there are potentially 250 to 300 unique combinations that would some day belong to an international network. If each combination has experiments at three locations and each has several satellite sites, the number of experiments becomes very large.

Obviously, priorities will have to be set by responsible organizations utilizing the best in-

formation available. For example, are there 15 agroclimates that are most critical for maintaining and increasing food production, and can two soil families in each be selected that dominate use and economic development? The challenges are there and so is the opportunity to become a partner in the sharing of agrotechnology.

Information systems that not only handle soil and crop performance data, but, more importantly, facilitate the evaluation and dissemination of relevant transfer information are a must. Horizontal transfer of research findings can save millions of dollars and speed up solutions to production problems, but the true meaning of sharing can only be realized when vertical transfer to agriculturists results in their improved well-being.

Benchmark Soil Studies in the SAT

How well can a yield of the same crop under the same management be predicted for the same field for the next growing season? Forecasting the future of a crop yield is like the game of life — it is full of uncertainty. Based on prior knowledge, we predict a continuing trend of events to occur, and if we could but control enough of the variables we would feel fairly confident of the outcome. In research laboratories controlled experiments can be conducted to examine the relationships and effects of carefully designed variables. Extrapolation to field conditions is often fraught with conflicting responses.

Longtime averages, fluctuations, and recurrence intervals of droughts or of floods provide insight but no guarantees of successful prediction. Perhaps we set our goals too high, or perhaps we have not been able to obtain satisfactory relationships between probabilities of reasonable success and the complexities of risk that underlie acceptance and application of change.

The mysteries of climatic vagaries make us painfully aware that water is the dominant natural constraint to increased and stabilized agricultural production in the semi-aid tropics. Combined with the wide range of soil conditions that alter the behavior of moisture and the final influecne on crops, the problems appear to be understood far sooner than are the economical solutions.

Shortcuts to potential solutions are indeed desirable. Better models of agroclimates, better models of soil moisture behavior, better understanding of crops and cropping systems that utilize the available moisture, and improved understanding of socioeconomic constraints to measured agricultural production are all parts of the effort to provide shortcuts.

Combining precious resources that speed up reliable answers and increase the implementation of effective practices makes a lot of sense. Cooperative work that brings together the scattered resources of a troubled world is feasible and practical. A shortcut of considerable importance is a network of agronomic crop research conducted by competent scientists on well-defined soils. Properly classified soils, compatible experimental designs, consistent conduct of research, information systems that work, and a concern for the needs of development at all levels of interest will make the network a working reality. Everyone can contribute, everyone is important, and the benefits accrue to all. The expansion of benchmark soil studies into a worldwide network can work; it has already started. Please give serious thought to your role, your obligation, your responsibility, and, most important, your opportunity to encourage and to assist in bringing about a system of global interchange of information on food production.

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Watershed Management and Technology Transfer in the Semi-Arid Tropics

Jacob Kampen*

Abstract

Frequent shortfalls in food production and a deterioration of the productive capacity of the resource base have become common in many areas of the SAT. Watershed-based natural resource development, which involves the optimum use of the watershed precipitation through improved water, soil, and crop management, has the potential to contribute significantly to greater productivity and resource conservation. The development of improved watershed management technology adapted to what farmers require, is a complex and long-term task; all land uses, including grasslands and forests, must be considered. To attain successful agricultural development, ICRISAT's responsibility consists of the generation of improved research methods, cooperative investigations focused on operations research and the integration of new technology, and training programs.

Many areas in the semi-arid tropics (SAT) are currently characterized by rapidly increasing populations. Shortfalls in agricultural production have become common in several regions of the SAT. The greater demands for food have resulted in a need for fundamental changes in the production systems that were characteristic of rainfed areas. Shifting cultivation is being replaced by permanent agriculture, and farmers' attempts to further increase production have caused an extention of cultivation to marginal lands that are frequently subject to crop failure due to lack of moisture. Increased numbers of animals are changing the hydrologic characteristics of vast areas of grazing lands (Kampen 1974). The demand for wood as construction material and fuel has resulted in the denudation of forest lands.

The Needs

This intensification of land use in the traditional agricultural setting is self-defeating, because it is exploitive and results in greatly increased runoff and soil erosion, reduced groundwater recharge, downstream flooding of agricultural lands and cities, as well as an accelerated sedimentation of reservoirs that negates irrigation and power investments. As a result, the land resource base is shrinking and its productive capacity diminishing. Thus, resource management that more effectively conserves and utilizes the rainfall and the fertility of the soil and new crop production systems that maintain productivity and assure dependable harvests are urgently required (Krishnamoorthy et al. 1977). Mechanisms must be found to attain sound husbandry of those lands most suitable for pastures and trees.

In rainfed agriculture, the only source of available water is the rain that falls on a given area. Runoff, erosion, and drainage represent serious problems for many areas in the SAT, and the solution to these problems lies in evolving development programs that recognize the natural topography and the drainage patterns of the land. In many areas, it is not unusual to experience significant quantities of runoff at one time of the season and serious drought at another time. The collection of excess water and its utilization to provide greater stability to rainfed agriculture appears to be a viable development alternative in such areas, particularly if soils are shallow (Krantz et al. 1978). Thus, the watershed[1], or catchment, is the

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1. "Watershed," strictly defined, refers to the divide separating one drainage basin from another; in this paper the term "watershed" is considered synonymous with catchment and drainage basin.

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natural framework for resource development in relation to crop production systems and resource conservation and utilization.

The Approaches

Watershed-based resource utilization involves the optimum use of the area's precipitation for the improvement and stabilization of agriculture on the watershed through better water, soil, and crop management. More effective utilization of water for the production of crops can be facilitated by one or more of the following means: (1) directly by improving infiltration of rainfall into the soil and thus making more soil water available for plant use; (2) through drainage, collection, storage, and re-utilization of runoff; and/or (3) by water recovery from wells after deep percolation beyond the root profile.

The need for development, conservation, and management of land and water resources is acknowledged. However, many small farms and fragmented land parcels — and often several different land uses — together compose a watershed: their presence must be accommodated within efficient watershed development and management techniques. In many situations group action may be required to attain the desired objectives.

The diversity of environments encountered in the SAT is recognized. The problems of technology development and transfer of new information to farmers in this ecological zone are difficult to solve because the moisture environment is unreliable and because the appropriate practices will be complex (Virmani et al. 1979). Improved technology will relate to crop, variety, fertility, management, land development, water conservation, etc. In the end, millions of often illiterate farmers with little capital or land must learn to apply the tools of science to extract more food and ultimately a better quality of life from their hostile environment. Compromises must be found between private short-term goals and common long-term objectives. The challenge is great.

The Implications

The envisaged implementation of integrated agricultural development programs, adapted to the specific requirements of different agro-climatologic and socioeconomic regions, has several important implications for research and training. Much greater attention must be paid to holistic investigations of the characteristics of existing land use and farming systems, the relationships between different system components, and the potentials and weaknesses of improved production methods involving food and cash crops, livestock, forages, and trees. Also, to facilitate such integrated development approaches, a greatly increased effort in terms of on-farm research must be evolved; applied research programs involving interdisciplinary teams of scientists working together with development agents are required. Such projects can be effectively used for training and for studies of group action potentials. It is in this setting that the essential involvement of farmers in technology development becomes feasible and that the desired feedback into basic and applied studies executed at research institutions can be generated.

Watershed-based Resource Development, Management, and Utilization

Past Resource Development Attempts

Until a few years ago, little attention was paid to the SAT in terms of agricultural research and with regard to resource development projects. Except for cash-crop agriculture on steep slopes of considerable elevation, the crops and farming systems common in most of the SAT have only recently caught the attention of scientists. In the past, some of the approaches to ameliorate the problems faced by farmers in the rainfed SAT have been: (1) to meet droughts and food crises by emergency relief programs, (2) to fallow heavy soils such as Vertisols during the rainy season in an attempt to accumulate a moisture reserve in the profile for growing a crop in the subsequent dry season, (3) to construct bunds as a soil and water conservation practice, and (4) to develop irrigation facilities.

The "crash" resource conservation and development schemes implemented as part of relief programs have not resulted in improving the stability and long-term productive potential of the environment. Cultivated fallow on deep Vertisols is questionable because of the erosion hazard; this practice also frequently results in

only a small portion of the total seasonal rainfall actually being used for crop production (Kampen 1977). It has not been possible to identify any results of controlled experiments that show significant and stable crop yield increases due to moisture conservation by contour bunds in the SAT of India (ICRISAT 1976, 1978). Experience with irrigation in the SAT shows that conventional projects usually provide continuous water on a seasonal basis to crops with high water requirements, such as rice and sugarcane; they do not presently have the flexibility required to act in a supplemental fashion. Few serious efforts have been made to explore how the limited available water resources can be used to stabilize and support larger proportions of rainfed agriculture for the benefit of a greater number of farmers.

Thus, past approaches to resource development to increase agricultural production in the SAT have achieved only limited success (Kampen 1974). These development efforts have not been planned and executed on the basis of the natural drainage basins, nor have they recognized the basic climatologic and soil characteristics of the SAT (Kampen and Burford 1979). Some of the techniques discussed have undoubtedly had benefical effects in limited areas; however, they have not provided the breakthrough in soil and water conservation and utilization that is imperative for rapid development of agriculture in the SAT.

The Watershed as a Focus for Integrated Agricultural Development

On watersheds exceeding a few hundred hectares in size, two major hydrologic zones can be distinguished (Fig. 1). In the upper reaches of a catchment is the "zone of recharge," where the net movement of water is downwards; after moistening the root profile, excess water discharges into groundwater. In the valley bottoms is the "zone of discharge;" here the net movement of water is generally upwards. A transition zone represents the variation that will occur in wet vs dry years. In earlier times the upper reaches of watersheds were covered with forest, shrubs, or grass, which helped promote infiltration into the soil and discharge to the groundwater. However, with the removal of trees and with more intensive agricultural use,

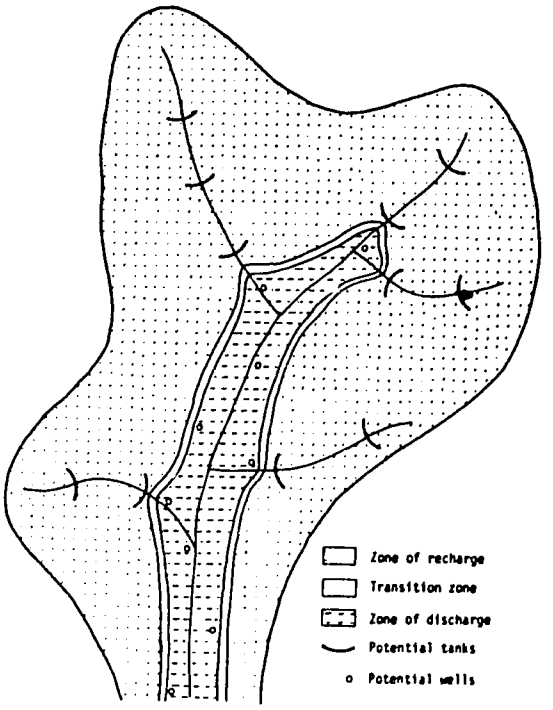


Figure 1. A schematic drawing of a watershed showing the zone of groundwater recharge, the zone of groundwater discharge, and the transition zone. Potential locations for wells and tanks (small runoff water reservoirs) are also shown.

runoff and erosion have increased. This situation has resulted in less water being actually available for plant growth in the uplands; often only a relatively small portion (about 20 to 50%) of the annual rainfall is used for evapotranspiration during the crop growing season (Kampen 1979). The rest of the precipitation evaporates from bare soil, particularly under cultivated fallow; drains beyond the root profile; and/or runs off the surface of the land. Thus, new resource development and conservation techniques are required to improve the crop growth environment on these lands.

Improved, in situ soil and water conservation measures and more suitable and productive cropping systems can considerably increase effectively used rainfall and decrease runoff and erosion (Thierstein 1979, Willey et al. 1979). At

ICRISAT, cultivation in graded broadbeds has been explored as one alternative tested on operational-scale watersheds. In cases where significant quantities of runoff occur in most years, small storage reservoirs for supplemental irrigation may be feasible in the uplands. To prevent rapid silting of tanks, the contributing catchments (even if they are not cultivated but used for grazing or forestry) need to be well managed so that little erosion occurs. The hard rock strata that underlie most of the Vertisols and Alfisols of the SAT generally provide meager water aquifers. Agriculturally significant groundwater is often related to the small drainageways in the lower reaches of watersheds; opportunities for wells in this area may be explored (Fig. 1).

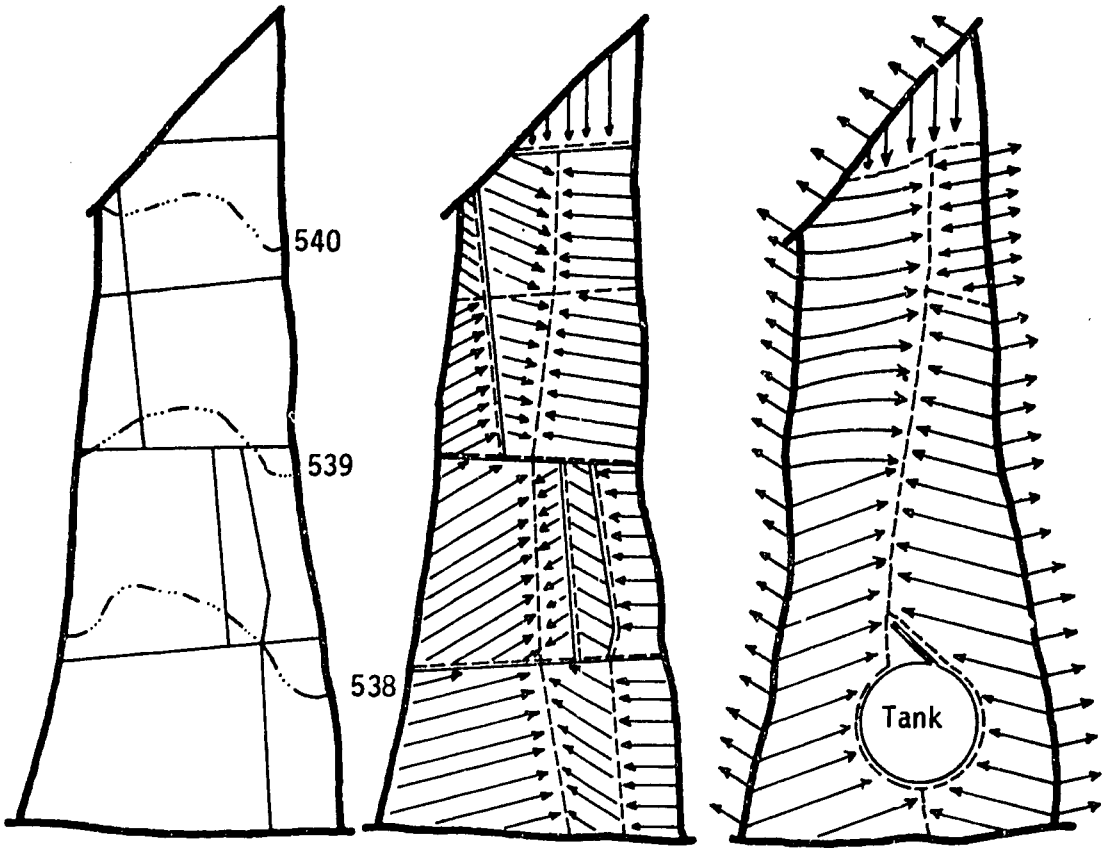
Bunding and watershed-based land- and water-management systems, consisting of graded broadbed cultivation with protected grassed waterways and runoff storage where needed, employ different concepts of resource conservation, management, and use (Fig. 2). With bunds, excess water flows in concentrated fashion through minor depressions on the land, collects at the bund, and is then impounded on a relatively small area or forced to flow across the slope and out of the watershed where it is finally disposed of in heavily grazed, uncontrolled, and often erosive drainage systems (Fig. 2a). Erosion between bunds can be substantial; inadequate bund maintenance often results in breaches. With cultivation to broadbeds, water management and control begins on the cultivated land itself (Figs. 2b, 2c). Excess water is allowed to flow through small furrows to a grassed drainageway and is then safely conducted to a tank. The flow velocity of the water is controlled by the slope of the broadbed system on the land and, where required, by drop structures in the drains.

On-farm Development and Implementation of Watershed Management Technology

Given the specific characteristics and needs of each area, few "handbook" development prescriptions can be expected to evolve. Although the principles for development may be clear, the ultimate task of finding appropriate solutions for the specific problems encountered in a given area will have to be assigned to technicians, extension agents, and, ultimately, directly to farmers. To fulfill their responsibility effectively, the technical staff will have to acquire the ability to "invent" the most appropriate solutions to each particular situation rather than to apply a given set of rules. Thus, a vast training program will be required, aimed at increasing understanding of the limitations, constraints, and potentials of present farming systems and the requirements of improved production technologies, as well as their adaptation and application. Such training programs, to be convincing and effective, may be best executed in the setting of on-farm operations research projects.

A small, on-farm watershed development project on Alfisols near Aurepalle — executed as part of cooperative research involving the Andhra Pradesh Agricultural University, the Indian Council of Agricultural Research (ICAR) and ICRISAT — illustrates the requirements and costs involved. The watershed area is about 12 ha and belongs to five farmers; it was developed during the dry season of 1978–79 when normally draft animals were idle and labor was underemployed.[2] The farmers were involved in all the planning stages and participated in the development activities. Land development consisted of the removal of stones and brush, a thorough cultivation, land smoothing, drainageway construction, and the initial layout and implementation of the semipermanent, graded broadbeds (Fig. 3). An existing shallow well was also rehabilitated; water will be used for supplemental irrigation. The total development costs amounted to about Rs. 450/ha (U.S. $56). The total cost of constructing 2500 m of waterways was Rs. 894; the cost of five small drop structures was Rs. 574. Thus, the cost of drainageways amounted to Rs. 125/ha ($16). Land smoothing was relatively expensive at Rs. 67/ha; the initial cultivation cost was Rs. 62/ha, and the ridge marking operation was Rs. 58/ha. Less than 10% of the total costs consisted of capital expenditures; the rest of the charges were paid for locally hired labor and bullocks. Reconstruction of the well cost about Rs. 135/ha ($17), 60% of which consisted of capital expen-

2. Costs were accounted for on the basis of the following rates: Rs. 5 and Rs. 3 day for male and female labor, respectively, and Rs. 10 day for a bullock pair exclusive of the operator.



a. Contour bunds

b. Broadbed-and-furrow system at 0.6% within field boundaries.

c. Broadbed-and-furrow system at 0.6% with grassed waterways and a tank.

Bed and furrow direction
Field bunds
Grassed waterways
Elevated inlet
Contour bunds

Figure 2. A Vertisol watershed with three alternative soil and water conservation and management practices illustrated for the same watershed. The broadbed (150 cm)-and-furrow system at 0.6% slope within the field boundaries (Layout b) was established 5 years ago and still exists. Layout c shows the same permanent broadbed-and-furrow system with field boundaries removed, a grassed waterway, and a tank. Contour bunds (Layout a) are seldom allowed by farmers as they do not want their small fields bisected. Therefore, the bunds are placed on the field boundaries, and problems of water stagnation and bund breaching occur.

Figure 3. Initial marking of the semi-permanent broadbeds after land smoothing in the Andhra Pradesh Agricultural University-ICAR-ICRISAT cooperative research project on watershed development on Alfisols at Aurepalle.

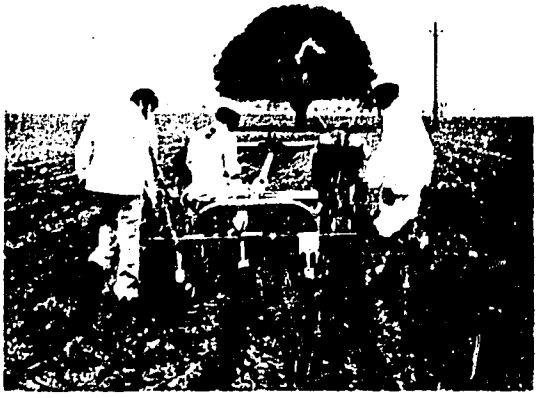


Figure 4. Planting of a millet-pigeonpea intercrop on broadbeds in the Mahatma Phule Krishi Vidyapeeth-ICAR-ICRISAT cooperative research project on Vertisol watershed development at Shirapur.

ditures for granite stones and cement. Almost half of the development costs were borne directly by the farmers. The watershed was planted to sorghum, a millet/pigeonpea intercrop, and castor early in the rainy season of 1979. Similar projects have been initiated near Kanzara and Shirapur (Fig. 4).

The Operations Research Concept to Facilitate Technology Development and Transfer

Several components of the systems of farming now common in the SAT must be improved simultaneously to attain substantially increased and more stable production (Kampen 1979). Thus, there is an urgent need for the integration of new techniques into technically and economically viable farming systems that fit major constraints now faced by farmers. Such integration is most effectively studied in operational-scale systems research at research centers and on farms.

At Research Centers

In studies on resource utilization for the SAT, the central objective is to make the best use of the rain that falls on a given area. In order to study water as an input, small, natural watersheds were chosen as a unit for research at ICRISAT and in cooperative projects with the ICAR. Alternative land- and water-management techniques are simulated and evaluated on Alfisols and Vertisols. Improved cropping systems are superimposed on these treatments; these consist, for example, of intercrops of maize or sorghum with pigeonpea, sequential crops of maize and chickpea, etc. All cultural operations are executed using two of the important resources of farmers in the SAT: labor and animals for draft power. Thus, these watersheds are operational-scale pilot plants where the integrated effect of alternative systems of farming on productivity, resource use, and conservation can be monitored and evaluated, and where feedback to specific projects is generated. One successful means of transferring resource management technology from these operations research projects to similar environments is the use of agroclimatic classification and simulation approaches (Virmani et al. 1979).

On Farms

Region-specific knowledge on improved soil and water management must be developed

through the initiation of small-scale (10 to 50 ha), on-farm watershed management projects. To ensure success of these projects and to build the foundation for regionwide implementation and long-term continuity, these programs ought to be part and parcel of the activities of existing research institutions and coordinated research projects with involvement of action departments at national and state levels. Leadership must be provided by state and university staff. Participation of scientists in soil and water engineering, crop improvement, agronomy, economics, and sociology during the phases of project development, execution, and evaluation will be necessary; farmers must also be involved in decisions on appropriate resource development and watershed management. ICRISAT can facilitate the initiation of such projects through participation in cooperative research at a few carefully selected, representative locations.

Integrated on-farm projects for operations research on natural resource development would ideally consist of four distinct phases: the collection of basic data, the design of an improvement program in which farmers participate, the implementation, and the evaluation. Successful execution of such applied research programs in representative agroclimatic regions will probably require not less than 5 years. Such projects will serve an important training function. On-farm projects are considered essential to facilitate farmers' acceptance and to prepare the ground for later regionwide, continuing programs aimed at improved watershed management.

Regional research programs for improved watershed management would have a number of primarily technical objectives related to the specific agroclimatic environments. However, each project should also be aimed at three goals, which are of critical importance:

1. To develop holistic soil-, water-, and crop-management technology that supports the maximization of economic and social returns, especially to the less advantaged cultivators; to test if efficient labor-intensive rather than capital-intensive technology can realize this objective; to involve farmers in the technology development process.
2. To shorten the time lag between the development of new soil, water, and crop management technology at research institutes and its application on farms; to test the profitability and applicability of research results under on-farm conditions; to provide feedback on priority research needs to scientists.
3. To evolve, through field research, guidelines on the desirability and the required incentives for group action in the development of natural resources and the operation of new watershed management systems.

Benefits from On-farm Operations Research

Incidental to achieving these major goals, applied on-farm research programs in watershed management are envisaged to have an impact on several other development issues. A significant contribution would be made to:

- Assist in building institutional resources for research, training, and implementation of soil- and water-management technology; find ways to directly involve research and training institutions and graduate and postgraduate students in field research programs aimed at the solution of urgent resource management problems; increase the awareness and understanding of researchers with regard to field problems.
- Facilitate the acceptance of improved soil- and water-management technology by farmers through investigation and, where possible, removal of existing constraints of social and/or economic nature; enhance the establishment of "field laboratories" where further data aimed at project evaluation, improved research, and design could be collected; where technical solutions and organizational frameworks could be tested; where new crops, varieties, and cropping systems could be tried under improved on-farm conditions; where technical staff of action departments could be trained; and where the potential impact of an integrated improvement program could be demonstrated.
- Help bridge the apparent gap between those professionals and organizations involved in planning and construction of engineering works for soil and water control and management and the farmers who

make use of these works in an agricultural production process.

- Collect evidence on the need for a legislative framework providing the social control imperative for effective resource development and watershed management.
- Improve the planning and execution of interdisciplinary programs aimed at improved watershed management by upgrading the training and procedures at district and state levels; train extension workers to help farmers make efficient use of soil and water resources and new technology, and to adjust to new forms of organization and changes in their social and economic environment.
- Extend successful concepts evolving from on-farm research. Although area differences will result in alternative forms of implementation, improvements in (and realization of) the agricultural potential at locations selected for operations research will have a significant impact on important segments of rainfed agriculture.

Cooperative Studies on Alternative Integrated Development Approaches

Before natural resource development projects integrated into agricultural production programs are applied to large rainfed areas, it is advisable to identify and test the most promising technical, organizational, and financial development approaches on larger watersheds (exceeding 1000 ha). A few representative regions — in terms of land uses, crops, soils, and rainfall — could be selected to test the viability of alternative agricultural development approaches and to monitor results and costs as well as other requirements. The goals of such cooperative research projects would be:

- To determine sufficiently accurate and feasible procedures for surveys and quantification of the natural resource base.[3]
- To select, in consultation with farmers and development agencies, two or three viable solutions and implementation methods.
- To integrate overall land use planning and implementation (forage, horticulture, silviculture) with development of the resource base for food and cash crop production.
- To monitor progress and identify bottlenecks, to feed information back to research centers; to determine cost and results with action agencies.
- To train technical development staff in innovative implementation of new resource management and utilization technology across large areas.

Involvement of farmers in selecting and adapting technical solutions to a particular resource environment should be sought rather than implementing just one selected "package." Assuming that enough is known to arrive at integrated, effective solutions, these studies on development alternatives would contribute greatly to maintaining a problem-oriented focus for research institutions. It is evident that ultimately agricultural development programs succeed or fail with the quality of the staff involved in implementing such projects. The suggested cooperative studies would provide a real-world setting for in-service training of large numbers of technicians. Successful projects would also serve a demonstration function for technicians and farmers from other areas.

Conclusions

Present farming systems in the SAT are characterized by low and undependable yields and by an inefficient use of the rains and the soil. Thus, substantial improvement in the productivity of the resource base is required. Recent results from operations research at centers and on farms indicate that this goal can be attained through watershed-based natural resource de-

3. For example, in a typical region on Alfisols on the Deccan Plateau, the resource survey might include quantitative measurement of the soil water-holding capacities and the present water balances of tank systems; representative wells would be studied in terms of the efficiency of water utilization. Existing records would be used to determine the approximate magnitude of different components of the water balance of cultivated, grazed, and fallow areas. On the basis of such investigations, priority problem identification and the selection of potential solutions would be feasible. One should determine what might be done to better utilize the already available infrastructure before new land and water development programs are designed and implemented; short-term and long-term resource development goals would be set.

velopment and management and the introduction of improved cropping systems.

Watershed-based natural resource development and use ultimately involves the optimum utilization of the water and the soil to the benefit of the people inhabiting the land. Cooperative operations research programs must be strengthened so that integration of new technology is emphasized, interdisciplinary research is facilitated, farmers are involved in technology development, and group action questions are solved. Training of scientists and development workers in holistic approaches is essential. Only sustained, integrated development programs — executed by well-trained professionals and supported by problem-oriented applied research projects — will have the desired impact. No short-term, miracle solutions should be expected.

ICRISAT's task in facilitating the transfer and early implementation of watershed-management technology is threefold: (1) to develop effective and efficient research methodologies aimed at the generation of new farming systems; (2) to involve national research and extension agencies in the generation of viable technology and transfer methods through cooperative research programs at research centers and on farms; and (3) to assist the development of manpower to initiate and guide a gigantic training program aimed not only at technicians but also at farmers.

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Village-Level Studies as a Locus for Research and Technology Adaptation

Hans P. Binswanger and James G. Ryan*

Abstract

This paper first discusses several traditions of socioeconomic enquiries in India. It then shows how the Village-Level Studies (VLS) of ICRISAT combine several of the features of the previous traditions in a novel way. The objectives, scope, and results of the socioeconomic observation phase of the VLS are discussed next, followed by a description of the ongoing research and adaptation phase of the studies. The VLS are viewed as a locus for many types of socioeconomic enquiries and adaptive technology development and research efforts. They attempt to impart a grassroots approach to technology development at ICRISAT.

Social scientists involved in empirical research on the rural economy have used a variety of methods to gather their data. In what follows we will briefly review some previous approaches, with special emphasis on the Indian context, and try to highlight their advantages and limitations. The village-level studies (VLS) of ICRISAT combine features of most of these approaches in a somewhat novel way.[1]

The Ethnographic Approach of Anthropology

In this approach the researcher himself resides in a village or hamlet, often for more than 1 year, and collects personal observations and data on production technology, economic relationships, customs, religion, demography, and language of a particular community. Due to its enormous scope and the fact that the researcher collects virtually all his data without the help of interviewers, the scope of the technological and economic data is often limited to a few case histories of particular individuals or families. It is therefore usually not amenable to statistical analysis. This weakness is compensated for by the thoroughness of the data collection, stemming from the researcher's own involvement and from his capacity to view data in the full context of the material and nonmaterial relationships existing in the community. The somewhat standardized approach of anthropologists, supported by anthropological theories, allows a comparison of ethnographies across time and space, and the field derives most of its generalizations from such comparisons.

Special-purpose Surveys of Economists and Sociologists

These professional groups have been more concerned with statistical validation of much more limited hypotheses than anthropologists. The standard advice to a young researcher has usually been to select a fairly specific topic or hypothesis for inquiry and design a sampling frame and questionnaires as economically as possible to answer that specific question. Economy in the scope of the data collection is stressed in order to cover sufficiently large samples for meaningful statistical analyses to be performed. Most often, these studies are confined to one or a few interviews with the

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1. Collection of All India data by the National Sample Survey and the Census Organizations is not covered in this discussion; although such data are frequently used by social science researchers, most data users are usually not involved in the collection phase.

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respondents and are carried out by trained interviewers, with more or less supervision by the researcher himself. The main advantage of this approach is the speed and economy with which data to answer a specific question can be gathered and processed. Its major disadvantage is that the data are generally used only once. Anybody interested in answering somewhat different questions than the ones posed will usually find that the data have deficiencies in terms of his own purpose. Since the survey teams are most often recruited on a short-term basis, it is seldom possible to complement the existing data via resurveys.

Farm Management Studies (FMS)

In the 1950s, economists in India perceived an urgent need to collect data on the structure and performance of farm enterprises. In developed countries such data were most often collected through voluntary farm-record schemes that lacked a rigorous sampling frame. The extraordinarily successful FMS of the Ministry of Agriculture via its Agro-Economic Research Centres aimed at collecting such data for selected districts all over India on a systematic basis using trained investigators who visited the homes almost daily during a 2- to 3-year period. Under the scheme, a number of districts were covered twice at roughly 10-year intervals. The inquiries were clearly multipurpose in nature; they provided a common tabulation and reporting framework on farm structure, yields, cost of cultivation, relative profitability of various farm-size groups, input, credit use, etc. The farm management reports and the original data were used by many researchers to answer a wide variety of economic and farm management questions. Despite the often considerable time lags between data collection and reporting, the knowledge gained from these studies has provided major insights that have been widely applied in agricultural policy matters.

The studies, however, were still limited in scope; they did not include agricultural laborers as respondents, nor did they pay much attention to technical and biological aspects of cultivation. They were designed by economists for their own purposes. Also, because the original data were not computerized, access to them was not open to many researchers outside the centers where they were collected.

The FMS were replaced in the early 1970s by the Cost of Cultivation Scheme (CCS). This was done at the request of the Agricultural Prices Commission, which wanted more reliable, rapidly accessible information on the cost and benefits of cultivation of specific crops for price policy purposes. The sampling framework was shifted from an agricultural-area basis to a specific-crops basis, and the task of collection was assigned to the agricultural universities. While the scope of data collection is virtually the same as in the FMS, the reporting is usually restricted to the cost of cultivation of a specific crop. It is unfortunate that the data are not utilized to produce the equivalent of the old Farm Management Reports. Furthermore, the Ministry of Agriculture restricts the use of the data for several years so that the cost of cultivation information can be fully varified before it is released. This reduces the usefulness of the studies to other researchers. A reappraisal of the decision to drop the FMS may be in order now.

The Village-Level Studies Scheme of the Agro-Economic Research Centres (AERC)

The AERCs are usually associated with economics departments of universities and are sponsored by the Directorate of Economics and Statistics of the Ministry of Agriculture. One of their earlier tasks (since the 1950s) was to conduct village surveys that focused primarily on demographic, economic, and sociological structures of these villages. The main purpose of these studies was to find out the structural factors that contributed to or impeded development. Villages were often chosen intentionally on the basis of presence or absence of such items as cooperatives, irrigation schemes, specialty crops, nonagricultural activities, and other locational factors. Data were collected by trained interviewers. Many villages were resurveyed after about a decade. As in the ethnographic approach, insights were to be derived from a comparison of data across space and over time. A comprehensive scheme to gather, process, and analyze all these studies was implemented recently by the Institute of Development Studies in Sussex (Moore et al. 1976).

These AERC village studies were often criticized for an absence of a statistical framework of choice for the villages, which limited the generality and statistical analysis of its results; but given their purpose, this criticism is probably somewhat unjustified. Another criticism was that the process of gathering and analyzing the data was somewhat routine, which often was done by junior researchers without high level analytical skills. Only a few AERCs continue these village studies, and those who do most often carry out resurveys rather than initiate new ones.

On-farm Testing and Demonstration of Agricultural Research Results

Most coordinated crop improvement projects of the Indian Council of Agricultural Research (ICAR), the All India Coordinated Research Project for Dryland Agriculture (AICRPDA), and the All India Agronomic Experiment Scheme have found it necessary to test and demonstrate their findings at the farmer's field level. This is done by systematic minikit variety trials all over India in the case of crop improvement projects, by demonstration programs, and, more recently, by pilot and operational research projects, such as the one sponsored jointly by AICRPDA and the Drought Prone Area Program (DPAP) of the Ministry of Agriculture. The pilot projects aim at testing and demonstrating packages of new crop, land, and irrigation technologies in groups of villages, biological-technical scientists interacting closely with the farmers. In the AICRPDA DPAP projects, a team of economists works with the technical and biological scientists to evaluate the economics of the prospective technologies. In addition to the input-output data from on-farm demonstrations and evaluations, the economists also undertake studies of traditional villages outside the schemes; these are used as comparisons with the demonstration villages. Adoption studies are also undertaken. Social scientists are not involved in the minikit and other demonstration programs. Most of these efforts focus on testing and demonstration of technologies developed at research stations rather than on developing on the farm something "from the bottom up," although there is of course a considerable feedback of ideas from farmers to researchers.

Initial Approach of ICRISAT Village-Level Studies

ICRISAT's VLS were designed initially by the Economics Program primarily for its own objectives, but in close consultation with technical scientists. An attempt was made to combine the most desirable features of several of the approaches discussed in the preceding section. The following approach was therefore used:

1. Two "typical" villages having no prior history of special programs were selected in each of three agroclimatic regions of semi-arid tropical India. Three areas were included to allow comparison *across* agroclimatic zones. Two villages were chosen in each region so that, at a later stage, one could be used for the development and testing phase of technology (to be discussed later) while the other served as a control village. The villages were chosen so as to represent the typical features of their zones (Jodha, Asokan, and Ryan 1977).
2. Within each village a sample of 30 cultivators in three size classes and ten landless laborers were randomly selected as a *panel* to be monitored over a number of years. Such a large within-village sample was judged necessary to statistically test hypotheses within and between regions, villages, and socioeconomic groups within villages.
3. An investigator with a university education in agricultural economics, coming from a rural background and speaking the local language, was stationed in May 1975 in each village to interview the panel households every 3 to 4 weeks and to undertake a number of agrobiological investigations. He was also to act informally as a *participant observer*. The investigators were directly supervised by senior staff of the Economics Program who initially spent considerable time in the villages.
4. Data on agricultural operations were collected on a *plot basis* and included labor inputs and time allocation of each household member and bullock pair, economic transactions and incomes (agricultural and nonagricultural) of each household,

farm structure, and capital endowment of each household.

5. During the 1976–77 crop year, special teams of medical doctors and home science graduates visited each village four times to collect *nutrition and health* data on each household member.
6. From 1978 onwards, anthropological data collection was intensified. (For a detailed description of the data gathered see Binswanger and Jodha 1978). From the socioeconomic point of view, the VLS are broader in scope than each of the types of inquiries mentioned above, except for studies adopting the ethnographic approach. The data are collected so as to allow *statistical* analysis, and the panel approach allows easy *resurvey capability*, as well as the administration of *special-purpose surveys*, which become necessary from time to time.

All staff members doing research that involves household-to-household variation are encouraged to do their work in the context of the VLS so as to economize on background data collection and to subject the data to analysis from many points of view. This has led to close interaction within the socioeconomics program, and to a greater accumulation of complementary results on the same areas and households. This has provided more than each individual project could have provided if carried out by itself.

During the first 2 years, the VLS was used by other ICRISAT programs for farm-level observations of existing techniques and problems such as the prevalence of pests, diseases, and weeds, and the study of germination problems in chickpea (Jodha, Asokan, and Ryan 1977). Before turning to the later development of the studies — with much closer involvement of technical scientists in actual research in the villages — we briefly summarize the objectives and scope of the socioeconomic observation phase just described.

Objectives, Scope, and Results of Socioeconomic Observations

The socioeconomic observation phase, which is continuing, has two main objectives: (1) observation and documentation of existing practices to help in the assessment of research priorities and potential technology and (2) generation of a data bank for a broad range of socioeconomic inquiries.

The first objective — observation and documentation of existing practices — is the most important to ICRISAT's Economics Program in terms of the overall ICRISAT objectives. Sufficiently detailed data at the farm level — with attention to technological factors — simply did not exist for the semi-arid tropics of India in 1975. The following studies were geared towards this objective and drew extensively on village-level study data.

1. "Resource base as a determinant of cropping patterns," by N. S. Jodha (1977), documents the important effects of resource endowments on cropping patterns and practices. In particular, it analyzes the importance and complexity of intercropping in poor soil-climate environments and on small farms. This study has helped justify more intensive intercropping research at ICRISAT.
2. "Economic aspects of weed control in semi-arid tropical areas of India," by H. P. Binswanger and S. V. R. Shetty (1977), documents the relatively high levels of human and animal techniques of weed control in these environments. Together with budget studies, which demonstrated that chemical weed control would be much more expensive than existing weed control practices and also highly labor displacing, these findings have led ICRISAT to deemphasize chemical weed control in the Indian part of its research program.
3. "Factor proportions, factor market access, and the development and transfer of technology," by J. G. Ryan and M. S. Rathore (1978), demonstrates that factor *endowments* differ widely on large farms and small farms but *factor use ratios* between small and large farms differ much less among the groups, although there is a large variation within the group. The closeness of the factor use ratios suggests that there would be little justification in India for developing separate technologies with basically different capital-labor ratios for small and large farms. Support for small farms must be

sought primarily via improvements in their access to modern inputs, credit, and extension.

4. "Risk attitudes of rural households in semi-arid tropical India," by H. P. Binswanger (1977), is based on a large special-purpose psychological experiment carried out with the panel households, supplemented by the general VLS background data. It demonstrates that risk attitudes differ little between small and large farmers in these six villages; nearly all of them are moderately risk averse. This suggests that not much can be gained by developing technologies with differential risk/return characteristics for small and large farmers. Emphasis has to be on relatively profitable and stable technologies for all farmers and support of small farmers via improved access to credit and inputs.
5. "Labor use and labor markets in semi-arid tropical villages of peninsular India," by J. G. Ryan, R. D. Ghodake, and R. Sarin (1979) looks at existing and potential labor and bullock-power bottlenecks in the study areas by comparing the existing labor use and availability patterns with those experienced in the research watersheds at ICRISAT Center. The study suggests that important new labor peaks could arise at harvest time if improved technology were to be introduced. It also documents the overriding importance of female labor in SAT agriculture and the extraordinary handicaps faced by female workers in rural labor markets compared with male workers.

The nutrition data are still being analyzed to further improve our understanding of human nutritional dificiencies and thus to help us determine what type of nutritional objectives — if any — it makes sense to include in our plant breeding programs.

The cultivation data are now being intensively analyzed to provide a comprehensive set of input-output coefficients for traditional technology. These will be used along with comparable input-output coefficients from research station experiments at ICRISAT and elsewhere, in benefit-cost analysis of potential technology. This is a particularly good example of how VLS data are used in conjunction with data from other sources. Activity analysis models are presently being constructed to provide a comprehensive framework for technology assessment.

The second objective of the socioeconomic phase — generation of a data bank for a broad range of socioeconomic inquiries — goes beyond technology assessment. It includes the collection of information that will help in formulating general socioeconomic policy in the SAT. Household data are an important source of such knowledge and the VLS are our primary source. Studies toward this objective based on the VLS data include:

1. "Role of credit in farmers' adjustment against risk in arid and semi-arid tropical areas of India" (1978) and "Effectiveness of farmers' adjustment to risk" (1977), both by N. S. Jodha. They demonstrate the high cost and relative ineffectiveness of the farmers' own measures to reduce the risk of farming in these areas of India and to adjust to drought and scarcity conditions. Together with the work on risk attitudes, they suggest that the high risk levels of SAT farming may lead to a general underinvestment of resources by farmers of the SAT relative to the socially optimum level. Furthermore, it appears that the official credit institutions are thus far ill-equipped to reduce the exposure of Indian farmers to these risks because they cannot or do not provide consumption loans to drought-affected farmers. On the other hand, public relief employment appears to be remarkably effective in meeting its objective; strengthening of that effort appears well worthwhile.
2. "Some aspects of agricultural tenancy in semi-arid tropical parts of India," by N. S. Jodha (1979). The author uses the close involvement of investigators in the villages to gather detailed tenancy data of an unusual quality and depth. He finds that renting of land by large farmers from other large farmers and from small farmers has become an important feature of the SAT. While resource adjustments are the most important reason for tenancy, there are many other complex reasons as well. The idea of the small and highly exploited tenant clearly needs to be revised, along with the notion that tenancy laws can be

enacted that will primarily benefit the small-farmer group. The situation is much more complex than believed, and well-intended legislative efforts can lead to unintended results. The same data are now being used by a Ph.D. student from the Indian Statistical Institute for a further detailed inquiry into all aspects of tenancy.

3. A Ph.D. dissertation by M. S. Rathore, a scholar from Himachal Pradesh University. He has used the VLS data to reinvestigate all aspects of the farm size-productivity controversy. He finds no uniform productivity advantage in small farms; in some areas small farms have higher total output per hectare and in others they appear to be less productive than the large ones. But he confirms that large and small farms pursue very different strategies to achieve their production levels. Large farms rely more on purchased inputs and have modest labor inputs, while small farms compensate for their low borrowing capacity primarily by more intensive and apparently more organized labor inputs.

In the coming year, the VLS data will be used by ICRISAT staff for an econometric analysis of seasonal-labor supply-and-demand behavior and for analysis of the relative access of small and large farmers to credit, to modern input markets, and to output markets; of the distribution of income and its sources in the study areas; and of the determinants of fertilizer use on semi-arid tropical crops. Other special-purpose inquiries may be initiated from time to time.

The richness of the data is not exhausted by these inquiries. We encourage ICRISAT staff and outsiders to make use of it. Our capability to provide the data to outside researchers has been hampered by the enormous problems of computerizing a data base of this size. We are currently reducing the amount of data processed by computer in order to speed up this operation, and the software to handle it has also matured. We were probably overambitious in the scope of computerization we planned. As a result, there has been a predictable slowdown in the operation. However, we feel that in the long run computerization of a large portion of the data is essential for easy access by researchers inside and outside of ICRISAT.

The Research and Adaptation Phase

Interaction with technical and biological scientists was sought from the beginning of the VLS. During the first 3 years, the socioeconomic staff reported their observations by means of informal tour reports. More importantly, the economic investigators were trained by the ICRISAT programs concerned to make systematic observations of disease and pest incidence, nodulation of legume crops, small germination experiments in chickpea, etc., and they were visited in the villages by the biological scientists. From 1977–78 onwards, one important component of the intercropping entomology research was transferred to farmers' fields, where it is carried out according to normal experimental procedures with replications, etc; because such research needs to be done on large plots in an environment in which pests are not disturbed to the extent they are at an experiment station. Furthermore, uniformity of soil is not as important in entomology experiments as in some other research projects. We anticipate that other research programs will find it useful from time to time to escape the land pressure and special conditions of the experiment station and do research in village conditions.

In 1977–78, the Farming Systems Research Program of ICRISAT started an experiment to assess the potential yield effects of herbicides over and above the yields achieved by the farmer's traditional weed control methods. The treatments contained weed-free plots, plots where farmers used their usual methods, and plots that were partially or totally treated with herbicides. The particular advantage of such research in farmers' fields is that one is sure of getting the "traditional" treatment right and does not set up control treatments that underestimate or overestimate the farmer's capacities. During the 2 years of the experiment, no yield effects of herbicides over and above the farmer's treatments could be statistically demonstrated (Davis 1979).

Starting in 1977–78, the Farming Systems Research Program also initiated studies of traditional tank irrigation systems in two villages. These involved the measurement of the actual flows of water, including ground water levels in

the irrigated command areas of these tanks, to determine the water use efficiency of the systems. It became necessary at that stage to hire technical staff in these villages to make the daily measurements.

At about the same time, sufficient results on the watershed-based soil and water management systems of the ICRISAT Farming Systems Research Program became available to narrow down the technical possibilities enough to make it worthwhile to pursue further research under local conditions at the level of the farmer's field. This had to be a collaborative effort between farmers, technical scientists, economists, and the anthropologist, because it involved technical, economic, and social problems of group action or collaboration among the farmers of a watershed. Research on group action problems of watershed-based soil and water management systems cannot be done at a research station, and their solution is a precondition for successful implementation of the concept.

Furthermore, technical adaptation of the concept to local soil and climate conditions made it imperative to associate the project with AICRPDA, with its research stations in Hayatnagar, Sholapur, and Akola as well as the coordinating cell in Hyderabad.[2] Other institutions collaborating with us are Andhra Pradesh Agricultural University, Punjabrao Krishi Vidyapeeth, Akola, Mahatma Phule Krishi Vidyalaya, Rahuri in Maharashtra, and the Central Soil and Water Conservation Research and Training Institute in Dehra Dun. The broad geographical experience of these institutions is necessary in defining the technical treatments at each of the three locations. Particularly in the definition of agronomic treatments, we rely heavily on the experience of the local centers of the AICRPDA, which specify the recommended varieties, fertilizer levels, etc.

During the 1978–79 crop season, an area between 2.5 and 4.0 ha in one village in each of the three agroclimatic regions was planted to a series of replicated trials in which the major purpose was to test the effects of improved land management systems on dryland cropping systems, which are typical or potentially important for the farmers of the areas. In the current year, in two of the three villages, full watershed land treatments have been implemented on areas of close to 20 ha overall. In a third village, it was difficult to gain the cooperation of all farmers on the experimental watersheds during the current year, but isolated treatments have been implemented on the fields of two farmers as an initial step. Agronomic experiments continue. To carry out this additional experimental load, one agronomic/technical staff member at the Technical Assistant level has been stationed in the three villages on a permanent basis; he is backed by visits of the concerned scientists.

Unlike the demonstration programs and pilot projects discussed in the first section, the goal of these studies is not demonstration of a fully or partially developed technological and institutional package of watershed-based soil and water management treatments; instead, the focus is on *adaptation of such a concept to the local agroclimatological and sociocultural conditions and feedback to researchers from the grassroots level*. It is well understood by all involved, including the farmers, that this process will be difficult. However, the village locus is the proper experimental setting for such adaptive research. Only there will the real problems have an opportunity to express themselves and thus lead quickly to the necessary changes in the technological and institutional options. The choice of the villages of the VLS makes profitability assessment of watershed treatments relatively easy, since the data on the panel households provides a "comparison treatment" both before and in every given year of the study. Furthermore, one village in each region is left unaffected, to serve as a control for assessing hidden impacts of a substantial research effort in the other villages. Thus we have comparisons both "before and after" and "with and without."

Should this research effort lead to successful development of adapted technology options, the villages would serve for demonstration purposes, but national programs would then have to move towards a more comprehensive demonstration and implementation phase. ICRISAT's mandate does not include extension.

Conclusions

The ICRISAT Village-Level Studies have pro-

2. These centers had assisted us from the start of the VLS, especially in the choice of villages.

vided a rich variety of opportunities for research.

For socioeconomic research, the semipermanent nature of the studies provides a unique setting for all inquiry that involves household-to-household and agroclimatic variation. By combining features of ethnographic research, special-purpose surveys, farm management studies, village studies, and on-farm biological/technical experimentation, the VLS provide flexibility in data collection and a rich data bank. They perform the same function for the socioeconomic researcher that the experiment station or laboratory performs for the technical/biological scientist. They provide a *locus for research*, or a tool to be used in a variety of studies. By channeling the analytical capability of a number of socioeconomic researchers inside and outside of ICRISAT on the same data base, they produce complementaries which add up to more than the simple sum of the individual results and insights.[3]

For the technical/biological researcher, the studies serve as an extension of the experiment station outside its physical confines, to be used in a variety of ways as dictated by the changing needs of individual researchers or programs. Research can be carried out in the villages under actual farm conditions and/or when land requirements exceed the land resources available at the research station.

From the point of view of *technology development and adaptation*, the studies have two main functions: first, they serve as the most important data source (but not the only one) for specific studies assessing research priorities and prospective technology; second, they provide a locus for a multidisciplinary effort on what may be the most difficult research problem of the semi-arid tropics: generating improved soil-, crop-, and water-management techniques that are adaptable to different agroclimatic, economic, and sociocultural environments. We believe that the village is the best environment for this effort. It involves farmers and scientists from the national program, as well as from ICRISAT, and we hope that it will continue to be successful. The VLS are our approach to the philosophy of agricultural research from the "bottom up" and development emphasized by Newman, Ouedraogo, and Norman (1979), Chambers (1979), and others.

3. One of the major problems of much survey research is that it appears to be easier to collect data than analyze them. Large bodies of data are therefore often unexploited. The VLS have been relatively successful in achieving a better relation between analytical and data-gathering effort.

Acknowledgment

The Village-Level Studies of ICRISAT would not have been possible except for the collaboration of the All India Coordinated Research Project for Dryland Agriculture and the respective Agricultural Universities in Hyderabad, Akola and Sholapur, the collaborating research programs of ICRISAT and the assistance of the ICRISAT computer section. Their help has been highly appreciated. Among the ICRISAT socioeconomic staff, who were almost all involved, the effort of the resident economic investigators S. S. Badhe, T. Balaramaiah, V. Bhaskar Rao, M. J. Bhende, N. B. Dudhane, and K. G. Kshirsagar deserves a special mention.

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Summary of Discussion – Session 3

Dr. Tiwari expressed the opinion that the agricultural tools for use by SAT farmers should be as simple and inexpensive as possible, improvising on tools already evolved over the ages and fitted to the farmer's particular soil type. He felt that ICRISAT's wheeled tool carrier is too sophisticated for SAT farm use.

Dr. Swindale remarked that the question of appropriate technology is exceedingly difficult. He warned against the danger of making technology so appropriate that it represents no advance at all.

Dr. Swindale also pointed out that no single institution can deal with all problems in all the socioeconomic and ecological niches in the world. To make changes requires both skill in transferring technology and an understanding of how innovations are diffused. For this reason, it is essential to develop a wide network of research.

Dr. Mengesha commented that technology handed out free often fails, whereas that requiring recipients to share in planning and expense is likely to be effectively transferred.

Dr. Hutchinson was asked what mechanism could be devised for linking funding agencies, which often do not coordinate their efforts in supporting agricultural research. He replied that there was no easy solution to this problem; funding agencies must look at what returns a program offers a donor and must also maintain the identity of funds from various sources. He commended the CGIAR for doing an excellent job.

Considerable discussion centered on the findings of ICRISAT's Village-Level Studies:

Mr. Russell commented that the VLS finding that small and large farmers differ little in their attitude to risk is surprising but encouraging, as graded risk is difficult to build into technology. However, getting credit poses a bigger risk for the small farmer than the large farmer, and failure to repay may bar the smallest farmers from access to credit. Therefore too easy credit, without proper supervision, is undesirable. He suggested providing the smallest farmers with alternative means, other than credit — such as provision for saving income from paid labor — for obtaining needed inputs.

Dr. Lipton remarked that relationships in a village — between landed and landless, surplus and deficit farmers, etc. — determine to a large extent who gets the most benefit from new methods and increased productivity. Some typology of village behavior and relations might be needed to ensure that benefits reach the poorest.

Dr. Binswanger replied that ICRISAT did not propose such a study; this is properly the task of national programs.

Mr. Melville pointed out that there is an important distinction between contacts made for gathering information in a village and those made for extension purposes. An extension agent must first work with the farmer most willing to risk trying new methods rather than with the village as a whole.

Regarding soil and water management on a watershed basis, Dr. Randhawa observed that even where cooperative action is possible, a problem arises in sharing the water harvested and the benefits of increased productivity. Distribution cannot be based solely on area of individual holdings, as the productivity of different segments varies. It was observed that constructing ponds on communal property poses no difficulties, but problems arise where individual holdings are involved.

Dr. Kampen said consolidation of land is not a prerequisite to improved resource management, but if such consolidation is taking place, land and water management systems can be developed to accompany it. He emphasized that ICRISAT offers no miracle solutions to the farmer. The approach in the on-farm experiments is to discuss with the farmers a range of possible means for improving productivity and help them choose the one best for local conditions. Thus, in Aurepalle, development is taking place without altering individual holdings; in Shirapur, the farmers have agreed to ignore farm boundaries for the duration of the experiment, though this does not mean that parcels of land are exchanged.

Mr. Melville commented that it is not always possible to introduce innovations in the ideal order; they must be introduced in the order most readily acceptable locally. For instance, in

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an experiment near Indore, a realignment of drains to prevent water from draining across fields raised croppable land in the rainy season from 30% to above 70%. This, in turn, led to interest in other possible innovations. Dr. Doherty observed that in SAT Indian villages, the unit of management decision is the individual family; success in watershed-based technology depends on respecting this basic unit.

Responding to a question from Dr. Joshi on risk management, Dr. Virmani stated that at ICRISAT drought risk is being quantified. In regions with assured initial rainfall, dry seeding is possible; in other regions, either new types of seed must be developed, or seeding must be done after moisture is conserved to a depth of about 20 cm.

Dr. Sekhon suggested that agroclimatology research should define areas, based on soil and climate types, where a successful *kharif* (rainy season) or *rabi* (postrainy season) crop, or both, can be grown, and indicate management practices to go with each.

Dr. Virmani said that despite similarities in soils, climate, and other conditions — as, for example, between Hyderabad and Sholapur — specific technologies cannot always be transferred from one location to another. An appropriate technology for a given area can emerge only when a full picture is available of soil characteristics, climate, and socioeconomic conditions, and when all available resources are considered.

Dr. Gill observed that a distinction needs to be made between horizontal (experiment station to experiment station) and vertical (experiment station to farmer) transfer of technology. The latter can only be accomplished by local people who are familiar with the particular social and economic structure of the area and can gain the confidence of the farmers.

Session 4

ICRISAT Cooperative Programs for Transfer of Technology

Chairman: W. K. Agble
Co-Chairman: A. Blumenschein

Rapporteurs: R. W. Willey
M. R. Rao
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ICRISAT Cooperative Programs: an Overview

R. C. McGinnis and C. Charreau*

Abstract

A major objective of ICRISAT cooperative programs is to strengthen the national research effort without duplicating or competing with it. The Institute exchanges genetic resource material with more than 40 cooperating countries; assists in training research workers; organizes international seminars and workshops to promote scientific interaction; and provides technical assistance to fit the particular needs of each country. In Africa, which contains 66% of the world's semi-arid tropical area, cooperative programs have received top priority and made good progress in both research and training. In India, an excellent two-way transfer system has been established. Cooperative programs have also been set up in other Asian countries and in Central and South America; further expansion is envisaged in keeping with ICRISAT's increasing international responsibility.

A basic premise in the establishment of ICRISAT was that the Institute would serve to strengthen and support national research programs on production of the five ICRISAT crops, both in the host country and in other nations of the semi-arid tropics (SAT). The major objective is to generate improved genotypes and technology to increase and stabilize food production. The form of assistance and cooperation may differ considerably, depending on each country's specific requirements, but at all times the assistance must be supportive and not duplicate or compete with the national program. It is essential to work in close harmony with national programs and with other agencies having mutual concerns and interests.

According to the climatic definition of the semi-arid tropics, most of the area (66%) is in Africa. The SAT regions form a wide belt below the Sahara desert, extending the width of the continent and south through East Africa to include large areas of southern Africa. In Asia, the SAT cover much of India, northeastern Thailand, and other smaller areas. Other SAT regions of the world include large sections of Mexico, Central America, northeastern Brazil, Paraguay, and northern Australia.

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Strategy for Strengthening National Research Systems

An objective of all international centers and agencies working within a country or region is to strengthen national research systems. Obviously, there is no simple single answer to the question of how this can be most effectively achieved. The countries with which an international center cooperates vary considerably in scientific expertise and infrastructure development; each country has its own particular combination of strengths and weaknesses that sets it apart from its neighbors.

Perhaps the ideal in working relationships between international and national research programs with an effective two-way transfer system is being approached by ICRISAT and its host government, India. From the earliest stages, ICRISAT has enjoyed the counsel and advice of senior members of the Indian Council of Agricultural Research (ICAR) and — under formal working agreements with ICAR — continuing collaboration with the All India Coordinated Programs and the Indian agricultural universities. Admittedly, India has a scientific resource base and sophisticated research and extension service not equalled in many countries, but we feel that much of the Indian experience can be applied elsewhere.

ICRISAT, like many international centers, has

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the capability of assisting national programs in four main areas:

1. Provision and exchange of germplasm. There is universal interest in strengthening national breeding programs; consequently, ICRISAT routinely supplies source material and various nurseries for screening, testing, and hybridizing to more than 40 cooperating countries. In return, ICRISAT has access to the indigenous genotypes within national programs, and has built up a broad-based genetic resource for further refinement and distribution. Proper storage facilities are under construction for maintenance of this valuable international genetic collection.
2. Assistance in training. ICRISAT considers training to be among its most important activities; the eventual goal is to make the research capability of cooperating countries self-sufficient. Various forms of training, designed to fit the particular needs of each country, are offered.
3. Promotion of scientific interaction. A third activity useful to all cooperating national systems is the convening of workshops, seminars, and conferences to promote scientific interaction and communication. Participants can also visit research programs and facilities at other institutions simultaneously. So far, ICRISAT has organized nine international workshops in various areas of research.
4. Provision of technical assistance. The fourth area where international centers can strengthen linkages with national programs is in providing technical assistance. The most appropriate form, whether short-term consultancy or long-term assignment, depends on the indigenous scientific strength and the actual organization of human resources within the host country. Although ICRISAT has only 4 years of experience in this type of cooperative activity, response from countries where scientists have been posted is encouraging.

Role of ICRISAT Scientists in Cooperating Countries

Agreement between ICRISAT and the host countries vary by country. Generally, the program of each ICRISAT scientist posted in a cooperating country has three components:

1. A direct contribution to the national program.
2. A contribution to the regional program, consisting mainly of the organization and supervision of regional trials and consultancy visits to neighboring countries.
3. A contribution to the international program in supervision of trials or nurseries to provide ICRISAT Center with information on the behavior and performance of different genotypes in various ecological situations. An important function is to provide germplasm from cooperating countries for inclusion in the germplasm collection and the breeding programs at ICRISAT Center.

The demarcation between these three components is not always clear and may sometimes appear to be somewhat arbitrary. However, in each situation, an attempt has been made to establish this tripartite role so that the relationship between ICRISAT scientists and their colleagues in the national programs can be defined and close working links can be forged. The relative importance of the three components may vary considerably both between countries and between scientific disciplines. As far as possible, ICRISAT scientists are integrated into the local research centers and are expected to follow the general working regulations of those centers; however, ICRISAT scientists have full control of the allocated funds, thereby maintaining the degree of autonomy necessary to effectively carry out their assignments.

On the whole, these arrangements with the national research services have proved satisfactory both scientifically and administratively. By such close association with national research, the ICRISAT scientists become fully aware of the research problems in host countries, of the progress of national research services, and of the various constraints on host country research and extension. The scientists are thus in the best position to reappraise their programs regularly to make them more meaningful. They have an important role in providing practical training to local technicians, and, in some cases, scientists on the staff; they also often identify candidates for training at ICRISAT Center. The exchange of both scientific informa-

tion and seed material between ICRISAT and the national research services is very free under these conditions. It is, in fact, a true cooperation, in the full sense of the word, in that there is reciprocal benefit for both parties.

Two main principles are followed regarding the transfer of new technology and improved germplasm to cooperating countries:

- This transfer is made only through the national research institutions, never directly to extension or development agencies.
- The transfer is not encumbered by any requirement of special references to ICRISAT. With improved germplasm, particularly, the local research institutions are free to choose any ICRISAT material for release to farmers and to label it as they wish.

ICRISAT Cooperative Programs in Africa

Growing population pressures in Africa have resulted in large food deficits in some of the more populous countries. Production of food in the continent over the last few years has failed to keep pace with population growth and with production in other regions. While some of the decline in output is due to the unfavorable weather of recent years, it is clear that the traditional farming systems have been unable to respond adequately to the demands of rapid population growth. The food prospects for sub-Saharan Africa are gloomy if these semi-stagnant trends in food production continue.

Accelerating growth and alleviating poverty in sub-Saharan Africa will depend primarily on the provision of additional impetus to agriculture, particularly in the small-holder sector, and secondarily on the pace of creation of employment in industry and direct action to improve essential public services.

For this reason the Doggett-Sauger-Cummings Report of October 1971 gave highest priority to the African SAT in the development of ICRISAT's programs of international cooperation. The ICRISAT Governing Board fully endorsed the recommendation and encouraged donors to provide special project funding for this purpose. Substantial progress in program implementation has been made since 1975, as described below. In this presentation western and eastern Africa are considered separately.

The West African Program

Within the West African program, several subprograms can be distinguished, all of which are closely linked technologically, whatever their source of funding. The oldest and most important is the UNDP/ICRISAT West African Cooperative Program.

The UNDP/ICRISAT West African Project

In January 1975, ICRISAT and UNDP entered into contract with the prime objective of cooperating with and strengthening existing West African agricultural research programs to develop higher-yielding varieties of sorghum and millet with consistent and reliable yield characteristics and to develop technology to accompany these varieties. The drought-stricken Sahel area below the Sahara was the focus of concern. Sorghum and millet are the staple foods for the majority of the people in this area and the food:population ratio is seriously disturbed.

Initially, the project covered 12 countries from Senegal to Chad, including nine French-speaking and three English-speaking countries. In 1977, following a request from Sudan for technical assistance to their national sorghum and millet improvement programs, Sudan was included in the UNDP/ICRISAT contract. Twelve scientists currently work under this contract.

Implementation of the program has proceeded steadily and carefully. Initial problems of logistic support and formulation of acceptable agreements were overcome with the assistance of the UNDP officials in each of the cooperating countries. Because ICRISAT scientists are posted in national research stations and can benefit from the existing laboratory and office facilities of these stations, construction of buildings was usually unnecessary, except in the Kamboinse station near Ouagadougou and in the Wad Medani station in Sudan. The program became fully operational for the crop year 1977 and has now entered its second phase.

The ICRISAT/Mali Program

In March 1976, in response to a request for

assistance from the Government of Mali, the Ford Foundation provided funds for an agronomist-breeder for sorghum and millet improvement to be stationed at the Sotuba Research Station near Bamako. A USAID grant, renewable annually, has subsequently maintained the program. Under this grant, a small laboratory and office facilities have been constructed at Sotuba. The USAID grant was extended in 1979 and, jointly with the Ciba Geigy Foundation, will help develop a full-scale agronomic research station in a drier area, near Segou, where both ICRISAT and national scientists will be accommodated and work together for the improvement of cereal production in the central zone of Mali (annual rainfall 400 to 900 mm).

Recent Developments in the West African Program

A project entitled Semi-Arid Food Grain Research and Development (SAFGRAD), designed to strengthen the research capability in West Africa through contractual arrangements with ICRISAT, IITA, and U.S. universities, was initiated by USAID and placed under the responsibility of the OAU/STRC (Organization for African Unity/Scientific, Technical, and Research Committee). Other donors, including the French and British governments, are also expected to contribute to the project.

Under the provisions of the USAID/ICRISAT contract, signed in 1978, ICRISAT posted a sorghum breeder at the Institute for Agricultural Research, Samaru, Nigeria, in 1979. Two other scientists, a cereal entomologist and a production argonomist, are being recruited and will shortly join the ICRISAT team at IAR. ICRISAT will also post a soil-management agronomist at the Kamboinse research station in Upper Volta.

SAFGRAD has also assigned a number of officers under the Accelerated Crop Production Program directly to national programs. These workers are conducting multilocation trials of the improved cultivars generated by the cooperating research centers.

In 1979, a cereal breeder for *Striga*, a cereal entomologist, and a production economist were added to the ICRISAT team in Upper Volta. Also in Upper Volta, a project proposal is being finalized to develop watershed management studies on the heavy clayey soils of the area developed by the AVV (Aménagement des Vallées Voltas; Volta Valleys Authority), after eradication of river blindness. A pilot study will be undertaken to identify methods for improved resource management that will facilitate agricultural development in semi-arid regions of West Africa. The main donors will be USAID and the Government of the Netherlands, with ICRISAT and the Government of Upper Volta also contributing.

Work Accomplished in West Africa

After a relatively slow start, because of the time required to fill the research positions, a good deal of progress has been accomplished both in research and training, considering that crop improvement, which constitutes the core of the research program, is a long-term process. During this first phase of the project:

- the major research problems specific to the target crops in this environment have been identified;
- the methodology for dealing with these problems has been defined;
- local germplasm of sorghum and millet has been collected and evaluated and a significant amount of exotic germplasm has already been introduced and distributed to the cooperating countries;
- some promising results have been achieved in the introduction and/or introgression of exotic materials, especially with sorghum. Likewise, important disease resistance sources in millet have been located for the Center program;
- promising results have also been obtained in crop management, land management, and intercropping studies;
- good cooperation has been developed between ICRISAT and national scientists in all countries where ICRISAT scientists are posted;
- national research capabilities have been strengthened and a significant contribution has been made to the transfer of technology through the participation of West African scientists in various conferences and through training of scientists and technicians at Hyderabad.

We can expect to see substantial progress in millet and sorghum improvement during the

next few years — perhaps more in sorghum than millet — as the adaptation of exotic materials to the West African environment seems to be more difficult in millet due to disease factors. There are good prospects for progress in agronomy, with emphasis on more efficient utilization of environmental and biological factors in combination with locally available inputs as a realistic alternative to basing yield improvement primarily on imported inputs.

The East African Program

The focus of ICRISAT's early efforts in Africa has been on the critical food production problems in West Africa. Since December 1977, the Institute has started programs in East Africa as well and has a sorghum breeder and a millet breeder working in Sudan under UNDP special project funds.

In Tanzania, through a subcontract with IITA, provision has been made for a sorghum breeder and a millet breeder to be posted at the Ilonga research station, as part of an overall Tanzania/USAID/IITA agricultural research project in which CIMMYT and ICRISAT also participate.

Future Development of ICRISAT Cooperative Programs in Africa

It is clearly recognized that in relation to the magnitude of the task in SAT Africa, present staff numbers are inadequate and should be augmented in several disciplines. A number of research requirements that are peculiar to Africa cannot be adequately tackled at ICRISAT Center.

In its final draft report dated December 1978, the ICRISAT Quinquennial Review (QQR) panel strongly endorsed the concept of strengthening the African Program, proposing that core funding should be provided for regional programs as distinguished from support to national programs, which would continue under special project funding. This is consistent with the view that the criteria for core funding should be that:

- the research is clearly within the mandate of the Institute;
- the research requires long-term support and it will be at least regional in relevance.

These two conditions are clearly met in the ICRISAT cooperative programs in Africa.

The QQR panel recommended that regional programs be developed at a few carefully selected representative sites, with a degree of flexibility within the network to allow for phasing out of programs or shifting of location as required. ICRISAT agrees with the QQR recommendations, and they have been taken into account in the proposed development of cooperative programs in Africa. Already existing programs in Africa can serve as a basis on which to build and relatively few new key sites may be necessary to fill in the important gaps.

Future Development in West Africa

In West Africa, the ICRISAT regional network will be organized around two main multidisciplinary teams, the first sited in a predominantly millet area (400–500 mm annual rainfall), the second in a predominantly sorghum area (700–800 mm annual rainfall).

High priority is assigned to the development of a regional ICRISAT program on pearl millet improvement and associated farming systems technology applicable to the drier, sandier soils where water is limiting. Preliminary investigations have been made in West Africa to determine a suitable location for this unit, which should be in the heart of the millet-growing region in a country that depends almost exclusively on millet as its staple cereal. A final decision on the specific site is pending, but it is envisaged that this unit, when fully staffed, will adequately serve the long-term research needs of the region.

For long-term research in sorghum, the Kamboinse research station, Upper Volta, appears the most appropriate location. It is in the main sorghum growing area (precipitation 800 mm) and is the base of the most comprehensive ICRISAT program launched so far in West Africa. This team, to be expanded as needed, is considered adequate to serve regional and national requirements in sorghum improvement research.

At the Kamboinse station, shortage of land may hamper the development of new research activities, especially on land and water management. A number of alternatives are being considered to alleviate this problem, including government purchase of adjoining land and provision of a nearby site for some of

the programs. Some use may also be made of the Saria research station facility, 70 km from Ouagadougou, which is underutilized at present.

The land and water management program research must be conducted at the station and on the farm, with initially several years of on-station research. The station must be a benchmark site carefully chosen on technical criteria and it must be under ICRISAT's control. ICRISAT will be able to undertake long-term research in farming systems only if the government is able to provide land that meets these criteria.

In addition to these two main multidisciplinary teams, to be mainly funded in the ICRISAT core budget, existing smaller teams, funded under special projects, will continue to be posted in research stations of various countries and will work in close cooperation with the national research services. These include a team of five scientists in Samaru, Nigeria; a team of two scientists in Bamako-Segou, Mali; a team of two scientists in Bambey, Senegal; and one scientist in Maradi, Niger. The present research teams may be increased and others created, as needs are identified.

About 30 ICRISAT scientists are expected to be stationed in semi-arid West Africa in the near future to work on sorghum, millet, and groundnut improvement as well as on related farming systems.

Future Development in East and Central Africa

Future programs in this area will concern sorghum, millet, groundnut, and pigeonpea improvement. ICRISAT already has one sorghum breeder and one millet breeder in Sudan, and one sorghum breeder in Tanzania; a millet breeder will be recruited soon for Tanzania. There is a need for entomological research on sorghum and millet in Tanzania and neighboring countries, and it is proposed that ICRISAT fill this serious gap as soon as possible.

In further development of a north-south African network, there is an obvious need to focus on the improvement of high-elevation, cold-tolerant sorghums. Except for an excellent ongoing program in Ethiopia and the work in Mexico, this class of sorghums has been mostly neglected; yet these sorghums are a major source of food not only in the highlands of Ethiopia, but also in Somalia and Yemen, and in the region of Western Uganda, Rwanda, Burundi, and eastern Zaire.

It is tentatively proposed that ICRISAT post in Ethiopia a senior breeder of sorghum, who would also be team leader, to be closely associated with the present national program headquartered at Nazareth, and a second breeder in the highlands of Kenya, at Kitale. These breeders would collaborate closely with the newly established FAO sorghum improvement program based at the Katumani research station, near Machakos, and would also be responsible for developing a network of multilocational trials in other countries in the region.

Concerning groundnut improvement, the QQR panel suggested that ICRISAT consider initiating a program in East or Central Africa to assist the national programs in the region. In view of the potential value of the crop both domestically and as an export commodity, research on groundnut should be given high priority.

Although a number of possibilities exist for locating an ICRISAT groundnut program, Malawi is probably the most appropriate country in view of the importance of the crop there and the backup support that could be provided by the national program. Other countries that might also be considered are Tanzania, Sudan, and Zambia.

Because pigeonpea is an important pulse crop in East Africa, it would be desirable to post a breeder/agronomist at the Katumani research station to work closely with the ICRISAT Center program in breeding pigeonpea and to investigate improved agronomic practices under East African conditions. There would also be close interaction with the national program.

ICRISAT Cooperative Programs in Asia

It was stated earlier that very close collaboration in both sorghum and millet research has been established between the Indian national program and ICRISAT and that this is serving as a pattern for cooperative links elsewhere. A study of the links with the Indian program is beyond the scope of this paper and, because of

the extensive and detailed nature of the cooperative agreement between ICRISAT and ICAR, will not be discussed here. It should be mentioned, however, that there is an exchange of germplasm and nursery material between the two research organizations, and that ICRISAT carries out experimental work at five research centers in India that provide a range of ecological conditions for special studies on sorghum, millets, chickpea, and pigeonpea. These centers are at agricultural universities located at Bhavanisagar (TNAU), Dharwar (UAS, Bangalore), Gwalior (JNKVV), Hissar (HAU), and Srinagar (J & K Govt.). In addition, our farming systems program has established cooperative research projects at a number of centers with agricultural universities and the All India Coordinated Research Project for Dryland Agriculture.

ICRISAT is also establishing closer cooperation with a number of other Asian countries, including Pakistan, Thailand, Burma, Sri Lanka, Bangladesh, and — most recently — the People's Republic of China. The development of closer ties is under way with some of these countries, and various forms of assistance, although relatively modest, have been provided by ICRISAT.

Since most Asian countries have rather well-developed agricultural and extension systems, with many highly trained scientists, the requirement for permanent ICRISAT staff to be posted in the region is likely to be modest. At present only one case is under discussion — for strengthening research in land and water management in Thailand, with the possibility that one ICRISAT specialist may be required. Other opportunities for closer cooperation will continue to be explored.

In the Middle East, a chickpea breeder has been posted at ICARDA in Syria in order to coordinate chickpea research in the region and to integrate the ICARDA and ICRISAT programs. This arrangement also provides for the acceleration of the breeding program at both centers, since the growing seasons are different and enable two generations per year to be grown under rather different environments.

Cooperative Programs in Central and South America

A first ICRISAT contribution concerns the high-elevation cold-tolerant sorghum improvement program. Under IDRC funding, a sorghum breeder was headquartered with CIMMYT, Mexico, in December 1975. This program was originally undertaken by CIMMYT, but responsibility for its continuation was transferred to ICRISAT in January 1977. The major objectives are to extend sorghum adaptation to the highlands in the developing world in order to intensify land use and to stabilize grain sorghum production in fringe areas, where severe losses occur due to occasional low temperatures. The addition of a pathologist and agronomist to the sorghum improvement effort based in Mexico is desirable in order to expand the present program to cover both highland and lowland sorghum improvement in Mexico and the region in general. Close linkages could be established with the program centered in Brazil, with all countries in the area benefiting accordingly.

Lowland sorghum is produced in Central and South America mainly for the livestock industry, although recent surveys have revealed that sorghum is increasing in importance as a food in the region, particularly as an insurance against famine during the dry years. For the same reason, pearl millet is also now given more attention.

Brazil is interested in strengthening its national research programs in sorghum and millet improvement and farming systems, and has requested ICRISAT to provide a small team of scientists for the SAT northeast to assist in development of these disciplines. In farming systems, specific interest has been expressed in land and water management and intercropping. Research station development has also been identified as a high priority requirement. It is considered likely that EMBRAPA, the national agronomic research institution, will provide funds for this cooperative program.

Pigeonpea is an important crop in much of the Caribbean region, and requests for assistance in improvement of the crop have come from several countries. There is great scope for varietal improvement, since present genotypes are low yielding and are susceptible to a number of insect pests as well as several diseases. Special project funds are being sought to provide a pathologist, an entomologist, and a breeder to be posted in the Dominican Republic. A chickpea breeder might also be posted in Mexico, where this crop is important. He would

receive backup support from, and would interact with, the pulse team in the Dominican Republic.

ICRISAT's international programs have expanded rapidly in the past 3 years, with 23 scientists having been outposted thus far. Several more are to be recruited before the end of 1979. Interest is developing rapidly in many more SAT countries around the world, and ICRISAT will make every effort to work with them in advancing their agricultural research and their prospects for increased food production and better lives for their citizens.

The ICRISAT Cooperative Program in Upper Volta

W. A. Stoop and C. M. Pattanayak*

Abstract

In recent years drought has been common in Upper Volta, causing poor yields and serious food grain deficits. Research data indicate that in spite of these droughts much higher yields should be possible. This paper attempts to analyze why these higher yields have not been realized and to indicate ways in which the ICRISAT Upper Volta program can contribute to improving this situation.

Upper Volta in West Africa is located between 8° and 15°N. It has about 8.9 million hectares of potential crop land. Around 2.4 to 2.7 million hectares are cropped annually. The important cereal crops are sorghum, pearl millet, maize, and rice with estimated annual cropping areas of one million, 700 000, 80 000, and 35 000 ha, respectively. The principal cereals — sorghum and millet — have estimated average yields of 500 kg and 400 kg/ha, respectively.

Annual grain requirements for the population of approximately 5 million is estimated at about 1.2 million metric tons (tonnes). However, in recent drought years, grain production has been in the order of 500 000 to 700 000 tonnes, resulting in a serious food deficit.

As is obvious from past research results, there is enormous scope for improvement. However, to achieve these improvements "the transfer of technology" bottleneck must be removed. For that purpose a detailed understanding of various environments and their limitations, both physical and socioeconomic, is required. Next, adaptable technology within reach of average farmers can be proposed.

In this paper an attempt is made to analyze the major constraints on sorghum and millet production in Upper Volta and indicate a strategy that ICRISAT intends to follow to improve the situation. Some promising results obtained over the first 4 years of ICRISAT involvement will be used to illustrate various points.

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Present Status: Environment and Limiting Factors

In this section some main characteristics of the present agricultural systems, their merits and their limitations, are described to provide a background against which any changes and improvements will have to take place.

Cropping Patterns in Relation to Climate and Soil

In Upper Volta distinct cropping patterns have evolved over the ages under the influence of both climate (particularly rainfall) and soils. These aspects will be discussed first, because they will logically indicate the major physical constraints to improved production.

Based on the rainfall patterns, the country can be subdivided into three broad ecological zones (Fig. 1). The total annual rainfall ranges from 400 mm in the north to over 1000 mm in the south; the duration of the rainy season increases from approximately 2½ months in the north to 6 months in the south, with the overall distribution becoming less erratic to the south. The start of the rains is rather erratic everywhere. For example, around Ouagadougou the rains are established by early June once out of 4 years, but the same probability occurs for the end of June or later. For the three major ecological zones — Sahelian, north Sudanian, and south Sudanian — more detailed data are provided in Table 1. Closely linked with this shift in rainfall are the predominant crops grown in each zone — mainly pearl millet in the northern, sorghum and millet

Figure 1. Climatic regions of Upper Volta.

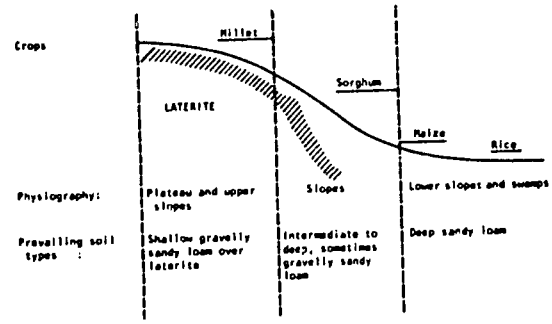

Figure 2. Schematic presentation of crops grown on different soil types commonly present in toposequences in Upper Volta.

in the central, and sorghum and maize in the southern zone.

However, within particularly the central and northern zones, similar changes in crops result from different soil types that commonly occur in toposequences (Fig. 2). Thus millet is grown mainly on relatively dry soils of the plateau and upper slopes (these are often shallow and gravelly loam soils, less than 50 cm deep, overlying laterite); sorghum and maize are grown on the deep sandy loam soils of the lower slopes and towards the swamps; and rice is grown in the swamps after these have been inundated, generally by the middle of July.

By using local varieties grown in long strips along a toposequence at the Kamboinse Experiment Station near Ouagadougou, we were able to confirm the wisdom of this traditional pattern in a striking way. Figures 3 and 4 demonstrate the crop adaptation to soil type for maize/sorghum and millet/sorghum studies, respectively.

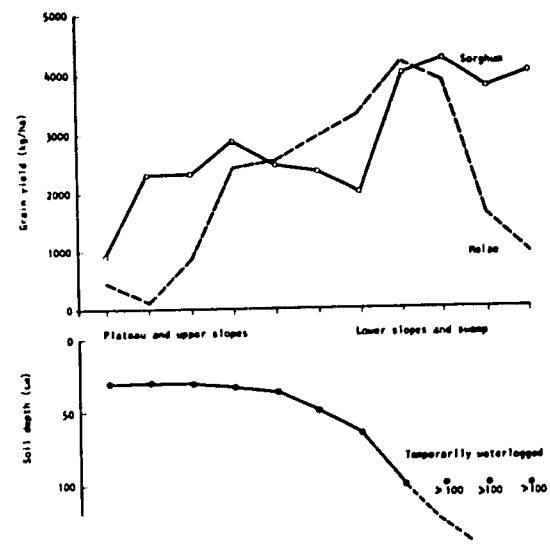

Figure 3. Adaptation of maize and sorghum to different soil types in a toposequence.

Table 1. Characterization of the rainfall pattern in three major ecological zones in Upper Volta.

Ecological zone	Mean annual rainfall (mm)	Approx start of rainy season	Duration of rainy season (months)	Approx no. of rainy days	Peak rainfall months
South Sudanian zone	> 1000	May	5–6	80–95	July, Aug, Sept
North Sudanian zone	650–1000	June	4–5	60–70	July, Aug
Sahelian zone	< 650	July	2.5–4	40–50	Aug

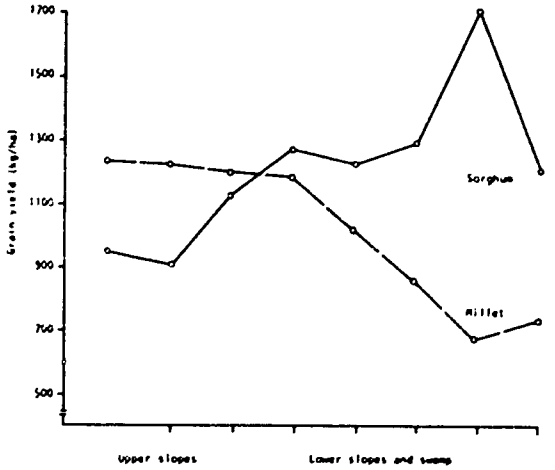

Figure 4. Adaptation of sorghum and pearl millet to different soils in a toposequence.

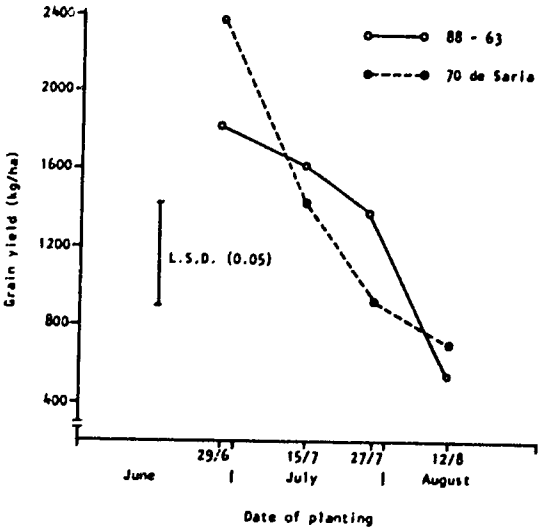

Figure 5. Effect of planting dates on grain yields of two cowpea varieties.

Obviously this interaction between *climate* (mainly total rainfall and its distribution), *soils* (their available water-holding capacities), and *crops* (their drought-tolerance and/or escape) is of prime importance in reducing risks and in stabilizing agricultural production. As such it is of fundamental significance to the introduction of improved crop varieties and agronomic techniques.

Major Factors Limiting Production

As mentioned earlier, one generally does not deal with single factors but rather with a complex of interlinked limiting factors. For ease of presentation, we will nevertheless distinguish between physical factors and socioeconomic ones while giving some examples.

Physical Factors

1. Rainfall: The total amount of rainfall and its distribution are unpredictable. Though the likelihood of drought is greatest at the start and end of the season, mid-season droughts are also common. Early planting, though risky, is essential to fully utilize a short growing season. Moreover, the yields of most photosensitive varieties suffer greatly from delayed planting (Fig. 5), especially if the rains stop early. As a result, the farmer in the central and northern zones faces a dilemma with respect to soil preparation, because the gains frequently do not outweigh the yield losses incurred by a delay in planting.
2. Soils: With the exception of the common shallow gravelly soils, most soils have reasonably available moisture-holding capacities (100 to 150 mm). However, they have a serious problem of crusting and low rate of infiltration of water, which seriously affects the crop stand and production.

   These soils also have low fertility because of a low amount of organic matter and general deficiency of nitrogen and phosphorus.

Socioeconomic Factors

1. Technology: Most farmers rely completely on traditional technology and use a small hand hoe as the only tool. As a result, soil preparation, incorporation of crop residues, and use of organic manures are uncommon. Fertilizers are also rarely used. The local sorghum and pearl millet varieties, which are mostly full-season and photosensitive, need early planting and are well-adapted to hand labor. However, with

improved cultural practices and fertilizer, they grow excessively tall and their harvest index is poor.

2. Subsistence farming: Many farm communities rely solely on subsistence farming. Thus the availability of ready cash to buy inputs — chemical fertilizers or insecticides — or to invest in oxen and machinery is very limited or absent.
3. Communication: This is probably one of the most serious bottlenecks in the transfer of technology and involves physical aspects (lack of roads and transportation) as well as traditional and cultural barriers (e.g., language).

The transfer of technology to these traditional communities can be jeopardized by failure to recognize various limiting factors and their interactions, and by efforts to introduce too many novelties at the same time.

Improved local sorghum and pearl millet varieties have shown yield potentials of 2 to 3 tonnes/ha when grown on experiment stations under improved management conditions, but average yields of these varieties in farmers' fields have remained static at the level of 400 to 500 kg/ha.

To pinpoint the reasons for these low yields is difficult. Nevertheless, it appears that many improved techniques were unrealistic for subsistence-type agriculture, that the long maturity duration of improved local varieties did not match with the available soil moisture in medium deep and shallow soils, and that the absence of an infrastructure to assure input availability and a guaranteed grain price may not have given adequate incentives to the farmer.

However, with consistent technical and financial support, progress can be made, as is shown by cotton. Yields of this crop have steadily increased as a result of a consistent effort by the CFDT (Compagnie Françiase pour le Développement des Fibres Textiles) assuring subsidized fertilizers, insecticides, and other inputs as well as a guaranteed price for farmers.

ICRISAT's Approach and Progress

ICRISAT initiated its research effort in Upper Volta with the stationing of a sorghum breeder in 1975, a plant pathologist in 1976, and a millet breeder and two agronomists in 1977. A *Striga* scientist, an entomologist, and a production economist will be joining the team during 1979. In view of the farmers' economic limitations, major emphasis is placed on efficient use of biological and environmental resources in combination with locally produced inputs (e.g., natural phosphate; animal-drawn equipment). The activities are concentrated mainly in the region between the isohyets 400 and 800 mm (northern and central Upper Volta).

Among the biological resources, crop improvement is of prime concern. On the agronomic side, the role of legumes either in rotation or intercropped with cereals is studied as a means to provide biologically fixed nitrogen rather than expensive fertilizer-nitrogen.

The exploitation of environmental factors such as rainfall and soils involves utilization of the entire crop season, while minimizing risks through intercropping (e.g., early and late-maturing crops), as well as studies on the adaptation of crops and crop varieties to different soils.

Multilocation varietal testing was started early in the crop improvement programs, and large demonstration plots for the most promising sorghum varieties were started in 1978. Agronomic off-station testing started in 1979 with a series of experiments along a north-south axis through the country. Meanwhile, an agronomic demonstration program has been developed for a traditional village in cooperation with the peasants. This is considered a crucial study in the development and transfer of improved and adapted technology.

Crop Improvement Needs and Introduction of Improved Varieties

Upper Volta has a wide range of different environments (climates and soils), in addition to a rather unpredictable rainfall. No single millet or sorghum variety can effectively cope with all these different conditions. In addition to the well-adapted photosensitive (full season) local varieties, other improved sorghum and millet varieties of various maturity classes could greatly assist in further increasing and stabilizing grain production.

The major breeding objectives for sorghum

are: shorter plant height (about 2 m) and high harvest index; resistance to diseases (sooty stripe, *Helminthosporium*, anthracnose, zonate leaf spot, charcoal rot, and grain mold), pests (shoot fly and midge), and drought; white, shining, bold grains with hard vitreous endosperm and high cooking quality; high seedling establishment; and a stable and superior yield over locations and years.

Similar breeding objectives are formulated for pearl millet, including synchronous tillering and resistance to diseases such as downy mildew, ergot, and smut, though for this crop one faces two entirely different ecological zones (Sahelian and central), which has required two different breeding programs.

Taking sorghum as an example, three major cultivar types are considered essential:

1. Full-season (130-140 days), photosensitive sorghum suitable for early planting on deep good soils near swamps, mainly in the 650- to 800-mm rainfall zone. To realize their yields these materials rely for grain filling mainly on residual moisture utilized in the dry month of October. This response is demonstrated in Figure 6 for a local variety grown on a toposequence. As a result of the greater available soil moisture at the lower end of the slope, the yield increased by approximately 50%. Because of their photosensitivity, these materials can be planted early (depending on the start of the rains) but not after the end of June, when yields will start to drop dramatically (compare Figs. 6 and 7). Currently, an improved high-yielding variety of this type is not available.
2. Partially photosensitive sorghum (approximately 120 days), suitable for planting in the second half of June and harvesting by the second half of October, are required also for the 650- to 800-mm rainfall zones. Such cultivars are suitable for planting on soils of medium depth (50 to 70 cm) or on deep soils when rains arrive, by the middle of June. The improved variety E35-1 was identified to meet these requirements in addition to acceptable plant height (2 m) and grain quality. In the same toposequence mentioned earlier, it outyielded the local variety for early June planting as well as late June planting, particularly on the upper part of the sequence, which was more drought prone. Similar superior yields were obtained in multilocational trials. Presently, E35-1 is being studied in large on-farm demonstration plots mainly in the central zone.

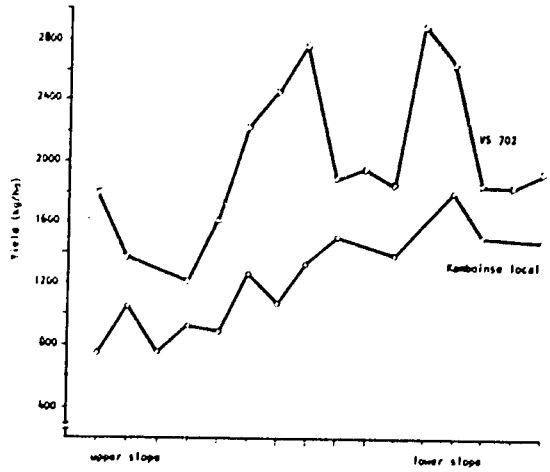

Figure 6. Yields for two sorghum varieties planted 28 June 1978 along a toposequence.

3. Photoinsensitive sorghum (approximately 100 to 105 days), suitable for planting during the first half of July and harvesting by mid-October. These cultivars would serve many purposes. Because of their short maturity, they are able to avoid both early and end-of-season droughts. As a result, not only can they be grown on shallow soils — traditionally in millet — in the 650- and 800-mm rainfall zone but they can also serve as an alternative when early plantings of photosensitives on good soils have failed (Figs. 6 and 7, giving a comparison of local varieties with improved photoinsensitive VS702 in toposequence of soils, are a good illustration of this principle). Varieties such as SPV35 and 65/30 serve well on good soils in the northern zone, where the rains are still less than 600 mm and the overall season is shorter. It is interesting that in all cases the yield potentials of these photoinsensitive materials have been 50–100% higher than for the local, even when the latter were planted at their optimum (early) planting dates.

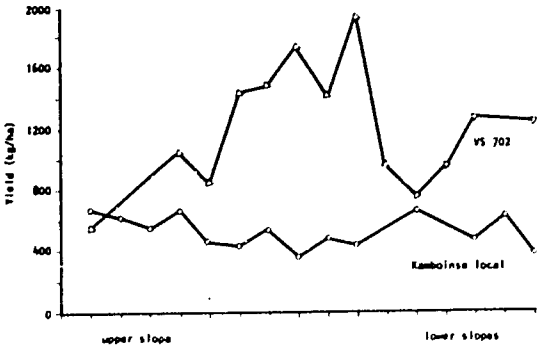

Figure 7. Yields for two sorghum varieties planted 15 July 1978 along a toposequence.

Presently, VS702 for mainly the central zone and SPV35 and 65/30 for the northern zone are being studied in large on-farm demonstration plots. All materials have been received well with respect to their cooking qualities.

Agronomy and Farming Systems

It is well known that experiment station conditions in general are rather different from those in farmers' fields. Moreover, agronomic studies tend to look at two or three factors at a time, which may or may not be important for a farmer.

In order to make practical recommendations suitable for farmers' conditions, our agronomic research has taken up these studies:

- On-station agronomic research (Kamboinse)
- On-farm testing and demonstrations (along north/south axis from Ouhigouya to Tiébele)
- Farming systems studies in a traditional village (Nakomtenga) and in a new and controlled development project such as the land resettlement scheme, AVV (Aménagement des Vallées des Voltas)

On-station Agronomy

Three main aspects are studied at the Kamboinse Experiment Station:

1. Varietal testing of the most promising sorghum, millet, and cowpea lines with respect to plant population, planting date, and adaptation to different soils (toposequence studies).
2. Intercropping studies with sorghum or millet as base crops and maize, cowpea, or groundnut as intercrops; soil type and rainfall characteristics are used as criteria for possible crop combinations.
3. Management studies, emphasizing the improvement of moisture infiltration and erosion control while maintaining soil fertility through cereal/legume intercropping or rotations.

The work on varietal testing is done in close cooperation with the breeding programs and results have been discussed under Crop Improvement. Those results are also of great importance for the intercropping studies. Indications during the first two seasons have been that intercropping serves to minimize risks in bad years and maximize yields in good years.

Intercropping work is presently done for areas with more than a 700-mm rainfall and a cropping season of more than 120 days, which allows the combination of early and late-maturing crops; land can thus be occupied efficiently for the entire season. Combinations mainly for the better soils are based on full-season sorghum as base crop, with early cowpea, maize, or millet as intercrops. Cowpea and maize intercrops have shown the most promise.

For drier areas of less than 700-mm rainfall and a cropping season of fewer than 120 days on poor shallow soils under high rainfall, crop combinations that complement each other in some other way than their maturity (e.g., cereal and legume; tall and short plant types) are studied. Interesting yield gains were obtained from millet/groundnut intercropping. During the 1979 season, major emphasis is placed on the cereal/cowpea intercropping systems, which are of concern to all rainfall zones in the country. Cowpea is an important component of the local cropping systems, but seems greatly underexploited. Among its useful secondary characteristics are competition with weeds, quick soil coverage that reduces erosion, and nitrogen fixation.

The beneficial effect was clearly demonstrated in a management study at Kamboinse. Cowpea as a preceding crop doubled sorghum yields in the following year, irre-

spective of the soil preparation treatment, plowed or nonplowed (Fig. 8), and in the absence of a N fertilizer application. Obviously, this type of result is applicable to both mechanized and nonmechanized farming conditions and therefore merits study on a larger scale in the on-farm testing program.

On-farm Testing and Demonstration

This part of the program serves a dual purpose: first, for the research worker to verify the effects of different environments (rainfall and soil) on the performance of new varieties and agronomic techniques, and second, as a demonstration to aid the extension worker and the farmer in the transfer of technology. For the latter, and because one depends on outside cooperators, the trials have a fairly small number of treatments, which are repeated as part of a much larger trial at the experiment station.

For the 1979 season, nine sites have been selected, covering the region between isohyets 500 mm (Ouhigouya) and 1000 mm (Tiébele). The study will include the following aspects: (a) comparisons between local sorghum and improved sorghum E35-1 and VS702, each planted at two dates to cover the entire planting season from end of May till mid-July; (b) comparisons between three improved cereal/cowpea intercropping systems; (c) responses to rock phosphate by cereals and cowpea and evaluation of residual effects in the following season; and (d) responses to residual nitrogen fixed by cowpeas in pure and intercropped conditions in the following season.

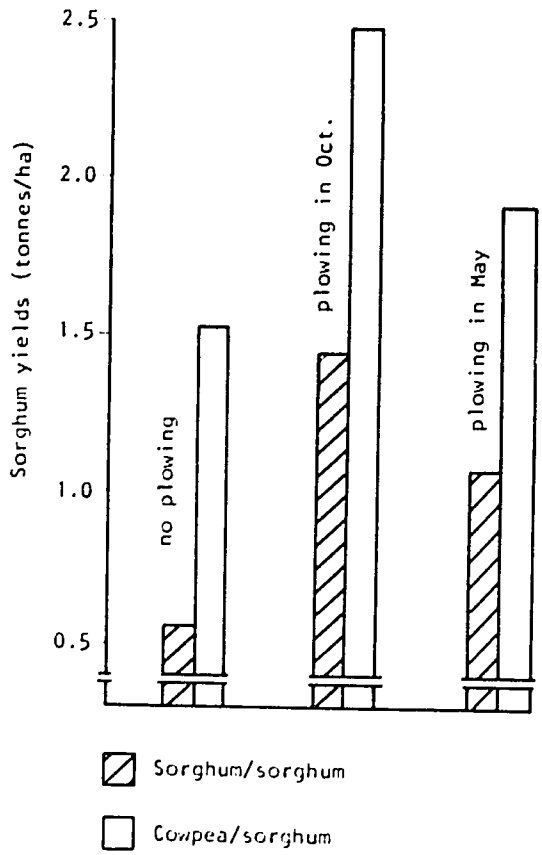

Figure 8. Effects of plowing and time of plowing on sorghum grain yields for a sorghum/sorghum and for a cowpea/sorghum rotation on shallow gravelly soil.

Farming Systems Studies

To really appreciate and evaluate the impact of improved varieties and techniques, these have to be seen in the overall context of a farm operation.

In this respect one can distinguish between two situations, both of which are present in Upper Volta — the traditional village hardly touched by extension workers, and the newly developed and greatly controlled farms in the AVV. In the first setup, operations are based on hand labor using mostly traditional cropping systems and patterns; in the second, animal traction is employed, and a strict rotation schedule of pure crops (cotton, sorghum, cowpea and maize) is followed.

During the 1979 season, a study has been started in a traditional village on the Mossi plateau. The aim is to involve the farmers in a small demonstration program, study their reactions to various improved technologies, and later evaluate the impact of these demonstrations on their way of farming. In this program, the production agronomist, land and water management agronomist, and economist will cooperate in an effort to set up guidelines for the transfer of technology.

It is hoped that by 1980 a watershed management study can be started on the second and more advanced type of farm.

Acknowledgment

The authors would like to express their thanks to their colleagues P. K. Lawrence, J. A. Frowd, and J. P. van Staveren for their contributions to the program described in this paper. The host government's consistent help and encouragement is highly appreciated.

Generation and Transfer of Technology in the Americas

Leland R. House*

Abstract

ICRISAT's involvement in the Americas has been primarily with sorghum and, to a somewhat lesser extent, with pearl millet, groundnut, chickpea, and pigeonpea. Scientists from these crop improvement programs have kept in close touch with developments in Central and South America through personal visits and exchange of information and germplasm with scientists. ICRISAT has a sorghum breeder posted at CIMMYT in Mexico, working primarily on high-altitude crop improvement. In recent years, sorghum production has increased tremendously in Latin America, principally in Mexico, Argentina, and Brazil. Sorghum serves mainly as a feed for animals in these countries, and it has made an indirect contribution to food production by freeing more of the primary crop, maize, for human consumption. But sorghum also serves as an important food for humans in Honduras, Guatemala, El Salvador, and Nicaragua, and other countries are showing an increasing interest in it as a food crop. Priorities for improvement of sorghum in Central and South America include the need to breed varieties for use by the poorer farmers as an intercrop with corn and beans, to screen for resistance to important pests and diseases found in these countries, and to increase the training of, and exchange of information with, Latin American scientists.

In recent years there has been a tremendous increase in the production of sorghum in the Americas, particularly in Mexico, Argentina, and Brazil. Increases in grain sorghum production have also been great in Colombia, Peru, Uruguay, and Venezuela; these increases have come both from area sown and increased per hectare yields (Table 1).

Because of this expansion, it is often assumed that little outside assistance is needed, even from such institutes as ICRISAT. Alexander Grobman (1978) with many years of experience with sorghum in the Americas, has summarized the situation thus:

"The tremendous increase in feed grain production that in most cases served as a base for the increase in production of poultry products was spearheaded by sorghum .... Crop production technologies, based on hybrid sorghum, hybrid maize, use and availability of fertilizers, tractor power, herbicides, combines, and the introduction of high-yielding soybean cultivars, lodging-resistant, shatterless, and combinable, were the basis on which a profitable agricultural pattern emerged. Very little of this technology went to small farmers. It was not intended to either by the technology generators and promoters or by the governments. In Mexico, the sorghum areas were mostly located in previously large cotton estates; rice was also expelled from the new sorghum areas. These were mostly medium to larger farmer crops. In the sorghum areas of Venezuela, Argentina and Colombia there were also larger farmers. In Peru, large farmers started planting sorghum, and as the agrarian reform proceeded, large agricultural units were retained in the process, so that no real change in economics of scale occurred, as large units continued planting hybrid corn and hybrid yellow feed sorghum.

"In all of the countries the emphasis was set up in quick-high technology increase in grain production over the shortest time span. This was achieved very quickly and efficiently, very little extension outlay having been needed in the process. The technologies were to a great extent transferred in complete packages and very easily adapted and adopted by farmers, who

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Table 1. Grain sorghum production in the Americas; 1977 compared to 1969–71 and 1961–65

Country	Area (1000 ha)			Yield (kg/ha)			Production (1000 tonnes)		
	1961–65	1969–71	1977	1961–65	1969–71	1977	1961–65	1969–71	1977
Costa Rica	22	6	20	1210	1639	1841	27	11	37
Cuba		3	1		1100	1100		3	1
Dominican Rep.		4	7		3496	3000		14	21
El Salvador	104	121	144	1020	1186	1226	107	144	176
Guatemala	25	50	54	640	915	1722	16	46	93
Haiti	260	214	224	700	981	982	181	210	220
Honduras	69	31	71	800	1378	867	55	43	62
Mexico	205	934	1190	2210	2766	2815	452	2 584	3 350
Neth. Antilles	3	3	2	1670	602	706	5	2	1
Nicaragua	50	56	52	940	1015	1018	47	57	53
USA	4909	5820	5692	2830	3318	3528	13 912	19 314	20 083
Argentina	855	1979	2630	1590	1932	2559	1 358	3 822	6 730
Brazil		1	182		2222	2485		2	453
Colombia	13	64	117	2390	2407	2290	30	153	406
Ecuador			1			2000			1
Paraguay	3	4	6	1070	1272	1000	4	5	6
Peru	1	4	18	1950	3072	2778	2	11	50
Uruguay	32	42	80	520	1259	1500	17	53	120
Venezuela	1	4	163	2170	1342	1994	3	5	325
N & C. America	5999	7243	7456	3000	3096	3232	19 816	22 427	24 097
S. America	905	2097	3257	1560	1933	2484	1 412	4 052	8 091

Source: FAO Production Yearbooks 1971 and 1977.

counted with a basically unlimited market, and prices mostly above international standards."

Several important things occurred in this process. The rapid increase in the use of sorghum was spearheaded by multinational corporations and later adopted by local corporations. Both private and public research was strengthened, and today in Argentina, for example, only about 20% of the sorghums used come directly from the United States. An infrastructure for sorghum research and production has been established in many Latin countries.

Maize is "king" in the Americas, but the value of sorghum in areas marginal for maize has also been realized. "As sorghum moved into the drier areas of the Argentinian Corn Belt, an interesting phenomenon took place with maize. Because maize was left in the more humid areas of the province of Buenos Aires, maize yields went up (1700 kg/ha in 1969 to 2840 kg/ha in 1974). Again in spite of sorghum being an imported technology, sorghum yields, as an average, are similar to the yields of maize in Argentina, in spite of the distribution — of both crops in different precipitation areas (mean sorghum yields during 1973–76 are 2529 kg/ha, while mean maize yields 1973–76 are 2546 kg/ha)" (Grobman 1978).

Sorghum has become a crop of importance (Table 2) in the Americas. The use of sorghum as an animal feed has released considerable quantities of maize for use as human food. This has been and will continue to be an indirect but important contribution to the food situation in the Americas.

Data in the *1976 FAO Yearbook* highlights a serious cereal deficit in the Central American countries, which imported 165 000 metric tons (tonnes) of wheat — 87% of their total requirement — and 223 000 and 160 000 tonnes of maize in 1973 and 1976, respectively. Honduras and El Salvador are food priority countries, based on a classification of the World Food Council. From 1972 to 1974 the Central

Table 2. Major cereal crops in Central America.

Country	Rank of Importance			
	Sorghum	Maize	Wheat	Rice
Mexico	2	1	3	
Belize		1		2
Honduras	2	1		
Guatemala	2	1		
El Salvador	2	1		
Costa Rica	3	1		2
Nicaragua	2	1		3
Panama		2		1

Source: IADS, 1978.

American countries imported from 11 to 58% of their cereal requirements (IADS 1978).

The nutritional information available for Central and South America shows that, except for Argentina, calorie and protein intake is low. In El Salvador and Bolivia, it falls below that of India. The poorest half of the population of Honduras consumes only 68% and 61% of the minimum daily requirements of calories and protein, respectively. Generally rural populations in the Central American countryside consume twice as much cereal (primarily corn), more beans, and about half as much milk, eggs, meat, green vegetables, fruit, wheat, and fats as urban populations (INCAP 1968).

Information such as this brings the situation into better perspective. Although sorghum production has increased substantially in several countries of the region, one cannot extrapolate this too far. Sorghum is the second most important cereal of the region, with average yield figures ranging from 1200 to 2500 kg/ha on larger farms. But on smaller farms in the same region, the average yields may range from 400 to 1000 kg/ha, indicating an obvious need to focus research on the poorer farmer.

It seems evident that ICRISAT need not be concerned about sorghum improvement in more temperate areas, where emphasis is on large-scale feedgrain production and where research input already rests on the vast investment in the United States and that rapidly developing in some of the temperate Latin countries. However, ICRISAT might well contribute its experience and knowledge of sorghums in the more tropical areas to which the Institute has access.

Much of the following information has come from study trips made in the Americas.

The subsistence farmer is found in essentially four situations:

(1) drier areas, such as northeastern Brazil, where rainfall is highly variable and drought is common;
(2) areas of acid soils, frequently with aluminum toxicity and poor availability of nutrients, particularly phosphorus; these soils are found extensively in Brazil, parts of Venezuela, and Colombia;
(3) high rainfall areas, where periods of drought are common, fields frequently are rolling to steep, with high runoff and poor water penetration, and soils have a low water-holding capacity; such situations are typical of much of Central America; and
(4) higher elevation areas, of both high and low rainfall, such as in parts of Mexico.

Generally, the larger commercial farmers sow hybrids, frequently in coastal or lower elevation areas; the poorer farmers sow varieties, frequently on rolling to hilly land. The cultivar range is substantial, from virtually 100% hybrid in Mexico to 90% variety in an area of Guatemala. More than 50% of the sorghum area in Central America — except Panama — is sown to varieties.

In Mexico, research has been under way for over 15 years to develop sorghums adapted to cold dry situations, and progress has been made in developing food and feed types. The initial problem was failure of seed set because of the cold temperatures; this was solved using three cold-tolerant types originating in Uganda. The problem now is to find varieties and hybrids early enough to be sown with the rains and to mature before killing frost.

Research to identify short-season cold-tolerant types was initiated by CIMMYT; the International Development Research Centre (IDRC) began support of the program in 1974, and ICRISAT assumed responsibility in 1977. During this period the Instituto Nacional de Investigacion Agropecuaria (INIA) and the University of Chapingo also initiated their own research programs, and all three agencies are continuing research for the advancement of this material.

An effort is being made to develop white-seeded food quality types that fit the short growing season (65-75 days to flowering). Currently, it is necessary to start the crop about 1 month before the rains, with irrigation, so that it will mature before a killing frost. This year a regional trial of cold-tolerant types has been sent to 14 countries:

Canada	France	Nepal
China	Guatemala	Philippines
Ecuador	Honduras	Rwanda
El Salvador	Kenya	USA
Ethiopia	Lesotho	

In addition, 80 shipments of seed were sent all over the world during 1978.

Last year, at the CIMMYT headquarters at El Batan (elevation 2240 m, latitude 80°N),a trial of food-type sorghums was conducted with irrigation. Results were as follows:

	Range	Mean
Yield (kg/ha)	2950 – 5850	4200
Days to 50% flower	84 – 120	103
Plant height (cm)	85 – 145	109

It is apparent that, while yields are good, the time to flowering is too long. Significantly, during the 1979 season, several plants flowering in less than 75 days were identified and are being advanced in the breeding program. It is worth noting that hybrid yields have exceeded 7000 kg/ha.

If special project funds can be found, there is interest in expanding research activities of the ICRISAT-CIMMYT station to devote about 20% of its total effort to sorghums for the highlands and about 80% for intermediate and low-elevation areas where sorghum is currently being used. Existing cold-tolerant types might be useful at lower elevations; this is being determined in Mexico, in cooperation with INIA. There is interest in Guatemala in an area of about 1800–m elevation.

The sources of cold tolerance generally came from long-season, photosensitive types from East Africa; as a spinoff from these came types with a range of maturities, and those of intermediate maturity have already been used in country programs.

Priorities for sorghum improvement have been identified:

1. There is a need, in Central America, to breed for varieties to be used by the poorer farmers as an intercrop with corn and beans. The current Criollo type is about 1 month too long in maturity. This type of research has been initiated at the Centro Nacional de Tecnologica Agropecuaria (CENTA), the research agency of El Salvador. Several earlier selections — ES-199, ES-200, and ES-406 — have been made from Criollo. Agronomic experiments involving variety, levels of fertilization, and intersowing techniques have been initiated. The ICRISAT program has not yet had the opportunity to become involved in this type of research, but is in a good position to contribute with its vast array of food-quality, tropically adapted sorghums. An El Salvador substation of the ICRISAT-CIMMYT station would be valuable.
2. Several insect pests are important in the Americas (Table 3), especially sugarcane stalk borer (*Diatraea* spp), fall army worm (*Spodoptera frugiperda*), and midge (*Contarina sorghicola*).

During the 1979 season, the second

Table 3. An approximate distribution of insect pests of sorghum in Latin America.

Country	Midge	Sugarcane borer	Fall army worm	Wire worm	Aphids	Green bug	Web worm	*Agrostis ipsilon*	*Heliothis zea*	Chinch bug	Grain storage pest	*Elasmophalpus lignosellus*
Mexico	x	x	x			x	x					
Guatemala	x	x	x									
El Salvador	x	x	x									
Nicaragua	x	x	x	x								
Colombia	x	x	x				x	x				
Venezuela	x	x										
Brazil North	x											x
Brazil Central	x	x			x							
Bolivia	x		x			x			x	x	x	
Argentina	x	x				x						

screening of selected sorghum entries for resistance to the stalk borer and fall army worm has taken place. Evaluation was by artificial infestation in cooperation with the CIMMYT entomologist. An input should be made to help expand this activity.

Resistance to midge has been a matter of concern at Texas A&M University for several years, and the breeding program for midge resistance at ICRISAT Center is being strengthened. Currently, resistant lines are available in Mexico but have not yet been effectively incorporated into superior agronomic types for the region. Over the next few years, this activity should be phased in.

3. Several diseases are of concern (Table 4): anthracnose (*Colletotrichum graminicola*), downy mildew (*Sclerospora sorghi*), grey leaf spot (*Cercospora sorghi*), other leaf diseases, and grain molds.

Research for resistance to anthracnose is under way in the United States and Brazil; cooperation with those programs is important but yet to be established. Anthracnose is not a severe problem in India and research could best be done in the U.S. and Brazil.

Table 4. An approximate distribution of sorghum diseases in several Latin American countries.

Country	Anthracnose	Grey leaf spot	Downy mildew	Zonate leaf spot	Bacterial leaf spot	Charcoal rot	Leaf blight	Rust	Grain molds	Virus
Mexico	x		x			x				
Guatemala	x	x	x	x	x				x	
El Salvador	x	x	x	x			x		x	
Nicaragua	x	x				x			x	
Colombia	x					x	x	x	x	x
Venezuela	x		x						x	x
Brazil North										
Brazil Central	x							x		
Bolivia			x							
Argentina			x							

Although downy mildew is being reported more frequently, efforts to find resistance to it in the Americas have been successful. The incorporation of resistance in breeding stocks does not appear to be difficult and should be undertaken as part of the summer nursery program at Poza Rica, a low elevation (50 m) CIMMYT station in Mexico.

The summer season at Poza Rica is wet and humid and provides an excellent opportunity for testing for resistance to leaf diseases, including grey leaf spot.

There is a substantial program at ICRISAT Center for the development of agronomically elite types with resistance to grain mold. Already, entries from this program have been sent to Mexico and to scientists in other Latin countries.

4. Sorghum is used in the Americas primarily for animal feed but it is also used as a human food (Table 5), and research to help expand this use should be intensified. In Guatemala, about 80% of the sorghum production is in association with corn and beans; about 64% of this is for home use, mainly for tortillas (40–50%). In El Salvador about 50% of the production goes into tortillas; in Nicaragua about 8% of the production goes into food, as tortillas, and into a drink called *tiste*. There is apparently a rising interest in the possible use of sorghum as a food in Colombia, where there is already a limited use in making soup, bread, and a fermented drink called *chicha*.

Sorghum flour is used in these countries to extend maize; sometimes tortillas are made of flour that is one-half corn and one-half sorghum. Several countries of South America — Argentina, Brazil, Colombia, and Venezuela — extend wheat flour with sorghum flour. Food technology laboratories are experimenting with the use of sorghum flour to extend wheat at the Manfredi station in Argentina and at the Campinas station of São Paulo State in Brazil. Elite sorghum types have been sent from ICRISAT to the Manfredi station.

Initially, sorghums in the cold-tolerance program were of a feed type, but 5 years ago emphasis began to shift to foodgrain types; now breeding for food-quality grain

Table 5. Countries using or interested in using sorghum for food.

Country	Sorghum now used as food	Interested in sorghum for food
Honduras	Yes (23 400 ha)	Yes
Costa Rica	No	Yes
Panama	No	Yes
Ecuador	No	Yes
Peru	No	Yes
Bolivia	No	Yes
Guatemala	Yes (24 400 ha)	Yes
El Salvador	Yes (62 500 ha)	Yes
Colombia	Very little	Yes
Nicaragua	Yes (5000 ha)	Yes
Mexico	No	Yes (high elevation)

is an important aspect of the ICRISAT-CIMMYT program. A number of samples have been evaluated by the food technology laboratory at CIMMYT, and a variety that makes excellent tortillas has been identified. This variety will be further evaluated at intermediate elevations. There is a program at ICRISAT Center to identify good food-quality types, and the best of these have already been sent to Mexico.

5. ICRISAT scientists have become increasingly involved in the Americas. Sorghum breeders from ICRISAT Center have made several study trips in Central and South America. The sorghum breeder stationed in Mexico has travelled extensively in the Americas. Twice, teams of ICRISAT scientists have visited northeast Brazil to evaluate research opportunities there, and individual scientists have returned to Brazil both to learn and to contribute. Major interest has been in sorghum, millets, and farming systems.

   As for other crops, one scientist from the ICRISAT groundnut program has visited the Dominican Republic, and the program leader has participated in a trip of the International Board for Plant Genetic Resources (IBPGR) to collect in Bolivia, Argentina, and Brazil.

   Six of the scientists in the ICRISAT Pulse Improvement Program have made trips to the Americas, cooperating with scientists in Trinidad, the Dominican Republic, the West Indies, Puerto Rico, Mexico, Panama, Colombia, Venezuela, Peru, Brazil, and Chile.

6. Seed samples have been supplied to various Latin American countries by all of the ICRISAT crop improvement programs. Since 1975, some 4167 samples of sorghum have been sent to eight Latin American countries, among them, Mexico (2359), Brazil (555), Colombia (408), and Argentina (185). In addition, since 1977, 674 sorghum samples have been sent to Latin American countries by the germplasm unit. Pearl millet samples (156) have been sent by the germplasm unit to Brazil, Venezuela, Surinam, and Haiti. Some 215 groundnut samples have been sent to Argentina, the Dominican Republic, and the West Indies. Some 574 samples of chickpea and 234 samples of pigeonpea have been distributed as follows:

Pigeonpea		Chickpea	
Argentina	Mexico	Argentina	Peru
Brazil	Panama	Chile	Trinidad
Colombia	Paraguay	Dominican Republic	Venezuela
Dominican Republic	Puerto Rico	Honduras	
El Salvador	Venezuela	Mexico	
Honduras			

7. Training of local personnel is desired by almost all countries of the region. Two persons were trained in the ICRISAT-CIMMYT program last year, and one is currently in training; six persons, five from Brazil and one from Honduras, have been trained at ICRISAT Center and one from Uruguay is in training now. We expect that such enrollment in ICRISAT training programs will increase.
8. Interest was expressed at the Reunion Internacional de Sorgo (Buenos Aires, March 1978) in the Sorghum and Millets Information Center developing at ICRISAT. Frequently scientists in the region request ICRISAT to help provide information. An extensive use of the Information Center by scientists in Latin countries can be anticipated.

Clearly, ICRISAT is in a position to contribute to sorghum improvement in the various agroclimatic situations where sorghum has, or can be expected to have, a useful place in the agriculture of Latin American countries. Additionally the ICRISAT station at CIMMYT provides a liaison between the ICRISAT system and sorghum workers in Latin American countries and the USA.

It can be expected that the interaction between ICRISAT scientists and those in the research institutes of Latin countries will expand in years to come.

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Training at ICRISAT

D. L. Oswalt and A. S. Murthy*

Abstract

International internships, research fellowships, research scholarships, in-service training programs, and apprenticeships provide opportunities for skill and concept development and practical experience at ICRISAT Center, linking national, regional and international research and development programs with ICRISAT's scientific expertise and research facilities. Designed to accommodate participants with diverse backgrounds, the programs enable each person to follow an individualized study program most relevant to his ability and his sponsor's need. Training ranges in duration from a few weeks to 2 years; a follow-up program communicates research findings to former trainees and maintains contact with their progress.

The objective of our training program is to train agriculturalists to work more efficiently in agricultural research, training, and extention programs and thereby increase and stabilize food production in the rainfed semi-arid tropics. By developing practical skills and concepts, the program provides for an increasing number of scientific, technical, and service personnel who can assist in improving the production and utilization of sorghum, pearl millet, pigeonpea, chickpea, and groundnut cultivars and in better exploitation of natural resources in improved farming systems. The training programs link the national, regional, and international research and development programs of the SAT with ICRISAT's scientific expertise, germplasm resources, and research facilities, which are not readily available elsewhere.

These programs enable scientists who are currently working on problems within ICRISAT's mandate to become familiar with the adapted germplasm and research technology for increased and stabilized food production in the semi-arid regions of the tropics.

Participants in the training programs at ICRISAT are primarily from, or are interested in working in, the semi-arid regions of the world. These regions urgently need persons skilled in research and technology transfer to manage the utilization and conservation of natural resources. Efforts toward increased food production and an improved standard of living in these agricultural regions are often limited by an insufficient number of experienced and qualified persons who can effectively adopt and communicate improved agricultural skills and technology. In addition, improvement in agriculture is often slow, as the producer must be assured that accepting new varieties and techniques will not adversely affect his source of food and farm income. Farmers are also slow to accept recommended changes when the scientist is unskilled and insecure.

ICRISAT's training programs are designed to accommodate persons with diverse education and experience. Individual programs are developed in association with scientific and training staff, permitting each student to conduct his own experiments, trials, or demonstrations, using the ICRISAT collection of natural and scientific resources unique to the physical, economic, and social environment of the SAT.

The transfer of technology in the training programs starts when the individual develops his research plans or undertakes practical experience with the research scientists and training supervisors. The staff, equipment, germplasm, natural resources, and physical facilities and the trainee's abilities, attitudes, motivation, and experience combine to form an ideal training-learning situation in which skill and concept development can be practically oriented to laboratory research and food production in the SAT.

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Types of Training

Five types of training programs, ranging in duration from 1 or 2 weeks to 2 years, currently serve a wide range of trainee needs.

International Interns, with recent PhD degrees from agricultural universities of donor countries, learn to use a team approach to problem solving, to applied research, and to technology transfer procedures. Interns work with research scientists on selected on-going problems for 1 to 2 years.

Research Fellows, SAT scientists with MSc or PhD degrees, work with teams of research scientists on specific problems, utilizing recent developments, techniques, and concepts. The length of training, a few weeks or up to 2 years, depends on the areas of research selected.

Research Scholars, university students conducting their thesis research, do so in a scientific environment in which they acquire practical experiences, concepts, and skills, and learn managerial techniques related to SAT food production and natural resource development. Research scholars are scheduled for 18 to 24 months' training at the research center in order to collect three to five cycles of data on their selected thesis problem for partial fulfillment of their degree program.

In-service Trainees, participate in three types of training programs of 6 to 9 months, based on field problems involving a full season for the area in which they specialize. In crop improvement, they develop the practical application of plant breeding techniques and the utilization of sources of resistance and tolerance for improved and stabilized yields of the crops in ICRISAT's mandate. In crop production, they learn to utilize production and management procedures for application to local conditions and to reduce adverse influences that limit crop production. In farming systems, they learn to assess the potentialities of natural resources and develop farming systems that will utilize genetic resources, cropping systems, land and water management techniques, machinery, power, markets, and economic and human resources.

Apprentices, who are agricultural engineering and other students, have a work-study opportunity to obtain practical experience in land development, water management, and economics, in the operation, maintenance, and repair of farm machinery, and in other field and laboratory techniques. The students are provided 1 to 2 months of work experience with engineers, research scientists, and maintenance personnel.

Organization of Training

An advisory committee representing the ICRISAT research program and the Associate Director for International Cooperation assists the training staff in developing training policies. All applications for training are evaluated by the advisory committee and the appropriate Institute scientist or research guide. To qualify for training at ICRISAT, each candidate must:

- Be sponsored by an agency or institution working or intending to work in the semi-arid tropics, or indicate an aptitude and desire to work in SAT agricultural programs.
- Present records of his academic training and experience — including capabilities in the English language — which indicate that he will profit from the training.
- Indicate a willingness to do practical field work and to study and conduct laboratory and field research in areas compatible with ICRISAT's mandate and the objectives of the sponsoring agency's programs.

Training programs for each category of candidates are organized within the specialized sciences of ICRISAT's five crops, farming systems, and other ICRISAT Center programs. Comprehensive individualized programs, based on precourse evaluations and interviews, are developed to provide practical and theoretical experiences in agricultural research, crop improvement, crop production, agricultural management procedures, extension programs, and training methods.

The duration and content of each training program are adjusted to the number of seasons necessary to obtain adequate data and the desired specialization of the trainee. As an integral part of his training, each trainee develops and conducts laboratory and field experiments or demonstrations within the approved research program of the Institute.

All field and laboratory studies are supervised by research scientists and training staff, with practical training activities forming the core of

the research and managerial experiences. The field and laboratory learning activities occupy more than 60% of each individual's training program. Accomplishments are periodically evaluated on the basis of skill performance and theoretical concept development. Final evaluations determine an individual's progress, help establish his personal confidence, and assess his reaction to the training program. Evaluations are also used in following up a trainee's later performance in fields related to the training received at ICRISAT.

Cooperation within ICRISAT

The field, laboratory, and classroom learning experiences are conducted by research scientists, assisted by the training staff. Research scientists participate directly in the training activity as field, laboratory, and classroom instructors, thesis research guides, and supervisors of interns and research fellows. The training staff coordinate the individualization of research projects, the instruction, the evaluation of practical concept comprehension, and the follow-up programs. They insure a balanced and comprehensive learning opportunity for each person.

Cooperation with other Institutions

Special assistance is obtained by utilizing the staff and facilities of neighboring institutions. French-speaking West Africans have been given intensive instruction in English language by the Central Institute for English and Foreign Languages and Osmania University. In addition, special extension methods, lectures, and laboratory exercises have been provided by staff of the Extension Education Institute. Scholars conducting their thesis and practical research at ICRISAT Center have been enrolled for their degree programs, or cooperative agreements for training have been established, at:

Andhra Pradesh Agricultural University, Rajendranagar, India
Himachal Pradesh Agricultural University, Simla, India
Punjab Agricultural University, Ludhiana, India
Haryana Agricultural University, Hissar, India
Jawaharlal Nehru Krishi Viswa Vidyalaya, Jabalpur, India
Tamil Nadu Agricultural University, Coimbatore, India
University of Agricultural Sciences, Bangalore, India
Iowa State University, Ames, Iowa, USA
Cornell University, Ithaca, NY, USA
Texas A & M University, Texas, USA
Agricultural University, Wageningen, The Netherlands
University of Reading, Reading, UK
Asian Institute of Technology, Bangkok, Thailand
University of Manitoba, Canada

The interaction among scientists of the Institute and university advisory committee members has been extensive and advantageous to both scholars and scientists. Indian universities, institutes, commercial companies, and local farmers have been contacted on educational visits. These visits demonstrate the adaptability of research findings and germplasm to other research programs and farms.

In-service Training Programs

The following objectives are used to develop specific training activities within each program for individuals or groups:[1]

Crop Improvement

The objectives of the crop improvement program are to provide opportunities to:

- learn breeding techniques for improving and stabilizing yields,
- assess and learn to utilize the potential of the germplasm available for use in the SAT,
- practice and learn breeding techniques and requirements for efficient and effective identification and utilization of resistances to factors that reduce production in the semi-arid tropics,
- work with crop improvement scientists, and
- develop skills in organizing and managing a successful breeding program.

1. Detailed outlines of these in-service training programs are available from the Training Program at ICRISAT.

Crop Production

The objectives of the crop production program are to provide opportunities to:

- gain practical skills for increasing crop production in the SAT through an integrated approach to natural and human resources in ever-changing environments,
- assess improved cropping and management procedures and learn how to adapt them to local conditions,
- learn to identify and reduce adverse influences that limit crop production in rainfed semi-arid tropics,
- develop an appreciation of the role of and the importance of utilizing social, cultural, and economic factors in improving agricultural production, and
- develop the ability to use extension techniques for communicating new and improved technology for increased and stabilized food production.

Farming Systems

Objectives of the farming systems program are to provide opportunities to:

- develop skills in natural resource utilization research related to catchment-area development for improved land and water management.
- become proficient in utilization of production factors, research methods and techniques related to agronomic practices, cropping systems, soil fertility, soil physics, plant protection, farm power, machinery, economics, and management skills to ensure increased and stabilized food production for the rainfed semi-arid tropics.

Specialized Areas

The specialized programs are to provide opportunities for:

- a skill development or improvement by practical experience, working with specific equipment and techniques,
- training and experience in working with a team approach to problem solving,
- developing specific new skills and techniques relative to identified special SAT problems for increased and stabilized food production.

Follow-up

National program scientists, in-country development program staff, and former trainees assist in identifying areas where trainee selection procedures can be improved, where additional training is required, and where additional training programs are needed. Contact is maintained through correspondence and personal visits by ICRISAT staff who are working and travelling in areas where former trainees are employed. Germplasm, reports, and newsletters and informational materials are provided to former trainees to keep them abreast of new developments. Such follow-up contact is maintained with 174 trainees from 35 countries who participated in over 30 000 man-days of training at ICRISAT from 1974 through 1978.

Looking Ahead

The number of trainees at ICRISAT Center is expected to increase by 1980 to an optimum at any one time of 60 to 75 in-service trainees, 10 to 15 research scholars, 10 to 12 research fellows, and 10 to 15 international interns, plus special area trainees (a few days to a few weeks for groups of up to 25 to 30 persons at a time) for intensive training in such areas as pathology, microbiology, entomology, land and water management and cropping systems.

A major restriction to the number of applicants will continue to be the inability of national research programs, development program sponsors, and Institute staff to identify persons qualified in English and agricultural science from areas where the predominant languages are French, Portuguese, Arabic, and Spanish. The number of potential trainees with satisfactory education, research, and agricultural training and experience in most SAT regions is relatively low, a condition expected to continue until the number of science graduates increases. The third limiting factor will be the number of persons the research and training staff can accept for instruction in the laboratory, classroom, library, and seminar facilities of ICRISAT Center.

To meet the needs of the regions within our mandate, the in-service training program anticipates accepting approximately 66% of its

nominees from African SAT regions where trained scientists are few. The remainder will be accepted from other regions. Approximately equal numbers of research scholars and research fellows will be considered from the African regions and from southern Asia; the remaining one-third will come from other regions of the world.

Instruction at ICRISAT will continue to be mainly in English. Intensive English language training courses will be conducted at Hyderabad or encouraged in the home country to facilitate the use of a common set of instructional materials and provide a wider source of literature to the trainees. Audio-tutorial teaching units in English and other languages can be used at ICRISAT to broaden the opportunity for those not fluent in English. Development of training programs in other language-group areas of the world will be explored as the number of potential trainees in a region increases or as regions obtain training facilities. However, the generally small number and widely scattered agricultural science graduates working in the semi-arid regions reduces the feasibility of establishing training centers in specific language regions for the 6-month type of individualized practical training programs. In addition, training in one's home environment is less valuable than experience gained in a new environment with a different range of natural resources and research facilities.

The number of requests for pigeonpea, chickpea, groundnut, and farming systems training programs will increase significantly as the national and regional programs expand their research and development activities with these crops and in farming systems. One of the major responsibilities placed on researchers at all levels is management of research farms and training personnel. Thus research farm management and training methods will continue to be emphasized in all our programs.

Persons who complete training and work in research and development programs of the semi-arid tropics are isolated and lack contact with other agricultural scientists. Hence, ICRISAT will — as part of the follow-up program — communicate current research findings and new germplasm developments to former trainees so that they can continue their professional improvement.

Summary of Discussion – Session 4

Dr. Govindaswamy asked what impact ICRISAT programs have made in Africa, who provides the needed inputs, and what part of the technology remains in use locally after ICRISAT has withdrawn.

Dr. Charreau said that it is too early to assess the impact of ICRISAT. The results will vary according to the country. The main input from ICRISAT so far has been the identification of sources of resistance to diseases, pests, and drought in both millet and sorghum. This should make a considerable impact on productivity in the near future. The impact also depends on the nature of the material. Some sorghum selections made in India during the *rabi* (postrainy) season have outyielded all other hybrids and varieties during the off-season in the Senegal River Valley. But they would have to be crossed with local material to give significant results. Regarding the adoption of technology by the African farmer, Dr. Charreau stressed that ICRISAT works strictly through national institutions and not directly with extension agencies or the farmers.

Dr. Blumenschein said that it is important for the developing countries to take the decisions needed to support agriculture and be prepared to receive technology generated by institutions such as ICRISAT.

Dr. Ajakaiye cautioned that evaluation of the work of an international institute should be done very carefully. ICRISAT will have finished its job when it develops a technology that can be transmitted to national programs; from there on it is the responsibility of these programs to pass it on to the farmer.

Mr. Russell asked about ICRISAT's plans for work in Sudan, observing that in southern Sudan particularly, no new sorghum introductions have been promising.

Dr. House agreed that ICRISAT must expand its testing beyond the Wad Medani area. Hyderabad-generated material has done poorly in Sudan so far, and ICRISAT is trying to develop material better adapted to local conditions there. Though much of the breeding work will be done at Wad Medani, testing will be extended to other sites, including southern Sudan.

Mr. Russell also asked whether ICRISAT has developed climatology and soil maps for African countries so as to determine what parts of the technology developed at Hyderabad would be applicable in Africa.

Dr. Kampen said that as far as possible ICRISAT tries to draw on the work done by other institutions. In this instance, a large amount of basic climatologic data collected in Africa and northeastern Brazil is available to ICRISAT. The CIEH (Comité Interafricain d'Etudes Hydrauliques) has completed a detailed study of the soil and water resources of the western savanna region of Africa and drawn up a soil capability map for the area; this will also be available to ICRISAT.

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Session 5

Interphase on Research and Development

Chairman: D. L. Umali
Co-Chairman: A. B. Joshi

Rapporteurs: Y. L. Nene
M. V. Reddy
J. P. Moss
D. Sharma

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The Relevance of a Research Program for Meeting the Needs of the Small Farmers of the SAT

Sir John Crawford*

Abstract

A research program becomes usefully relevant to the needs of the small farmers only if it is possible for them to adopt its findings. This requires not only a new technology which, if adopted, promises significant improvement, but also the supply of support services on terms that make the estimated returns feasible. Neutrality to scale, in a technical sense, may be a necessary condition to relevance, but it may not be sufficient if the support services are not neutral between large and small farmers.

I am not very clear whether "Research Program" means a research program (i.e., without regard to ICRISAT) or is limited to ICRISAT's program. I have chosen to emphasize the general problem of relevance in a research program, but inevitably (and properly) ICRISAT's activities are highly pertinent. Also I assume we are talking of small farmers who are poor, for whom an increase in living standards is desired.

Broadly, I will argue that a research program becomes usefully relevant to the needs of the small farmers only if it is possible for them to adopt its findings. This requires not only a new technology which, if adopted, promises significant improvement in return, but also the supply of support services on terms that make the estimated returns feasible. Neutrality to scale, in a technical sense, may be a necessary condition to relevance, but it may not be sufficient if the support services are not neutral between large and small farmers. Let me explore this matter further — even if it does no more than emphasize the importance and relevance of economic research activities not only at ICRISAT but, of course, in all agricultural research directed to improving the lot of small farmers.

It is a useful — and probably essential — start to devise a technology that is neutral to scale in the sense that any farmer, large or small, can adopt it if he can command the resources required to provide the necessary inputs. But if the resources are not at the ready command of the small farmer then "relevance" becomes limited by the constraints. Degrees of relevance are possible. Thus a small farmer may be able to improve his income merely by adopting an improved seed and a better cultural practice. This may be practicable despite constraints on a more complete and advanced system. The income results will generally be far less satisfactory, however, than if he is able to adopt a whole new system in which soil preparation, water conservation, improved seed varieties, fertilizer, and necessary cultural practices act together synergistically to give a result greater than the sum of the results of each improvement adopted in limited singular fashion. This is the benefit of a systems approach — which ICRISAT and Indian research activities have shown to be essential to any major lift in incomes of small farmers in the SAT regions with which they are concerned. *But,* "being able to adopt" a system requires more than the devising of the system in research trials. A first step in this is to learn what the constraints are.

Before I further develop this line of argument about the real meaning of relevance, let me make three small points and one major point.

a. Theoretically, if water conservation is an essential element in a system but requires cooperation of small farmers in a catchment area, then the technology is not neutral to scale. This is clearly likely to be of potential importance in some areas in the application of ICRISAT's work and the work of Indian Dry Land Farming Research Project. I mention this only to express the

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hope we will not push the definition of relevance to an extreme that w ' rule out attempts to secure cooperation among small farmers. I could illustrate a parallel problem in making viable village growing of coffee in Papua, New Guinea, by the pooling of land for various cultural and marketing practices and as a basis for raising the credit each grower requires.

b. A technology relevant to small holdings in ICRISAT territory in India may not be relevant in another SAT area — e.g., in Africa. This is obvious; nevertheless, some elements and principles from the work in Hyderabad may prove to be useful in building up an appropriate system elsewhere.

c. Again there may be a situation in which a technology is technically neutral, but is adverse to employment. Thus mechanization that is labor displacing may be discouraged for clear reasons of policy. On the other hand, a new technology may be so employment-creating (e.g., at harvest) that essential operations like threshing may call for mechanization to meet labor shortage (See discussion in Ghodake, Ryan, and Sarin 1978). I believe scientists must and do keep such matters in mind. This is not ruling out improvements in essential hand implements used by small farmers — or possibly the use of contractors in preparing a water catchment tank.

d. Finally, and not really a small point, but one that we may all take too much for granted: a technology may be neutral and feasible for small holders, but it is not likely to be adopted unless the returns are substantial and reasonably assured (some of the best of ICRISAT's economic work bears on this).

now return to the main argument — abundantly borne out by the work of economists at ICRISAT and IRRI and indeed increasingly at all the international institutes as well as in some national systems — that technical neutrality to scale is not sufficient. If the institutions that provide credit, inputs, and other support services (including extension) are biased against the small farmer, then relevance does not produce the response that it may well do on medium and large holdings. Inertia may well also play a part and will be encouraged if the risk factor is high. But I assume that this can be broken down if a clearly profitable and stable technology is promoted and well supported with appropriate services.

The probability of an improvement in the situation of the small farmer is increased if the research that is relevant to his need is both systems-oriented and attends to the support services required by the systems recommended. The major constraints may well be here. Significant change calls for more than a single element (such as a new variety of seed). This is recognized; but it is also easier to catch the imagination of governments or village leaders if a feasible system can be linked to the argument for an improved support service — such as a cooperative providing inputs, credit, and a marketing service. Clearly, improvement in services is itself the proper subject of research. It is not enough to identify them as problems. I warmly commend ICRISAT's efforts in this respect — but I am not sure that the detailed work should not be left to the agricultural universities' economics and sociology departments.

The relevance of research in these terms is naturally increased significantly if a system indicated at the research station is tested under on-farm situations. This, of course, merely underlines the importance of village level applications. As a general proposition, I support their development under conditions in which risk is borne or subsidized in the first 2 or 3 years of trial. Risk of the untried is almost certainly greater in a semi-arid rainfed area than it is in adopting an irrigation-based system, such as in Punjab.

The work of Dr. Ryan and his colleagues has shown up the biases against small farmers in the supply and terms of credit and provision of inputs as well as in marketing. Even under all these constraints some new technologies may pay, but it is fair to argue that these constraints do not have to be accepted as unchangeable. Full relevance of the work of ICRISAT and the related Indian institutions cannot be achieved until the constraints are greatly lessened or removed.

A major point follows from this last observation: the required services will, in practice, be achieved only by a combination of changes in policies and programs at macro as well as micro levels. Inertia regarding the performance of

credit cooperatives, banks, and fertilizer firms, may, for example, begin at the top level in governments, banks, or firms -- especially in responding to the needs of small farmers. Center-State relations in respect to ensuring small farmer services may be as much involved as is the local initiative of district officials.

Although implicit in my very summary remarks about improving support services, I think it worth giving a special mention to post-harvest technology. This applies both to cash crops to home storage of food grains. The reference to home storage applies with particular force, I would think, in SAT areas in which sorghums and millets are the common staples. The national stocks are not very relevant in this case. There are special gains possible here over and above the benefits of a farming system relevant to the total income situation of the small farmer.

What are the prospects that research that appears to be relevant will prove to be so? I think they are brighter; but let me be quite dogmatic on the limited responsibility of the research workers concerned. They may be frustrated by the slowness with which their results are adopted but their responsibilities are not unlimited and their power is limited. Our discussion is about ICRISAT, but my remarks apply more generally. Natural scientists and the social scientists in an international institute and in national systems have a joint responsibility to endeavor to produce farming systems that are both applicable and profitable for small farmers to adopt. They have a responsibility to demonstrate the result and to make the results known to those able to advance the use of these results. They will be aided in this not only by their own publications, workshops etc., but by the groundswell of interest and demand they create among their consumers of knowledge — the farmers themselves — and among those responsible particularly at the government level for the infrastructure of services. The supply of inputs, credit, and appropriate institutions is largely the responsibility of governments (political and administrative) at all levels. It is essential that their interest and understanding be enlisted and sustained. The relevance of the research is not lessened by failure of political interest and will, but the returns to research will be lessened. The scientist by himself *cannot* transfer the technology. He can promise it and demonstrate its viability under appropriate conditions.

There is today a growing recognition that improved technologies for small farmers are available or well on the way. The more favorable the conditions, the more they are being adopted. ICRISAT is, in fact, dealing with the riskier climatic situations under rainfed conditions. But the results are encouraging and need and justify more intensive trials. Will these trials be undertaken and will the institutional bias against small farmers be tackled? Dr. Ryan and colleagues have shown that the returns are there, but I believe more has to be done to bring these results home at a national level. Let me explain why I think this even though this really involves me in going beyond my brief.

We are today faced with a situation of somewhat tragic irony. Indian agricultural production is rising significantly and will continue to do so, especially as irrigation systems become more and more effective. The government understandably gives priority to this course of action. And yet, unless it attends to the employment situation, it will face a position in which production increases may exceed increases in market demand. Per capita consumption has not risen commensurately with production nor, it seems, with the rise in average incomes. It seems probable to me that at the higher level of incomes, consumption is becoming more diversified — that is, the direct demand for grains is not rising and is even falling. At the lower end of incomes, it seems not to be rising significantly, and I suspect that increased unemployment and underemployment may be a factor here. (The subject calls for research!)

It would follow from this that more attention has to be given to the smallest farmers and landless laborers whose consumption needs are not yet met. They need both off-farm employment and increased income on their own farms. This is abundantly evident in the SAT areas in which rising employment is needed concurrently with more productive rainfed farming. The small farmers will consume more of their own increased product, but nonfarm rural populations need employment (on and off the farms) and the consequent incomes to enable them to share in rising farm productivity. Another strong inference is that a technology that creates employment has a strong social relevance that is of high impor-

tance.

This situation is clearly recognized in India's draft 5-year plan, 1978–83, and it is hoped that policies and programs outlined there will be made effective. Fundamentally, this document is a statement of political economy. To me we are in a situation where agricultural research has made an adequate supply side of the food-population equation decidedly more feasible. The technologies emerging are relevant — the more so because the required conditions of feasibility are better recognized.

Making production feasible is but one major part of the political economy problem. Feasibility includes provision of an adequate and well-trained extension service. It includes the support services — input and credit supplies. But there is also yet another political economic requirement: this is the creation of demand among the poor. These are the people — especially in rural areas — with the highest income elasticity of demand for food. They require employment. This country's planners recognize this and have the right approach. But patience may well continue to be a necessity for reasons that seem to point to New Delhi from which the central leadership in a complex task must come. Nevertheless, momentum in the major administrative departments has gathered; I am certainly confident that this will continue, resulting in a "gearing into" (Dr. Ryan's phrase, I think) the problems of the small farmer.

It so happens that ICRISAT has perhaps the hardest end of the research spectrum: rainfed farming in the semi-arid tropics. The research workers, as I judge it, have made an excellent start. They have recognized many of the constraints on relevance. It is well that both center and state governments, ICAR itself, and the universities have all increased their linkages. This increases the hope for large-scale testing and final adoption of new and income-rewarding technologies. Realization of that hope requires the lessening of the constraints represented by inadequate support services for small farmers: credit, inputs, price support, and marketing facilities. By and large, the bigger farmers can look after themselves.

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The Role of International Institutes

Ralph W. Cummings*

Abstract

The Consultative Group on International Agricultural Research (CGIAR) provides support for 13 international institutes whose primary function is agricultural research. The translation of that research into practice is properly the task of the national and local agencies; the institutes, however, have the responsibility of finding and developing interfaces with national agencies to assure widespread reliable testing of potential technological innovations and dependable feedback, positive and negative. This has already been addressed in many cases. The establishment of ISNAR in 1978 is an important step towards strengthening national research programs; this, in turn, will enhance the effectiveness and usefulness of the international institutes and help ensure that there is no break in the chain from the discovery of knowledge to its final application on the land.

The Technical Advisory Committee (TAC) of the CGIAR has recently prepared and presented to the CGIAR an updated working paper on "Priorities for International Support to Agricultural Research." This follows a report of the Review Committee of the CGIAR, which made an extensive analysis of the CGIAR system in 1976. The TAC is now engaged in a "Stripe Analysis" across the several international institutes of the "off-campus activities" of these centers. The latter study will not be completed for some months ahead. The subject I am discussing, namely, "The Role of International Institutes" in interphasing on research and development, was considered by the first two studies mentioned above and will be a major concern of the stripe analysis now under way.

The Consultative Group on International Agricultural Research (CGIAR) provides the support for 13 international institutes. The basic objective of this system, as set forth in the TAC priorities paper, is to support agricultural research in and for developing countries that will contribute to:

a. Increasing the amount, quality, and stability of food supplies in the LDCs, and meeting the total world food needs.
b. Meeting the nutritional requirements of the less advantaged groups in the LDCs.

At the same time, the system is to take due account of the need to improve the level of income and standard of living of the less advantaged sections of society in the developing countries (especially rural), which determine their access to food, equity in distribution of benefits of research, and efficiency in the use of agricultural resources.

The primary function of the international centers is research. At the same time, they have a deep concern for the application of research to improve the agricultural production and the level of living of the constituent people. The centers do not have the physical and human resources to mount action programs to carry their findings to the vast numbers of farmers concerned, nor should they do so. National and local agencies are the proper ones to undertake this task. But the international centers do have the responsibility to find and develop the kind of interfaces that will assure that there is no break in the chain from discovery of knowledge, through its translation into appropriate technology, and its application on the land.

The direct links to the farmers and the methods of instructing them on advances in technological practices that could improve their productivity must be worked out within and by each nation concerned; recognizing that, we must consider the character, the strengths and weaknesses, and the effectiveness of the national agricultural science establishments

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for research, training, and extension. Several nations, such as India, the Philippines, Brazil, and others, have made great strides in recent years in building strong and effective national agricultural research and extension programs. I doubt if any of them are fully satisfied but many now have quite good and effective internal agricultural scientific establishments. Others are well on the way toward building their national agricultural research capability, but recognize their limitations in the present scope of their organizations and in their supplies of trained manpower with the experience and confidence required to meet the needs of their developing agricultural economies. And a large number of countries — notably the small, resource-poor, recently independent nations — have not yet been able to identify and train even the nucleus of manpower and scientific leadership necessary to rapidly accelerate advances in their agricultural sector.

The international centers and the CGIAR recognize the universal need — yes, the essentiality — of strong research and extension organizations within the nations with which they are cooperating. Without such internal strength within the nations concerned, the international centers are handicapped and greatly limited in developing the links through which technological advances can be translated into practice.

In recognition of this acute need, many of the industrialized nations have joined with national agencies on a bilateral basis to help strengthen national research programs or portions thereof. Some of the philanthropic foundations such as Rockefeller and Ford have also made significant contributions to this effect.

In 1975, the International Agricultural Development Service (IADS) was organized, under initial sponsorship of the Rockefeller Foundation, with the express purpose of helping to strengthen national agricultural research and development programs. This organization is gaining valuable experience in this field and is actively engaged in work with a number of nations in the developing world, assisting with building and strengthening their national capabilities for dealing with agricultural development and with technology introduction, development, and application. IADS has also sponsored several related studies and is preparing and publishing books and bulletins dealing with various aspects of the problem.

The TAC has, from its first meeting, recognized the importance of this subject and has encouraged greater attention hereto. In late 1978, the CGIAR formally entered this field in authorizing under its auspices, and with its support, an International Service for Strengthening National Agricultural Research (ISNAR). ISNAR's first Governing Board has been selected and it hopes to become operational in 1980.

The need for stronger internal national agricultural science establishments is now broadly recognized. It is to be hoped that the next decade may witness a rapid growth in national agricultural research capability around the world. This will in no sense diminish the importance and need for the international agricultural research centers or institutes. It will give them more effective instruments with which to interact and cooperate and should greatly enhance their effectiveness and usefulness. It will, undoubtedly, bring about an evolution in their specific roles.

Their role in a nation with a strong agricultural science establishment will be different from that which they might fill in a nation which still has limited capabilities. A great deal of flexibility will be essential in addressing the variety of needs. The International Rice Research Institute (IRRI), as a part of its long-range planning exercise, has attempted to describe the nature of its changing role. It is no longer releasing finished rice varieties as named IRRI varieties but, through its widespread cooperative genetic evaluation and utilization (GEU) program, has decided that this particular responsibility can best be entrusted to IRRI's national cooperators. An increased assumption by national programs for final variety and technology evaluation and release is visualized. The Institute sees a growing proportion of its resources going toward knowledge generation, genetic studies, supply of relevant germplasm, methodology development, and the earlier stages of technology development and training, as the national programs move further and more effectively into technology development and its evaluation, adaptation, and application. No sharp line of demarcation between international and national efforts is visualized, but an increasingly close cooperation and coordination to assure no gaps in the continuum from

knowledge generation to technology application in farmers' fields and a steadily rising and more efficient production and utilization.

The recent conference of agricultural research directors from developing countries held at Bellagio, Italy, foresaw an evolving role for the international centers. They reaffirmed the continuing essentiality of the internationally supported centers, with adequate support, continuity, and flexibility, and cited the following among their anticipated longer term continuing functions:

1. collection, conservation, cataloging, and distribution of germplasm;
2. organization of pathfinding research designed to raise the ceiling of yield and to impart greater stability to yield (i.e., research which can lead to the development of high-yield and high-stability varieties with desired quality);
3. development of improved research techniques;
4. organization of relevant training programs;
5. organization of information and bibliographic services; and
6. organization of symposia, seminars, and monitoring tours.

As the above and other functions are discharged, the international centers will serve the national programs — particularly the smaller and less developed ones — in increasing their awareness of the advances made elsewhere, including in other LDCs, and will greatly accelerate the interchange of information and technological advance among nations.

But having said the above, let us now turn back to the international centers themselves. They cannot, they should not, and they will not withdraw within their own walls and revert to abstract, nonrelevant scientific research. The pattern has been set in such a way as to keep them moving in an outward-looking fashion. The problem of agricultural production, whether on a commodity basis, a factor basis, or otherwise, cannot be viewed or encompassed from a single location or at a single point in time. International institutes have a responsibility for determining the range of applicability of the technology with whose development they are concerned. Leads coming from their research laboratories and test plots must be exposed to other environments.

For example, IRRI has to go outside of the Philippines to study gall midge. Its deep-water rice research is concentrated in Thailand. The devastating effect of zinc deficiency was first recognized in a cooperative program in India. Some of ICRISAT's millet lines, which seemed to be resistant to downy mildew in India, did not hold up when planted in some locations in Africa. Water conservation measures based on management of entire catchment areas may be difficult to adapt to varying land ownership patterns. These same measures if based on animal-drawn implements may encounter different problems where the only power available is human muscle and the farmers have been accustomed to using different kinds of hand tools for cultivation. The strains or species of *Striga* in Africa differ from those prevalent in India. Highly productive sorghum lines may have more limited usefulness if they mature in a season of heavy rainfall and are highly susceptible to grain mold.

An endless array of situations could be enumerated to illustrate the fact that a practice that is highly effective in one location may not work in another. Some are biological or ecological in character, while others may have social, economic, or anthropological bases.

Thus an international institute must work out arrangements for exposing its biological materials and its indicated technological innovations to a wide variety of environments — physical, biological, and social — and get reliable feedback as to the results. The various institutes will naturally approach this in different ways. It is unlikely that any one pattern will prove superior in all cases.

ICRISAT is fortunate to be located in a large country with a wide diversity of ecological situations, and which has developed an advanced model of agricultural science institutions. The opportunity for developing close cooperation with the relevant All India cooperative research projects provides an interface of first-order importance. The germplasm resources of the Institute; its breeding, crossing, and progeny fields; and its test plots on water conservation, intercropping, tillage practices, and farming systems are fully open and available to Indian scientists in these related programs. Seeds are made available freely as requested. This two-way exchange makes ICRISAT's program richer and more relevant,

and the contribution it makes in ideas and materials is of real benefit to the Indian program. This should be cultivated and fostered. The opportunity of working out contractual arrangements with Indian institutions to provide some of the early testing and evaluations in different environments (providing screening ahead of entry into All India evaluations) provides another invaluable interface. The very constructive approach taken with plant quarantine, which has permitted large-scale interchange of genetic materials with other parts of the world while protecting the nation and other nations from exchange of exotic pests and diseases, appears very commendable. The work with a sample of India's farm villages and village people is of immeasurable value in helping to identify some of the limitations and real problems of farm people in introducing technological innovations.

These are only a few examples of effective and valuable interfacing in the host country. But this is not enough. ICRISAT's responsibility extends to the seasonally dry semi-arid tropical regions around the globe. Africa has the largest such area in the world. ICRISAT has been moving vigorously to develop its interfaces in the sorghum-, millet-, and groundnut-growing areas of that continent. The social and cultural patterns in Africa differ from those in India. The wet and dry seasons in the Sahelian and Sudano-Sahelian areas seem to be more sharply defined. Disease and pest complexes have much in common with the ones in India but also have important differences. Animal power is less common and human power for cultivation is more dominant. There are soil and climatic similarities and differences. In addition to the local indigenous languages, French is spoken in some countries, English in some, and Portuguese in others. The interface with all is necessary if the Institute is to fulfil its mandate. A different pattern is being tried there, involving a combination of interdisciplinary teams at a couple of selected locations, smaller groups at others, and a degree of mobility of its staff that attempts to maintain contact and provide assistance and materials to all the nations concerned.

In Latin America, the attempts at developing an appropriate interface have not yet advanced as far as in Asia and Africa but the Institute does have a significant role for the region.

Early successes in the development and spread of improved food crop production technology came through the vehicle of seed. Varieties that had a markedly different plant architecture and capacity to produce could be readily recognized and rapidly multiplied. The responses to fertilizer and pest control could be readily demonstrated and were highly visible. Direct comparisons with established varieties and conventional production practices could readily demonstrate when and where new varieties could be used; if they did not immediately encounter new pest and disease problems, their profitability was evident. Seed became the vehicle for introduction of improved production technology, new rates of fertilizer application, precision field operations, pest, disease, and weed control, etc. Farmers will adopt new technology when they have confidence that it is dependably superior, profitable, and can be fitted into their systems of production, the appropriate timing of their labor demands, and their resources. Where these are doubtful, or risks are higher, we can expect farmers to be more cautious.

IRRI and CIMMYT took the early lead in developing and introducing improved lodging-resistant, fertilizer-responsive rice and wheat varieties, primarily in areas of assured and dependable water supplies. Their results were spectacular. The "green revolution" initiated thereby has raised great hopes and expectations. These institutes are now trying to tackle some of the less favorable environments in which their mandated crops are grown. The world is placing great hopes on the institute system as a force to accelerate progress in all sections of food production to meet the demands of the growing world population.

ICRISAT is dealing with five crops which prevail in areas where moisture supply is less dependable. With these crops, seed can still be an important vehicle for introducing technological change but the problems of managing the moisture regime so as to reduce risk to a minimum and give maximum probability of a successful crop yield, add other dimensions to the problem of technology transfer. This places acute demands on establishing the kinds of relationships with national authorities that will assure widespread reliable testing of potential technological innovations and dependable feedback, both positive and negative. The more

complex the technology and the greater the number of factors to be considered, the greater will be the pressure to define with precision the conditions under which given innovations can be expected to be successful.

The international institutes all recognize the necessity of developing effective links, cooperations, or interfaces with national programs and for assuring the two-way continuum from problem identification, scientific research, technology generation, technology testing and verification, to its application. Techniques include visits of institute scientists to national programs, visits of national scientists to the institutes, publications, newsletters, exchange of germplasm and genetic material, posting of scientists with national or regional stations away from headquarters, regional liaison representatives, conferences and symposia, workshops involving scientists from the international institutes and the cooperating institutions, and training programs. Each institute will develop its own mix of these and perhaps other techniques in its search for the best way to assure that it is performing the functions most needed and that it is using its resources most effectively in strengthening its part of the chain for advancing agriculture in its part of the developing world.

I will not comment further on most of the techniques listed above. Perhaps their value and necessity may be self-evident. I would, however, like to say a few words on training. This will take many forms and the training programs will vary considerably in length and character. An increasing number of scientists in developing countries have spent enough time in organized programs at one or another of the international centers to become personally acquainted with the center's staff, programs, aims, and objectives to know what resources they can call on for consultation, advice, and assistance as they encounter new problems in their own work; they can inform institute scientists of their own observations and call their attention to problems and situations peculiar to their area. These scientists should, if actively cultivated, develop over time the kind of effective working interfaces so essential to realization of the aims and goals of the system.

As the current "Stripe Analysis" on off-campus activities of the international centers proceeds, I feel sure we can count on the full cooperation of all concerned, and it is my hope that we can glean from our individual and collective experience some general principles and guidelines that will be useful to all.

Role of National Programs in Linking Research and Development

M. S. Swaminathan*

Abstract

A dynamic national research base is a must for launching and maintaining an agricultural development program that can work toward the triple goal of more food, more income, and more jobs from available resources. While international institutes can act as catalysts of change, only a strong national program can ensure sustained advance. Location-specific research must develop an economically viable technology for each production system and its probable impact must be assessed to prevent new and unexpected pest, disease, or soil problems. In India today, actual farm yields are less than 25% of the potential available even at current levels of technology. The immediate task, therefore, is for research, extension, and development agencies to cooperate in bridging the gap between actual and potential yields.

The major goals of agricultural development in most developing countries are:

a. to build a national food security system that can ensure that no child, woman, or man goes to bed hungry,
b. to generate more income in rural areas through the conversion of farming into a market-oriented occupation and through improved post-harvest technology leading to the preparation of value-added products,
c. to generate more opportunities for gainful employment, particularly under conditions where agriculture is the major avenue of employment, and
d. to ensure that the ecological infrastructure essential for sustained agricultural advance is preserved and that the short-term and long-term goals of agricultural development are in harmony with each other.

National agricultural research systems, therefore, have to base their priorities on the triple developmental goal of more food, income, and jobs from the available land, water, sunlight, and other production endowments. An additional dimension that has recently become important is the need for delinking production advance from increased consumption of nonrenewable forms of energy. The continuous escalation in the cost of petroleum products underlines the urgency of research on integrated energy supply systems involving an appropriate blend of renewable and nonrenewable forms of energy.

Need for Location-Specific Research

Apart from the challenge posed by increasing energy costs, agricultural scientists of most developing countries also face the challenge of having to develop high-yield, high-stability technologies for very small farms. For example, in India, the average size of a farm holding is tending to go down rapidly holdings become fragmented by the increasing pressure of population on land (Table 1).

This challenge can be met only by optimizing the benefits from the agricultural assets of each region and minimizing the prevailing risks and hazards. This, in turn, will call for relevant location-specific research tailored to the needs of each agroecological, socioeconomic, cultural, and political milieu. While international institutes can generate material, conserve germplasm, and organize testing and training programs of great value for national research systems, only the national programs can help sustain a dynamic agricultural development

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Table 1. Size of land holdings as revealed by agricultural census.

Name of the state	Average size of holdings		Percentage increase or decrease in the number of holdings in 1976–77 over 1970–71					
	1970–1971	1976–1977	Total holdings	Marginal (below 1 ha)	Small (1–2 ha)	Semi-medium (2–4 ha)	Medium (4–10 ha)	Large (10 ha & above)
Uttar Pradesh	1.16	1.05	8.5	12.6	3.4	−1.5	−4.0	−23.2
Karnataka	3.20	2.99	7.3	17.9	5.8	3.7	1.4	−9.1
Madhya Pradesh	4.00	3.60	14.4	17.5	23.0	18.6	8.6	−7.4
Rajasthan	5.46	4.65	7.1	40.4	15.7	12.3	8.9	−2.9

effort. Several large development projects in developing countries have come to grief within a few years because of new pest and soil health problems. Often, irrigation leads to problems such as alkalinity, salinity, and waterlogging if scientific management practices based on anticipatory research are not introduced. When the High Yielding Variety Program was initiated in India in 1966, the brown plant hopper was practically unknown in rice fields. Today, it has become a major menace. Similarly in wheat, Karnal Bunt has become a serious problem, although it was of practically no importance a decade ago. In pearl millet, downy mildew and ergot became serious within a few years after the release of HB-1. Therefore, a dynamic national research base is a must for launching and sustaining a dynamic national development program.

Mixed farming involving crop-livestock integrated production systems is a way of life for farmers in India and in several other developing countries. A major strategy for providing additional income and employment in India to small and marginal farmers has been the introduction of dairying, poultry, sheep husbandry, or other animal-based enterprises. Therefore, agricultural research agencies in developing countries will have to take a total view of the entire farming system. Similarly, aquaculture both in coastal and inland waters is an important source of income, employment, and nutrition. If thriving aquaculture production systems are to be promoted, the agricultural technology introduced for combating the unholy triple alliance of pests, pathogens, and weeds will have to be compatible with the need to avoid water pollution. Thus, the development of economically viable technologies appropriate to each production system should be the major goal of national programs.

Research Goals and Priorities

In addition to the major requirements of agencies involved in development, the potential as well as the limitations of the clients of research — farmers and fishermen — must be clearly understood. The first obvious step is to have a clear idea of the absolute maximum production potential under a given set of growing conditions. These can be calculated through a theoretical analysis of the climate, soil, and water resources of each region. Buringh and coworkers (1975) have estimated that the absolute maximum global production potential may be on the order of 49 830 million tonnes of grain equivalent per year. Sinha and Swaminathan (1979) have estimated that the absolute maximum production potential in terms of grain equivalent in India may be of the order of 4572 million tonnes per year (Table 2).

While these are absolute maximum limits on the basis of our current understanding of production parameters, the immediate task is to bridge the gap between actual and potential farm yields. An estimate of the untapped production reservoir available at current levels of technology can be obtained by conducting suitably designed on-farm testing and demonstrations in farmers' fields. Such studies carried out in India indicate that in most farming sys-

tems less than 25% of the available potential is being realized today. Research on bridging the gap between potential and actual experimental yields should also receive adequate support. Both mission-oriented basic research and interdisciplinary applied research will be necessary for this purpose.

Table 2. Actual and potential agricultural and irrigated land.

	ACL	AIL	%	PAL	PIAL	%	MPGE
World*	1402	201	14.3	3419	470	13.7	49830
India**	142.8	34	24.5	142.8	77.6	54.3	4572

ACL = Actual cultivated land (10^6 ha)
AIL = Actual irrigated land (10^6 ha)
PAL = Potential agricultural land (10^6 ha)
PIAL = Potential irrigable agricultural land (10^6 ha)
MPGE = Minimum production of grain equivalents, including irrigation (10^6 tonnes/year)

* Data of Buringh et al. (1975)
** Data of Sinha and Swaminathan (1979)

Constraints Responsible for the Yield Gap

By organizing an interdisciplinary constraints analysis, it is possible to identify the relative roles of ecological, technological and socio-economic factors in causing a specific gap between actual and potential farm yields. Once the precise constraints are known, it should be possible to initiate appropriate corrective steps to eliminate the constraints.

Three major steps are involved in the transfer and sustenance of new technology:

1. availability of economically viable technology,
2. organization of extension and other services, including the supply of credit and other inputs that will enable all farmers — irrespective of their innate potential for mobilizing inputs and their willingness to take risks — to adopt new technology, and
3. public policies in the area of pricing, storage, marketing and distribution.

Once the research agency has been able to identify the constraints responsible for low yields, it would be useful if seminars and workshops are organized for those engaged in the formulation of public policies and development programs, as well as field extension and input supply work. Such seminars should be based on carefully conducted case studies that can reveal to the participants the size of the yield gap and the nature of the constraints responsible for it. To undertake this task successfully, it is essential that social scientists and agricultural scientists work together as a team. At the field level, social and biological engineering will have to be integrated. For example, watershed management in semi-arid areas will be possible only if all the farmers in the watershed cooperate with each other. Integrated individual and community action will be necessary under conditions of small holdings to obtain good yields and to reduce the cost of production in both irrigated and rainfed areas.

Methods Used in India for Promoting Linkages

In India, agricultural research is organized through 21 agricultural universities, 35 ICAR Institutes and National Bureaus, and over 50 All India Coordinated Research Projects. The Coordinated Projects represent a national grid of cooperative experiments organized by scientists belonging to different institutions and disciplines. Once the data from coordinated tests indicate that a variety or a particular farm management system can enhance the income of the farmer, these are tested and demonstrated in farmers' fields through:

a. national demonstrations,
b. minikit demonstrations,
c. whole village or watershed operational research projects, and
d. pilot projects introduced on an area basis.

There is also extensive on-farm testing of research results, particularly under the All India Coordinated Agronomic Experiments Scheme. The National Demonstration Programme was introduced in 1964 to familiarize farmers with the new vistas in crop production opened up by the high-yielding varieties of wheat, rice, sorghum, maize, and pearl millet. The program

was so successful that the clamor for seeds of new varieties became suddenly widespread. The rapid spread of new varieties, along with adoption of appropriate management practices, led to an increase in wheat production of nearly 300% in the course of 15 years.

In addition to the organization of demonstrations based on the principle of "seeing is believing," agricultural universities and central research institutes in India help to organize training programs both for the staff of development departments and teachers of farmers' training schools. In addition, a grass roots level training organization called "Krishi Vigyan Kendra" was started about 5 years ago. Learning is by doing; consequently, formal literacy is not a prerequisite for joining the training courses.

Another very important linkage between national programs and development agencies as well as farmers is provided by mass media such as newspapers, radio, and television, and the Training and Visit system of extension.

Conclusion

In the past, linkages between research and development institutions have been weak in many developing countries. Whatever linkages do exist are mostly ad hoc in nature. It is only in recent years that both these groups of agencies have started realizing that without a continuous feedback relationship between them, research will not be socially relevant nor development programs lead to the desired socioeconomic objectives. Therefore, research, extension, and development agencies will have to function as links in a chain, if agricultural progress is to move speedily and without interruption.

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The Role of ISNAR in Transfer of Technology

Klaus J. Lampe*

Abstract

ISNAR is the newest member of the family of organizations supported by the CGIAR in its effort to improve agricultural production in developing countries. Unlike the international research centers, ISNAR is a service organization; it will complement the activities of the other institutes and programs. Its primary mission is to strengthen the national agricultural research capabilities in developing countries. It will serve as a linkage mechanism between the international agricultural research centers and national institutions, as an intermediary between interested partners to promote bilateral cooperation in agricultural research, and as a linkage to ensure that target-group-related research will reach – via an effective extension service – the rural population of countries which invite ISNAR's assistance.

Most of you might have already heard about ISNAR, the International Service for National Agricultural Research, which will start work in the near future. For those of you who have not had a chance to familiarize yourselves with this new service, let me make a few introductory remarks about ISNAR's background.

ISNAR's Family Background: The CGIAR System

ISNAR's parent organization is the CGIAR — the Consultative Group on International Agricultural Research. The Consultative Group is well known to all of us — primarily through the success stories of its offspring, the international agricultural research institutes.

This morning, in fact, Professor Cummings spoke to us about "The Role of the International Institutes," paying due tribute to their outstanding record of achievements.

ISNAR will be the youngest addition to the family of CGIAR. And it will be quite different from its sister institutions within the system:

- It will be a service rather than an institute.
- It will complement the activities of other institutes and programs.
- It will provide assistance to developing countries — at their request — to enable their national agencies to do their own agricultural research more effectively.
- ISNAR will be concerned primarily with research policy, research planning, research organization, and research management.

We all know that in many developing countries, assistance of this kind is essential if full advantage is to be taken of the work of the international centers. Hence, we can confirm that ISNAR will complement the activities of its sister institutions.

ISNAR's Historical Background

To deal with history first, I feel I ought to mention a few of the more noteworthy milestones on the way to the establishment of this new service. After 2 years of informal and semiformal negotiations, during CG meetings in April 1977, European members of the Consultative Group gathered at Munich for another informal meeting to consider means of assisting developing countries to strengthen their national agricultural research systems.

There had been, for some time, a growing awareness of the more and more pressing need for additional assistance in the strengthening of national agricultural research capabilities. The main concern was to enable national research systems to generate and adapt technology suitable to local farming conditions. The consensus

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of the Munich meeting was that the CGIAR should be asked to establish a service for this purpose as a part of the CGIAR system.

The Technical Advisory Committee of the Consultative Group (TAC) endorsed this idea and recommended the establishment of a task force on the subject.

This task force was set up to "identify the constraints on the availability and application of external assistance to strengthen national agricultural research capabilities in developing countries." The group was requested to consider the feasibility and desirability of alternative means of overcoming these constraints, including the creation of an international service or any other appropriate entity.

The composition of the task force was representative of major interests of both recipients and donors, industrialized and agriculture-oriented countries. Its findings and recommendations can be summed up in the proposal to establish an "International Service for National Agricultural Research" under the auspices of the Consultative Group.

The CGIAR accepted this proposal. In accordance with the experience and tradition of the CG, a committee was formed — the ISNAR Committee — to take decisions on the Group's behalf and to initiate action to get ISNAR started.

The German Agency for Technical Cooperation (GTZ), which I have the pleasure to represent, has been appointed to serve as Executing Agency for the establishment of ISNAR.

At this juncture, I might add that we at GTZ are pleased to be involved in the construction of this new service. We are deeply convinced of the importance of its mission and we have great trust in the impact it will have on national research capabilities in developing countries. We are working hard to get it off the ground as soon as possible; we try to invest our own experience, gained during the last 15 to 20 years and, where necessary, we try to learn as quickly as possible.

ISNAR's Objectives and Functions

Objectives

As spelled out in its draft constitution, "the purpose of ISNAR is to help strengthen national agricultural research capabilities in developing countries. This includes cooperation in identifying research problems and in formulating research strategies and policies, assistance in building up an adequate institutional infrastructure and other research facilities, as well as in promoting specific national or regional research programs. The ultimate goal is to enable developing countries to plan, organize, manage, and execute research more effectively from their own human, natural, and financial resources."

These rather broadly defined terms of reference for ISNAR have to be seen against the overall setting of national agricultural research in Asia, Africa, and Latin America.

A brief view of the science statistics of 1974 collected by Agrawal for UNEP and the IIED might be interesting as another contribution to the North-South dialog. According to these figures, 28 industrialized countries invest 97% of the world's research budget and employ 87% of the world's research worker community. Despite these figures, 23% of the 4.6 million university graduates of 1972 are from developing countries. In most cases they are graduates without adequate future; without adequate research career opportunities; without adequate research facilities, policies, and programs; without adequate international linkages; without adequate political support for development-oriented research. But quite often they have alternative professional chances in industry, trade, and research institutions abroad.

At this point, the imbalance of research support in Africa, Asia, and Latin America cannot be neglected. In Asia, only 50% of the Third World research capital is invested, despite the fact that 70% of the Third World population is living in this area.

The CGIAR task force on ISNAR — in evaluating this overall setting and its implications for assistance activities — found a clear and urgent need for additional possibilities to strengthen national agricultural research. The concern is to strengthen the national research system as a whole in order to generate and adapt technology suitable to local farming conditions for commodities important to national development objectives, including but not limited to, the food commodities covered by the international agricultural research centers. It is a

well-known fact that research needs vary widely among developing countries, depending on their agricultural potential, the stage of development of their research capabilities, and last but not least, the market for agricultural products. A few countries with an adequate supply of skilled scientists and well-managed systems may need only financial help to build facilities. Others with totally inadequate research resources need expatriate scientists and technicians from neighboring countries or abroad, in addition to facilities, to initiate even limited research programs. Many countries fall in between.

The root of the problem in most countries is the need to plan, organize, and manage research more effectively. This involves a broad range of activities, such as:

- Establishing research priorities in accordance with national development objectives, resource potential, and farmer's needs
- Developing research programs and projects
- Organizing and managing the research system to use research resources (including external assistance) more effectively
- Creating effective means for transferring new technology to the extension service and thus ultimately to the farmers
- Developing training plans to provide the skilled scientists and technicians needed for a balanced system
- Arranging for the facilities and other support that will enable scientists to work effectively
- Establishing links with other research institutions, particularly the international centers
- Creating political awareness, understanding, and support for a target-group-oriented research policy

It takes years to build an effective research system. Unless the national systems are strengthened in their planning, organization, and management so as to enable them to undertake more productive research, the research establishments will continue to have difficulties in enlisting the commitment of their governments to provide adequate long-term support. In the absence of such improvements, they are also likely to continue to have difficulties in attracting necessary financing from external assistance agencies. Most external agencies would be willing to increase support if suitable programs or projects were presented to them. Such a policy, in my opinion, is also a very important requisite to stop the flow of know-how from developing countries to the industrialized world defined by that ugly term: brain drain.

Development assistance agencies — international and national — have contributed much to improving national research capabilities, largely through training substantial numbers of scientists and providing financial assistance and expatriate technical expertise for specific research operations. But much more remains to be done in these aspects. Moreover, relatively few countries are receiving long-term contributions at the level of overall research planning, research organization, and management. Traditional assistance agencies are limited in their ability to fill this need for a variety of reasons, such as the difficulty of providing highly qualified personnel for the long periods required to build research systems; budgetary and operating constraints that attend most of the larger organizations; and political sensitivities and fluctuations in political relationships which can hamper long-term bilateral assistance at a policy level.

In view of this situation regarding research needs on the one side and potential support facilities on the other, the task force concluded — and we concur with its findings — that:

- Existing agencies, both multilateral and bilateral, cannot meet the needs of national agricultural research systems in full;
- Additional support is needed; and
- The CGIAR system can and should contribute by the establishment of a special service like ISNAR.

ISNAR can thus be seen as the logical expansion of the Consultative Group's concern to assure that the benefits of improved technology are made widely available to increase global agricultural production.

Functions

From this rather broadly defined set of objectives of ISNAR, the functions of the service can — in my view — be narrowed down to three principal tasks:

1. ISNAR will serve as a linkage mechanism between the international agricultural research centers of the CGIAR system and national agricultural research institutions.

   It has for long been a well-known fact that the international centers are performing an outstanding job in developing crop varieties and farming systems that are broadly applicable over relatively wide environmental regions.

   It is equally well known that a particular country will obtain the full benefits of research done by the international centers only if its own research system can effectively cope with the needs of refinement and adaptation.

   I see no need to prove again the immense need for adaptive research in developing countries on the one side and the need for strengthening of research capacities to cope with these requirements on the other. Looked at from this angle, it becomes obvious that ISNAR can be helpful to the international centers. It is clear that the centers must continue to work directly with national organizations to validate their research findings and in other matters related to center programs. ISNAR will not by any means interfere with such cooperative activities.

   The centers have come under considerable pressure to provide to national agricultural research programs assistance that exceeds their own mandates and proper interests but that they find difficult to refuse because of the urgency of the needs. In future, developing countries can turn to ISNAR rather than to the centers for such cooperation.

   To the extent that the service is successful in contributing to stronger national research systems, it will facilitate and make more effective the cooperative programs of the centers. Conversely, the service will find it important to be able to call on centers on behalf of its client countries for training and for specialized expertise, which the centers are able and willing to provide within their mandates.

2. The second main function of ISNAR will be to serve as intermediary between interested partners in order to promote bilateral cooperation in the field of agricultural research. This function could be described as that of an honest broker. ISNAR will provide assistance in order to promote cooperation in the technical as well as in the financial field; in other words, ISNAR will assist developing countries in the elaboration of programs of action, including specific projects for external financing, at the same time it will assist countries in contacting potential donors for the financing of such research programs and projects. In doing so, ISNAR can indirectly or directly become a partner for the implementation of the TCDC philosophy in the area of agricultural research.

   In doing this, ISNAR will not supplant other sources of technical assistance; on the contrary, it will help governments of client countries to find and use such source more effectively, and enable assistance agencies to provide support within the framework of a comprehensive program for the development of the national research systems. Thus the service will not only be complementary to the activities of other assistance agencies but also be helpful to them. Undoubtedly, the service has to meet the felt needs of developing countries. An additional advantage in this context will be ISNAR's close relationships to the financial resources of the CGIAR donors.

3. The third of ISNAR's main functions is one of linkage in promoting target-group-related research to ensure that its results will reach — via an effective extension service — the rural population in the respective countries. In my opinion the overriding importance of well-functioning linkages between research organization, extension services, and farming community cannot be overstressed. ISNAR's role in this context could be described as a liaison function. ISNAR will promote wherever necessary the improvement of links between research, extension, and the farming community.

The Principles Underlying ISNAR's Activities

ISNAR's founding fathers have devoted great

attention to the definition of eight principles that shall guide all of ISNAR's activities. These principles are an essential part of ISNAR's draft constitution. They are clearly formulated and self-explanatory:

1. ISNAR's services will be available to any developing country. ISNAR will provide assistance to a country only at the country's request.
2. ISNAR will work in close cooperation with all international organizations — in particular, the Food and Agriculture Organization (FAO), bilateral agencies, foundations, and national and regional organizations concerned with agricultural research. ISNAR will complement, not compete with, such other programs and sources of technical assistance.
3. ISNAR will concentrate its assistance mainly on program, policy, and organizational and management issues of agricultural research.
4. ISNAR will give emphasis to the generation, introduction, and use of adapted technology suitable to resource-poor farmers and local farming conditions.
5. ISNAR will be concerned with commodities important to national development objectives including, but not limited to, the food commodities covered by the CGIAR system.
6. ISNAR will be essentially limited to giving assistance in the organization of research. It will also maintain an awareness of the linkage among research, training, and extension. ISNAR may, to the extent necessary, promote effective research, concern itself with improving links between the research systems and the farmer.
7. ISNAR will not undertake research activities in its own right. ISNAR will, however, initiate on request national or regional surveys in order to assess the appropriateness of research policies, research systems, and organizations. Such surveys will be undertaken in cooperation with the recipient country and other organizations.
8. ISNAR will, for the execution of projects, normally seek the service of existing international or national agencies. Only in exceptional cases may ISNAR assume operational responsibilities. Each such involvement will require prior approval of the ISNAR board of trustees, provided that costs are fully covered from noncore funding.

These principles clearly define the scope of ISNAR's mandate. They will ensure that the new service can perform its tasks in accordance with the ideas that led to its establishment.

Proposed Activities of ISNAR

The CGIAR Task Force on ISNAR has narrowed down with some precision the list of activities and has seen to it that this list became part of the draft constitution. In accordance with this list, ISNAR will provide assistance to developing countries in:

- Identifying needs for planning and carrying out agricultural research;
- Determining research priorities;
- Formulating overall research policies and strategies;
- Elaborating programs of action, including specific projects for external financing;
- Designing necessary organizational and institutional arrangements for carrying out research programs and projects;
- Finding the necessary resources for the execution of such activities;
- Contacting potential external sources for financing research programs and projects;
- Promoting effective links between research organizations, extension services, and the farming community;
- Determining the basic facilities required to conduct research (laboratories, equipment, experiment stations, adequate staffing, finance, etc.);
- Establishing and strengthening links to existing information systems in order to speed up exchange of information on research results, ongoing research, and training opportunities at international and national institutions;
- Organizing appropriate flows of information within a geographic region so that interested countries may arrange to cooperate on specific research efforts;
- Arranging national training programs for research and research support staff;
- Organizing and supporting symposia and

seminars for the interchange and dissemination of ideas and information useful in the development and operation of national research systems;

- Evaluating the effectiveness and suitability of various forms of research organizations and activity.

ISNAR will establish an information system insofar as it enables the services to fulfill its functions and does not duplicate existing information services. This information system will collect and disseminate information about:

- Completed and ongoing research of the international agricultural research centers of the CGIAR system and research accomplished at national and regional levels;
- Training opportunities at the international or relevant national centers on specific research topics, on research administration and management, or for training of technical staff.

ISNAR will keep abreast of policies, practices, and capabilities of other agencies active in agricultural research. ISNAR will also keep abreast of important technical developments in agricultural research.

Status and Organizational Structure of ISNAR

To round out the picture that I have been trying to draw of ISNAR, we now ought to deal briefly with its status and its organizational structure. These two points are of a more indirect importance to ISNAR's scope of action and to its potential of success.

First, the service will have characteristics that will enable it to operate with maximum effectiveness:

- It will be autonomous and nonpolitical in management, staffing, and operations;
- It will be a center whose sole business is to help strengthen national research systems, normally by providing assistance over long periods, and with a career staff of the same caliber as the staff of the international agricultural research centers;
- It will be a relatively small organization capable of — hopefully — quick response to requests from developing countries;
- It will have sufficient stature to be able to assist the countries it serves to obtain external finance for support of their research systems.

Second, the service is being established as an integral part of the CGIAR system, with full participation in the benefits and the responsibilities accompanying that position. The service's policies, programs, budget, and performance will be examined by the CGIAR and TAC in much the same manner as for international centers. This procedure is designed to ensure the maintenance of the close family relationships within the CG system with all its direct and indirect advantages for users of the system.

Conclusions

On this 31st of August in Vienna, 4000 delegates from more than 120 countries conclude the UN World Conference on Science and Technology. The outcome of this fifth technical conference is unknown yet. But you don't have to be a prophet. The 4000 suitcases of the mentioned delegates are filled with papers and documents but most probably more questions than answers. If this century, which has influenced mankind by science and technology so deeply, will not find solutions to the problems which world population will face in the twenty-first century and beyond, you may be allowed to question the overall value of the progress of mankind during the last 100 years.

Since it is well known that we need at least 20 years to get research results out of the laboratories to the often-mentioned farmer's field we are already far behind schedule.

A futurological approach is very much needed to invent production systems on renewable resources and to save the nonrenewable ones for the centuries ahead of us. You are definitely not a pessimist if you believe in the limit of growth but a realist. Hopefully, scientists as well as politicians will join in a realism which is geared to research and development policies that will allow 8 billion or more at the end of this century to live on our globe with a fair chance of an adequate human life.

Today we are very far from that point. Our spaceship earth is in bad need of a program of global character for its own future. We should accustom ourselves and the political

decision-makers to the fact that agricultural research in the broad sense — research for the development of rural areas — is not a multimillion but a multibillion dollar undertaking for the years to come, in order to give a positive answer to the Malthusian question: to be or not to be.

ISNAR wants to be and will become a small stone in that mosaic, perhaps also a part of a spearpoint in a global campaign for agricultural research promotion of a new dimension.

The Role of IADS Programs in Transfer of Technology

D. S. Athwal*

Abstract

IADS was established in 1975 to provide services required by developing countries to design, organize, and strengthen agricultural research and development institutions. IADS fosters cooperation among assistance agencies and helps to integrate resources to support national efforts. Three-fourths of IADS' present activities are direct services to help more than 12 countries in Asia, Africa, and Latin America in planning and implementing research programs. Other activities involve development of leaders and managers, preparation of development-oriented literature, and liaison with assistance agencies and developing country institutions. While primary emphasis to date has been work with national research systems, IADS is now prepared to participate in projects more oriented to development, in accord with its original mandate.

When conventional approaches do not provide satisfactory solutions to critical problems of development, administrators and scientists, working together, seek answers through new institutions and innovate organizational arrangements. In recent years, many knowledgeable individuals have been increasingly concerned about deficiencies in existing approaches to technical assistance in rapidly building national capabilities in agricultural research and development. The International Agricultural Development Service (IADS) is one of the organizational responses to this situation.

But the story really begins at least two decades ago. In 1960, in response to the actual and predicted food problems of rice-consuming nations of the world, the Ford and Rockefeller Foundations, working together with the Government of the Philippines, created the first international agricultural research center — the International Rice Research Institute.

Here this week, some 19 years later, we are dedicating this new center, one in a unique network of international research institutions dedicated to helping the developing nations to increase agricultural production.

These international centers, operating independently but supported through the forum of the Consultative Group on International Agricultural Research — an innovation in itself — are making breakthroughs in methods and technology that can lead to increased productivity of major food crops and other commodities.

Whether this technology reaches and benefits a nation's farmers depends upon the ability of the national agricultural research system to incorporate research findings into varieties and practices appropriate to the micro-environments of producers in each country. This process requires strong research and development organizations within each country.

In recognition of this need, the Rockefeller Foundation established the International Agricultural Development Service on an experimental basis in 1975. IADS, a non-profit, independent organization, offers the scientific, technical, and managerial services a developing country might need to strengthen or expand its agricultural research and development capabilities.

My colleagues and I appreciate the opportunity this occasion provides to describe the rationale and scope of the IADS operation, to outline the kinds of services currently being provided, to share our experience in technical cooperation, and, finally, to indicate the future program directions of IADS.

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Rationale and Scope of the IADS Operation

While new technology has significantly increased cereal production in many countries, the specter of serious food shortages is still with us. Most developing countries must double their food production during the next 10 to 20 years to meet projected consumption requirements. Each nation will need to produce food locally to the extent possible to achieve some level of food security, to provide gainful employment to rural people, and to ensure political stability.

Although production of adequate quantities of food has special urgency, it is really the development of the agricultural sector as a whole and improvement of incomes of small farmers that deserves attention. Agricultural progress and improvement in purchasing power of the rural people is fundamental to national development in the poor countries, most of which are predominantly agrarian.

To provide adequate nutrition and purchasing power to rural people in developing countries, agricultural growth must substantially exceed the historic rate of less than 2% per year. Exceptional research and development efforts will be required to achieve these growth rates. Much effort must be made by the developing countries themselves, beginning with their own agricultural research and development systems and the national framework of policies and priorities within which they operate.

As the network of international centers was rapidly taking shape, founders of IADS felt that a major bottleneck in world agricultural development efforts was the lack of adequate means for directly helping countries to organize institutions and programs tailored to national needs.

The Rockefeller Foundation has had experience in providing support for agricultural research and, to some extent, for development in several countries. Some of these efforts have contributed significantly to strengthening national capabilities and to raising agricultural output. The Foundation's resources were too limited to help any large number of countries; consequently, it established IADS, which provides a mechanism for using funds from other sources and facilitating cooperation among donor agencies in providing technical assistance.

In organizing IADS, the founders drew upon the ideas and experiences of many individuals and agencies. They acted in the belief that professional agriculturists in many of the developing countries were seeking more effective ways to work with the world's technical cooperation community. Opportunities existed to speed the adoption of science-based agriculture in ways that would increase food output as well as incomes of rural people.

The International Agricultural Development Service was established with the primary objective of assisting individual countries to design, organize, and strengthen their own institutions and programs concerned with agricultural research and development.

IADS is a private, nonprofit, professional organization. It has no research program of its own; it helps developing countries to secure the services of particular individuals and institutions with which they wish to work in their research and development efforts.

IADS' operations have a high degree of flexibility. It uses this flexibility to foster cooperation among assistance agencies and to help integrate their support in the best interests of the host country. With IADS as an executing agency, donors may fund cooperatively or individually any technical assistance activities of interest to them.

IADS is authorized by its charter to provide a broad range of services. It could undertake almost any service requested by a developing country that would contribute to agricultural production and raise farm incomes. At present, however, IADS concentrates on strengthening research institutions and applying research to production problems. In addition to direct services to individual countries in the design and implementation of projects, IADS engages in a range of indirect services important to agricultural development. These include the preparation of development-oriented literature and activities related to leadership development.

Current Activities

IADS headquarters staff, numbering about one dozen, possess a range of capabilities. Three

individuals are responsible for general administration, and five for developing and supporting country activities in Asia, Africa, and Latin America. Others are specialists in communication and training, research planning and organization, agricultural economics, and publications. More staff will be added as operations expand and need arises. But the objective is to keep the core staff small and to draw on experienced and highly qualified individuals on a part-time or consultancy basis when the need arises. Any major expansion will be in field staff associated with specific country activities.

Present IADS activities have evolved over the past 3 years in response to requests of the developing countries. The largest and most rapidly growing part of the total program has been direct support to national agricultural research programs. Individual countries tend to seek two broad categories of direct services: (a) program planning, and (b) program implementation. IADS has restricted its effort to multi-commodity programs and to ones that do not fit the mandate of any one international center.

Program Planning

Typically the planning work of IADS has called for small teams of experienced scientists to work with agricultural leaders of a country on short but intensive studies of national agricultural research and development programs, their goals, and the means of achieving those goals. Some studies have represented the first step of the country in seeking funds for research. Others have related to reorienting agencies, to enable them to be more responsive to urgent national needs. National agricultural leaders are asking questions about organizational structures and operating procedures that will enhance the contribution of research programs to national development. IADS gives top priority to responding to requests for consultants on these topics.

IADS has participated in planning activities in ten countries and regions — Sudan, Senegal, Thailand, Bangladesh, Nepal, Western Samoa, Panama, the Dominican Republic, Honduras, and the Central American region as a whole. In such planning missions, IADS staff and consultants work as members of joint teams that include leaders of national programs and institutions.

In countries where IADS is already participating in project implementation — for example, Bangladesh and Nepal — assistance in planning has focused on organizational and management improvement of the national research system. This activity complements the ongoing project and promises to increase the benefits of the project to the host country.

In other countries where there has been no previous involvement, such as Sudan and Senegal, IADS has responded to national institution and donor agency requests for assistance. IADS generally helps to prepare the master plan for strengthening national research capabilities. Often this includes the design of a project for funding consideration by donor agencies.

In some countries, IADS has assumed full responsibility or provided leadership for planning, while in others IADS has contributed one of its staff as a member of the project design team. The participation of IADS in these planning exercises has been supported on a special project basis by such donors as the World Bank, Asian Development Bank, United States Agency for International Development, Ford Foundation, and Rockefeller Foundation.

Also, IADS is now participating in special programming missions of the International Fund for Agricultural Development, which are concerned with broad aspects of agricultural development specifically aimed at helping the rural poor.

Program Implementation

Implementation of programs has called for long-term involvement by IADS covering a range of services. These have included resident specialists in research and development management, and in specific subject matter areas. Also included are short-term consultancies in specialized fields, arrangements for overseas and on-the-job training of national scientists, improvement of research facilities, and procurement of equipment and supplies.

IADS staff in country projects work with their national colleagues as members of teams. They are not advisors but are active participants in national programs. They work through their counterparts and help them plan, organize, and conduct research. They operate within the local

administrative and support system, and while doing so, attempt to improve it.

Projects are usually set up for 3 to 5 years, often with provision for extension. They are undertaken by the host country and IADS with the conviction that attempts to achieve rapid increases in agricultural production must be combined with efforts to strengthen national institutions. In this way countries can sustain their own progress with a minimum of external assistance.

IADS is currently helping to implement cooperative country projects in Nepal, Indonesia, Bangladesh, Botswana, and Ecuador. IADS provides the requested services on a cost-reimbursable basis, with financial support coming from host countries and various donor agencies such as the World Bank, USAID, and the Inter-American Development Bank. IADS has also been asked to provide the services of a senior research administrator to act as advisor to the head of the agricultural research system in Sudan.

In cooperative country projects, IADS scientists are helping to organize and implement national research programs designed to improve the production of major commodities and cropping systems. They involve multidisciplinary research and are coordinated on a countrywide basis. These projects emphasize strong links between research and extension through initial orientation to farm problems and early testing of research results in farmers' fields. Efforts are made to strengthen ties of national programs with international centers and other outside institutions involved in relevant research or training.

Most of the projects are concerned with food crops, but other commodities of national importance may also be involved. In Indonesia, for example, the project includes establishment of a strong rubber research program. Besides research, IADS helps to improve support services such as library and information services, which have a direct bearing on output and application of scientific research.

Leadership Development

Availability of appropriately prepared and oriented individuals for leadership roles in agricultural research and development projects is the most important ingredient of success. Since 1977, IADS has considered ways to prepare professionals for international agricultural programs. In so doing, it has met with representatives of the international agricultural research centers and donor agencies.

Several critical problems concerning the personnel needs of agricultural research and development projects have been identified. There is a worldwide shortage of experienced agricultural professionals to staff technical cooperation programs. Also, host country professionals with experience in establishing and managing agricultural development strategies, organizations, and programs are scarce. Young scientists do not get opportunities to learn how to implement production-oriented, multidisciplinary research programs.

In February 1979, IADS sponsored a workshop on preparing professional staff for national agricultural research and related programs. Participants considered several proposals concerned with the training of young professionals, management training for mid-career scientists, and in-service training for national program personnel. IADS revised these proposals in the light of workshop recommendations and is coordinating further action.

IADS is building a personnel roster that includes names of individuals interested or experienced in international work. The roster contains 3000 names and is used for identifying consultants and specialists for assignment by IADS as well as other agencies. Computer storage and retrieval of this information enables IADS to serve itself, other organizations, and those registered, more efficiently and rapidly.

Liaison

Through meetings, conferences, and staff visits, IADS has developed and maintains liaison with technical assistance agencies, international centers, and national institutions in developed and developing countries. The liaison activities are meant to inform appropriate agencies of the IADS program and objectives; to gain greater understanding of the working of other agencies; to identify project opportunities; and to focus attention of some groups on the problem of food production and rural poverty.

One outcome of these activities has been a

publication on agricultural assistance sources which brings together pertinent information on agencies involved in technical and financial assistance to developing countries. Others have been less apparent, but highly important in long-range implications. Among these has been active participation by IADS in the series of events which led the Consultative Group on International Agricultural Research to establish ISNAR with the mandate to assist national agricultural research systems.

Preparation of Development-oriented Literature

Most of the professional staff of IADS and other assistance agencies are biological scientists with limited background in areas outside of their specialized fields. Many agricultural policy makers and administrators do not have the technical background or experience in either agricultural or social sciences, and make decisions over a range of agricultural policy areas. Recognition of these situations has led IADS to seek ways of developing and implementing a program to plan, produce, and distribute a range of development-oriented reference materials on technical subjects.

Two development-oriented books have been published. To Feed This World, by Sterling Wortman and Ralph W. Cummings, Jr., describes the ways nations may accelerate agricultural growth and proposes a strategy for doing so. Rice in the Tropics, by Robert F. Chandler, Jr., reviews the scientific advances in tropical rice and outlines the implications for nations that wish to help farmers grow rice more productively.

Two other books in press are concerned with farming systems in the humid tropics and national seed programs. The manuscript of a book on tropical tomatoes is being reviewed. Similar books on wheat and potatoes are under preparation.

In carrying out this activity, IADS has received excellent cooperation from some of the international centers and financial support from a number of donor agencies.

Lessons of Experience

In IADS' operations it has become evident that most developing countries feel much less need for expatriate experts than some of the technical assistance agencies expect. Many developing countries now have well-trained and experienced personnel equivalent in qualifications to most available foreign specialists. The current demand is generally for experienced mid-career scientists or administrators who are not easily available. Suitable individuals should not only have the broad knowledge of agricultural research and development, but also possess personal qualifications so essential in building meaningful collaborative relationships.

We have learned that the most effective use of funds for technical assistance can be made by employing a small number of high-quality resident specialists and supplementing their services with competent short-term consultants in specialized fields. A short-term consultant can greatly enhance the range of expertise available to a project. Sometimes a continuing relationship with a consultant and his institution can be highly productive.

Many countries lack well-conceived master plans for strengthening agricultural research and for accelerating agricultural development. There appears to be no dearth of loans and grants from funding agencies for good projects. However, there are few well-defined and adequately documented projects. Many nations need assistance in developing master plans for agricultural systems as a basis for coordination of work and for allocation of local and external resources. In the absence of a national plan that identifies priorities, programs, and requirements for 5 to 10 years, the external agencies themselves attempt to identify priorities. They sometimes compete with one another to support the areas of need that they perceive.

Another observation is concerned with the level of technical assistance required by individual nations. This varies greatly in relation to the size of the country and the stage of agricultural development. National authorities appreciate the flexibility of technical cooperation agencies in adjusting to local needs and promptness in responding to requests for services. Whereas each country requires a research system, the scope of its activities must relate to the technical and financial resources of the country and availability of appropriate ag-

ricultural technology from abroad. Some developing countries may attempt to become so self-sufficient in agricultural research that they could miss opportunities to capitalize on external technology available from other countries and regional and international institutions.

Developing countries now give high priority to training, and some have built a sizable pool of well-qualified scientists. But full utilization of the scientific capacity is often hampered by archaic administrative and management procedures. Because of poor support services, scientists often spend a large proportion of their time doing things for which they are not qualified or especially trained. Several nations have begun to improve the organization and management of their national research systems, and this subject deserves greater and continued attention if productivity of scarce manpower is to be increased.

A major problem of most national agricultural programs is to relate appropriately to the national planning organization, the finance ministry, and other agencies responsible for national development. Unless the agricultural research program is closely associated with national goals and carries out studies that promote development, it cannot expect to receive adequate support. The national research agencies with which IADS works are grappling with this problem. In some countries where institutions have been established to foster this interaction, the job is relatively easy. In others, the fragmented structure of research within the government makes it difficult to progress towards realistic goals.

IADS stresses the importance of agricultural research being firmly linked in a continuum from the planning phase through its application on farmers' fields. In most developing countries, a high proportion of the farmers live in remote areas and have small holdings. They are generally not aware of the technological components available and are unable to put together for their situation profitable combinations of new practices. For this reason, scientists are needed to help develop and evaluate farming systems for specific localities, and to work closely with extension staff in helping farmers to learn how to use new technology.

Cooperation between the research system and extension services as well as other agencies concerned with farmers' adoption of technology ensures that production campaigns are based on sound technology. But equally important is the opportunity this cooperation provides for researchers to learn about deficiencies in the technology, and consequently, to identify problems requiring more research. Interaction with agencies involved with application of technology is so vital that boundaries between them and the research system cannot be sharply drawn.

Future Program Directions

IADS has operated for less than 4 years. It started its program with emphasis on technical cooperation for strengthening national research systems. During this period, we have seen the need for such a service translated into effective demand. Opportunities to participate in national agricultural programs have been growing faster than the immediate ability of the new organization to respond.

IADS programs will continue to evolve further. IADS has now reached the stage where it can venture to undertake projects more oriented to development, in accordance with its original goal.

We welcome the establishment of ISNAR as a unit of the Consultative Group on International Agricultural Research mandated to provide technical assistance to national research programs. The IADS Board of Trustees has offered ISNAR full cooperation in getting established and beginning its operations.

With the establishment of ISNAR to help developing countries strengthen research services, IADS now plans to expand its activities in support of development efforts of individual countries. Although strengthening agricultural research will continue to be a major interest of IADS, as appropriate technology is fundamental to development, we do not foresee any undesirable overlap between the activities of ISNAR and IADS. The demand for such services is so great that there is ample opportunity for the two organizations to develop a complementary relationship and mutually supportive roles.

IADS has demonstrated that it can work with multilateral and bilateral funding agencies in providing services to national programs. Whereas we expect that this relationship will grow, IADS will actively seek a broad base of

private support and cooperation for its activities in development, drawing upon the private sector, foundations, and voluntary organizations.

Many industries and business firms in the United States, for example, recognize they can play important roles in helping to mobilize and strengthen private sector activities in developing countries as part of national development efforts. But they have not developed effective means of linking with the public or private sector in those countries. Discussions are under way with key individuals to identify ways in which an organization such as IADS might help developing countries share in the technological and managerial expertise of industry and business. This is particularly important as developing countries direct attention to improving, reorienting, and synchronizing the public and private activities in support of national commodity production or defined-area programs.

IADS will emphasize two basic approaches for agricultural development. When infrastructure is sufficient, an effective development strategy is the mounting of commodity programs aimed at increasing production of major crops on a national scale. If the objective is to improve incomes and standards of living of great numbers of rural people, defined-area development programs may be most effective. Both commodity programs and defined-area campaigns depend upon synchronized government services oriented to support accelerated rates of development. Such services are a basic component of any national strategy for forced-pace development.

Many nations have successfully used commodity production campaigns to increase the production of a particular farm product, notably wheat and rice. In recent years, concern has been expressed about the adverse effect of these commodity campaigns on income distribution of farming families. Also, concentration of efforts on major cereals has resulted in some neglect of grain legumes and other crops which are important sources of nutrition for small farmers and poor people.

IADS recognizes the need for a balance in research on agricultural commodities and for the improvement of farming systems as a whole. Improved farming systems are a requisite to progress in defined-area development programs. In its future work, IADS is considering the possibility of active participation in development projects oriented to defined areas as well as to specific commodities. Wherever possible, IADS encourages a combination of these two approaches, supplementing them as appropriate with efforts to strengthen relevant institutions.

Finally, it has become increasingly evident that developing nations can and wish to learn from one another's development experiences. IADS continues to seek ways to stimulate and facilitate interaction among institutions and individuals in developing countries. There is much concern these days about how to encourage technical cooperation among developing countries; in a small way, IADS has demonstrated that this is not only possible but highly desirable. We appreciate support of various institutions and individuals in helping us to do this and look forward to even greater opportunities for mutual cooperation in the future.

Crop and Livestock Integration in the Semi-Arid Tropics

D. J. Pratt and C. de Haan*

Abstract

This paper attempts to isolate some of the interactions between livestock and cropping in semi-arid areas, and to discuss some of the trends affecting these interactions. It can be expected that more integrated production systems will emerge through a combination of political and administrative measures and biological innovations aimed especially at increasing the quality and quantity of dry-season feed. ILCA's own systems research suggests that the development approach will need to combine a number of components to be successful. It is in the nature of farming systems that the key to improved livestock production may be interventions that increase the yield of subsistence crops (even crops of no direct value to livestock). Equally, manipulation within the livestock component may offer means to improve crop production.

Although the majority of people in the semi-arid tropics sustain themselves primarily by crop cultivation, livestock also play an important role in the local economy. The degree of dependence on livestock varies widely, ranging from the pastoralist who is subsistent entirely on his livestock to the sedentary millet grower who invests some of his excess capital in livestock. In this paper an attempt will be made to isolate the different types of relationships or linkages that characterize the interaction between cultivation and livestock production so as to indicate the conditions under which these linkages occur and how they affect opportunities for successful crop-livestock integration. The basis of this paper is a more exhaustive review on this subject prepared for publication by ILCA staff members (McCown et al. 1977).

Linkages Between Crop and Livestock Production

Symbiotic Linkage

Crops and livestock are frequently bound in direct symbiotic relationship within the farming system, with the one feeding the other. A typical example is found in the Sahel where, during the dry season, the natural forage is in short supply — or inaccessible through lack of drinking water — and is of low quality. Crop residues then provide a superior livestock diet. At the same time, manure deposited on the fields as the cattle graze benefits the subsequent crop, while the trampling in of residues and breaking up of ridges are also considered beneficial (Van Raay 1974).

However, the manure contributed by animals kept only on crop residues is small. Moreover, manure deposited on the land during the dry season declines greatly in value before it is incorporated in the soil. Various attempts have been made (e.g., in Senegal, Mali, Upper Volta) to increase the quantity and quality of manure through the introduction of manure pits (Hamon 1970), but the high investment and labor inputs required, and the difficulty of finding enough water during the dry season, have acted as constraints. The amount of manure available is increased when animals are kept overnight on the harvested fields, and when the period of a stay is prolonged, whether through bringing in feed from outside or as a result of abundant natural forage nearby. Typical examples are found in Western Dafur and Senegal, for example, where *Acacia albida* trees grow in the cultivated fields. Their pods, which are palatable and high in protein, fall or are stripped off in the dry season, thus making an additional source of feed available that enables

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cattle to stay longer in the cultivated areas.

Draft-animal Linkage

This linkage was rarely found in traditional agriculture in the semi-arid regions of Africa, though it is common in other regions. However, with increasing involvement in the market economy and decreasing returns to labor in cropping, the draft linkage has grown in importance, especially in West Africa, where it can be cited as one of the successes in livestock and crop development.

The type of traction used depends on environmental conditions. For example, in the sandy soil of Senegal, where plowing is not a major necessity, horses are used to pull light planting machines for groundnuts. In the heavier soils of neighboring Mali, and generally throughout the semi-arid tropics, wherever plowing is required, oxen are used. In certain arid regions, camels and donkeys may be used, singly or in combination.

But the choice of methods of cultivation is also determined by farm size and many other factors (Cassé et al. 1985). Often it is only the larger and more successful farmers can own draft animals. This may be either because they have easier access to credit or because only on the larger farms is increased labor productivity realized with draft animals. Also, there is often a relationship between animal traction and the relative extent of cash and subsistence crops, especially where there is a cash requirement to pay off the investment in traction. Thus, in Senegal, farmers using animal traction planted 10 to 16% more groundnuts and 3 to 7% less millet than farmers using hand cultivation.

The tendency for rich farmers to obtain animal traction and thus increase their labor productivity, coupled with the shift to cash crops, works to accentuate the gap between more and less fortunate cultivators. This might be a constraint on the further development of the draft linkage. Another constraint is the supply of draft oxen. If an imaginary semi-arid country with a cultivable area of 10 million hectares is considered, and it is assumed that an average pair of oxen can cultivate 5 to 10 ha per growing season, the total need will be about 2 to 4 million oxen, or a national herd of approximately 10 million. This is likely to be more than the grazing resources of the country can support. Thus, unless farming systems are developed that can profitably produce substantial forage supplies, most of the future increase in crop production will have to come from the direct transformation of hoe cultivation to mechanized farming in spite of all the drawbacks of mechanization.

Investment Linkage

Given the situation where pastoral land is either free or communally owned, and where the possibilities for capital investment in agriculture are limited, surplus cash from crop production is often invested in livestock. This gives added security in time of drought and enhances social status. Where skilled labor for livestock husbandry is not present in the crop farming population, herding is often carried out on a contractual basis by pastoralists.

The investment linkage can have negative consequences under adverse conditions if the crop farmer has greater security than the livestock producer. Typical examples can be found around irrigation schemes in the Sahel where, even in drought years, crop producers have the security of water and stubble grazing. If cash surpluses are then invested in cattle, overgrazing of natural rangelands around such schemes readily develops, with consequent detrimental effects on the livestock producers. This was clearly shown in Mali, where irrigated rice growing added substantially to the degradation of surrounding rangelands (ILCA 1978). When, as a result, pastoral units fall below the subsistence level, they tend to invest their own labor in cropping. The aggregate effect of this increased cropping is, of course, even greater pressure on the reduced area of grazing land.

Exchange Linkage

Exchange of goods typically occurs when one population or group is partially dependent on the product of another. Traditionally, milk, ghee (melted butter fat), meat, and hides are exchanged for millet and sorghum. With increasing commercialization, markets play a more and more important role in this exchange. Outside the market economy, the symbiotic linkage noted earlier can also occur as an exchange linkage, when crop residue grazing is exchanged for manure. When pressure on land is

not great and fertility is maintained by shifting cultivation, manure is not so highly valued by the farmer, and the livestock producer normally has to pay in fresh milk for the right to graze the crop residues. As the pressure on land increases, however, the demand for manure can be so great as to reverse the direction of payment. In densely populated areas of the semi-arid tropics, there is a market for manure gathered from pastoralists' camps.

Competitive Linkages

Competition between crop and livestock production develops as land becomes scarce. An example has been given in the context of investment linkage. The population increase, expansion of industrial crops, and reservation of public land all hasten this trend. The increase in court cases against pastoralists for crop damage illustrates the same trend (Van Raay 1974).

Other examples arise when crop farmers encroach on valley bottoms for purposes of irrigated cropping, thereby restricting the access of livestock to permanent water and to whole regions of valuable dry-season grazing. This situation arises in the Ogaden region in Ethiopia (ILCA 1977). Where crop farmers invest surplus capital in livestock, the increasing numbers of animals that are grazed around villages in the wet season can create a distance between the water and forage necessary for transhumant herds sufficient to destroy the viability of the traditional pastoral system; the crop farmers themselves can support their livestock on crop residues at this time of year.

On a regional basis, the loss of range grazing can be more than compensated for by the fodder contributed by crop residues. However, the degree of compensation depends on the crop — with sorghum and cowpea ranking high and millet ranking low — and usually declines with time. The productivity of abandoned crop land is often so low that the longer term effect on the regional fodder resources is negative (ILCA 1977).

Prospects for Future Development

It can be expected that increased population pressure and decreasing availability of grazing land will cause more and more pastoralists to take up cropping. Rapidly growing demands on land by old and new crop farmers will lead in turn to over-exploitation, reduced fallowing, and declining soil fertility, and subsequently to a decline in the population that the land can sustain. This will then lead to migration towards urban centers and increased reliance on food imports. The only sure way to combat this cycle is to increase the productivity of land and labor.

If livestock are to contribute effectively, there is a great need for forage that is superior in dry-season quality to range forage and existing crop residues. A sown leguminous crop could be expected to be more effective in this regard and in maintaining soil fertility than a bush or grassland fallow. However, until now, returns to labor and land do not justify investment in sown fodder crops under rainfed conditions. More particularly, the high labor requirements for sowing and weeding subsistence crops and the low yields of those crops impose serious labor constraints on the introduction of forage crops.

Besides increased yield per unit area of subsistence crops, other measures needed will be politico-administrative measures ensuring land tenure systems with exclusive user rights for investors and subsidies on inputs such as fertilizers. In view of the low returns to labor of existing subsistence crops, the inclusion of fodder crops will have to be accomplished with a minimum amount of additional labor. Intercropping, therefore, rather than sown leys, seems to be the first step on a development path.

It is also to be expected that there will always remain areas where livestock production is the only form of agricultural production possible. A stratification using these areas for the less productive stock and better areas for dairy production or fattening seems indicated. Research will have to indicate production systems and institutional arrangements that will facilitate the development of such systems.

An Illustration of an Integrated Approach: ILCA's Highland Program

ILCA's study in the highlands of Ethiopia (elevation 1800 m) can be used to illustrate the

linkages described above and to demonstrate a research approach to better integration of crops and livestock.

In the area under study, rainfall is relatively high (800 m) and so is population pressure, with an average farm size of approximately 2.2 ha per household. Fallow has almost disappeared. The average required area for subsistence cropping is 1.7 ha, the rest being used for cash crops. On average, 3.2 animal units[1] are kept, mainly for animal traction, although the low liveweight results in the use of inefficient implements. The genetic potential for meat and milk production is low. Manure is an important byproduct, but is carried out of the system and is used for fuel and building material.

The main source of feed is crop residues, complemented with some roadside and communal grazing. The initial survey carried out by ILCA showed that only 60% of the dry matter requirements of local livestock is met from within the farming system; obviously, if improved dairy production and more efficient animal traction is to be achieved, increased fodder production is necessary. However, even if the area now used for cash crops were to be converted to forage crops, only 85% of the dry matter requirement would be met. In view of the importance of subsistence crops to the farmer, it could not be expected that he would replace these for forage crops.

Clearly, therefore, an improvement in the yield per unit area of subsistence crops is the key factor, since this would reduce the area required for subsistence and enable improved animals and high-yielding forages to be introduced. Consequently, a package was devised for testing including improved grain varieties and fertilization, coupled with an improved dairy animal, better forage production, and improved livestock management. This package reduces the area required for subsistence cropping to 1.2 ha and leaves some space for cash cropping, while meeting the forage requirements completely. It is now being tested in on-farm research in comparison with farms without this package.

The results of the first year (ILCA 1978) show an increase in dairy production of 40% and an increase in family farm income also to the same extent. Additionally — and this is very important for the success of an innovation — average return per unit of land used for forage production is somewhat higher than for other crop production. Tentative results from the second year tend to confirm these initial indications.

This package approach is also useful in indicating needs for further research and data collection. For example, in terms of animal traction, the increased liveweight of the offspring will make improved implement use possible, although increased liveweight will also mean higher feed requirements. Besides quantifying this balance, socioeconomic research will be necessary to see whether, for example, ox-sharing is socially as well as technically feasible.

In this example, it appears that a biological innovations can be adapted to the situation of the small farmer by a manipulation of the total system. At lower elevations and in drier areas, price relationships are less favorable for such interventions, although changing economic trends and research in low-input alternatives might make similar interventions possible.

1. Defined as an animal with a liveweight of 250 kg.

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Summary of Discussion — Session 5

Dr. Govindaswamy, commenting on Dr. Swaminathan's remarks, suggested that for breeding varieties suitable for a particular location, there should be a triangular linkage between plant breeders, agroclimatologists, and growth analysts. He also requested that nutritionally rich *Eleusine coracana* be added to the ICRISAT program as it is a staple food in parts of the SAT.

Dr. Badruddoza observed that the linkage between international centers and national programs has been well established. However, national research capabilities can be further strengthened if various national programs could be better linked with one another and share their experience. At present, the developing countries know little about one another's research capabilities. ISNAR will partly fill this gap but perhaps there is a need for another institution like ISNAR.

Dr. Ganga Prasad Rao summarized points discussed at a workshop on sorghum, stating that marginal yield increases are not enough, as progress is offset by environmental fluctuations. What is needed is technology that can effect a quantum jump in production.

Chairman Umali summed up the morning's session, making five points: (1) Technological innovation cannot be separated from social and institutional factors, for under unjust agrarian structures, the benefits of technology get siphoned off by a small group: the landlord, the loan shark, the middleman, the local official, the transportation people. (2) Special programs should be developed to overcome the institutional bias that works against the small farmer; the kind of comprehensive credit program developed in Nepal is an example. (3) Mechanization should not displace labor but should create employment. (4) Public opinion should be influenced in favor of agricultural development; everyone, including school children, should be welcomed to see the work of the research stations. (5) Governments should be convinced that self-sufficiency in food production is a basic element of economic freedom, without which there can be no political freedom. South Korea and the Philippines, where the leaders recognized and supported this view, were able to achieve self-sufficiency in a remarkably short time.

C. Subramaniam, former Minister of Agriculture of India, said that India is fortunate to have a large reservoir of scientific and technical personnel in agriculture, industry, and related activities. He recalled that after the drought of 1964, India had to import 10 to 11 million tonnes of grain per year. Despite widespread skepticism, the steps taken in the "green revolution" succeeded, and today India has a buffer stock of 20 to 21 million tonnes of foodgrains that will enable it to meet the current drought, though it may be in difficulty if a second or third adverse season follows.

India's scientists are able to maintain a certain stability of production, he said. Much of this has been made possible by the work of international institutes, backed by the national research program; it is hoped that the country will reach a stage where no more famines or scarcity occur. Mr. Subramaniam said he hoped this symposium would stimulate research and development that would give a new impetus to agricultural production in the semi-arid tropics.

Session 6

Experience in the Semi-Arid Tropics

Chairman: Louis Sauger
Co-Chairman: H. Doggett

Rapporteurs: M. H. Mengesha
S. N. Nigam
M. von Oppen
B. C. Barah

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Indian Experiences in the Semi-Arid Tropics: Prospect and Retrospect

N. S. Randhawa and J. Venkateswarlu*

Abstract

In India about 75% cultivated land – contributing 42% of the total food production – is rainfed. Even after full development of water resources, about 50% of the land will continue to be dependent on rains. Yield levels in drylands continued to be around 0.5 t/ha in spite of earlier research efforts on rainfed agricultural management during the thirties and again in the fifties. The availability of new plant material during the mid-sixties showed promise for improving agricultural production in drylands. The national project on dryland agriculture with 23 regional centers was launched in 1970. The cooperating centers have generated a new package of technology with an increased yield potential of 250 to 400% at the agricultural experiment stations. The on-farm testing of the new technology has given consistent yield increases of 100 to 200% on large pilot/operational project areas. New cropping systems especially suited to regional situations have been developed, incorporating oilseeds and pulses. Area development on a watershed basis along with in situ water harvesting and/or runoff collection and recycling are other important features of this technology.

The central problem of sustained land use in the dry regions has always been to find and maintain a balance between man's requirements and the productive capacity of the land. Throughout history, man has, by overuse, consistently reduced the productive capacity of the drylands. In spite of the great concern about this problem, the situation has not changed in India, where both human and animal population far exceeds the supporting capacity of the region. Overgrazing has caused an overall reduction in the plant cover, thereby accelerating erosion; this in turn has contributed to instability of production, with permanent damage to the environment.

The semi-arid tropics represent seasonally dry areas, receiving most of their precipitation during one season of the year, whilst the rest of the year is more or less dry. The rainfall is sufficient for raising certain types of crops when adequate management techniques are adopted. Since soil profile moisture and its environment are modified by the extent of irrigation, for the delineation of SAT areas the irrigation command area covered in the region needs to be taken into account. Assuming that the areas receiving an annual rainfall of 375 to 1125 mm and with less than 30% irrigated area fall in this category, the SAT region covers 115 districts in the country. Nearly 280 million people live in this belt.

In the lower rainfall area of 375 to 750 mm, covering 41 districts, the subsoil is not properly charged and the shortage of groundwater is acute. The available water is generally brackish and often unfit for use on agricultural lands. The areas having an annual rainfall of 750 to 1125 mm, covering 74 districts in the country, are considered areas with the highest potential for agricultural production with moderate effort. The drought-prone areas, covering about 60 million hectares, are spread in the 72 districts representing both arid and semi-arid regions, with a population of 30 million.

In many of the SAT districts of India, the cultivated area is a high percentage (70 to 90%) of the total geographical area. However, about 54% of the holdings are smaller than 1 ha, and these tiny holdings are comprised of three or four fragmented parcels. Only 3% farmers own more than 10 ha.

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The production in the semi-arid tropics in proportion to the total crop production is: 30 to 40% for wheat and rice; 60 to 70% for maize, ragi, and cotton; 80% for sorghum and pearl millet; 90% for oilseeds/pulses; and 100% for small millets. Therefore, the only way to meet the shortages of protein, edible oil, and cotton is to improve the productivity of these crops in the rainfed areas of the country.

But the yields of crops in the region are low and fluctuate from year to year. Besides having erratic rainfall and poor quality groundwater, these areas quite often are heavily eroded and have very shallow soils. The problems of salinity and alkalinity are quite widespread in the region.

To summarize, the SAT region of India is characterized by intense rainfall interspersed with drought; short rainy seasons; low soil organic matter content; poor natural soil productivity, and, at times, low infiltration capacities of soils; severe runoff and water erosion hazard; small fields and segmented farms; limited capital resources; and animal and human labor as primary draft power sources. Therefore, the largefarm technology prevalent in the developed countries is not directly applicable to the Indian situation.

Research and Development

Early Research Approaches

Organized research efforts to improve crop production on the drylands were initiated as early as 1933 by the then Imperial Council of Agricultural Research when it sponsored five dry-farming research centers located at Rohtak, Sholapur, Bijapur, Raichur, and Hagari, which operated for 10 years, up to 1943–44. The recommendations emerging from these centers emphasized bunding to conserve soil and water; deep plowing for improved water intake and storage; use of farmyard manure to supply plant nutrients; and use of low seed rate, wide row spacing, and interculture of crops for efficient use of the limited moisture in the soil. However, the marginal return of 15 to 20% over the base yield of 200 to 400 kg/ha did not encourage the farmers. Therefore, the dryland agriculture research receded to the background and the research effort on irrigated agriculture was given greater attention.

The establishment of soil conservation research centers in the mid-fifties provided further needed information on factors of production, such as land-use classes, rainfall patterns, runoff collection, fertilizer use, etc. During this period, the soil and water conservation development programs became more popular with the government and later on these became synonymous with contour bunding. The solution to the problem of low productivity continued to be elusive, and the available research information lacked in proper understanding of the constraints and limitations within which crop production is carried on in the low rainfall areas. It was recognized that in these soils water was available to the crop plants for only a short period of 100 to 120 days and that only crops and varieties maturing within that period could yield high in such areas. The impact of this program also did not become as spectacular as expected, because the desired plant material was not available until the early sixties.

In 1965, short-duration hybrids/varieties of some important dryland crops (sorghum: CSH-1; pearl millet: HB-1, and FRS cottons) became available for extensive field testing. With needed refinement in agronomy, these hybrids/varieties gave large yield increases under rainfed conditions, both on research farms and on farmers' fields. In fact, the superiority of CSH-1 sorghum and HB-1 pearl millet over local varieties was more pronounced in years of subnormal rainfall. Availability of this much-needed biological component of short-duration, input-responsive crop plants provided the real breakthrough in production on drylands.

National Research Project on Dryland Agriculture

The All India Coordinated Research Project for Dryland Agriculture was formally launched in June 1970 in active collaboration with the Government of Canada. It is a multidisciplinary research unit with 23 cooperating centers located in typical agroclimatic zones listed below.

Production environments vary from region to region and each center identified and analyzed the constraints limiting crop yields in the area and developed a relevant location-specific re-

Region	Centers
1. Submontane region	
a) Humid	Dehra Dun
b) Semi-arid	Hoshiarpur (Ludhiana), Rakh Dhiansar (Samba)
2. Desert soil region	
a) Arid	Hissar, Jodhpur
3. Alluvial soil region	
a) Subhumid	Varanasi
b) Semi-arid	Agra, Dantiwada
4. Black soil region	
a) Semi-arid	Udaipur, Indore, Akola, Sholapur, Bijapur, Kovilpatti
b) Arid	Rajkot, Bellary
5. Red soil region	
a) Subhumid	Ranchi, Bhubaneswar
b) Semi-arid	Hyderabad, Bangalore, Jhansi
c) Arid	Anantapur

search program to solve production problems. These programs were reviewed by a coordinating cell consisting of senior scientists from India and Canada. These scientists provide the lead research and identify areas of research, keeping the national goals in view.

The primary objective of the project is to develop practices and/or systems leading to substantial improvement and stabilization of crop yields in different dryland areas of the country within the constraints and limitations specific to each region. The important results obtained so far are discussed in the following paragraphs.

Achievements

The new phase of dry-farming research during the last 8 years has generated considerable data on better moisture conservation and use, timely preparatory and seeding operations, establishment of adequate crop stands, satisfactory weed control, efficient fertilizer use, new cropping patterns, crop life-saving techniques, and mid-season correction in crop planning in the drought-prone areas. Adoption of these improved soil, water, and crop management practices has reduced fluctuations in production from year to year.

Only illustrative results relevant to broad objectives of this project are presented.

Potential of New Technology

Comparing results from the technology of the thirties with those from the technology of the seventies, it is significant that adoption of the technology has greatly increased production potential (Table 1). Under normal rainfall (501 to 518 mm) at Hagari, Bellary, and Bijapur, the yield of sorghum was much lower during the period 1934–1941 (4.91–5.50 q/ha) compared with 1971–1977 (21.7 q/ha).

Table 1. Relative yield of crops with earlier and new technology of crop production in drylands.

Station	Normal rainfall (mm)	Crop	Period	Mean yield (q/ha)
Hagari	515	Sorghum	1935–40	5.5
Bellary*	518	Sorghum	1971–77	21.7
Bijapur	601	Sorghum	1934–41	5.1
Bijapur	606	Sorghum	1971–77	11.1
Sholapur	616	Sorghum	1934–41	2.3
Sholapur	680	Sorghum	1971–77	16.6
Rohtak	446	Gram	1935–38	6.3
Hissar*	413	Gram	1971–77	13.8

* Since Hagari and Rohtak stations ceased to function by 1970, data from the nearest research centers have been used for comparison.

Cropping Season

Based on climatic water-balance studies, the growing seasons have been identified for all the 23 regions where dryland research centers are situated (Table 2).

It is obvious that with a 10- to 20-week cropping season, only a sole crop can be attempted. For regions with a 20- to 30-week growing season, cropping intensity can be increased through intercropping, whereas with a 30- to 50-week period, double cropping is possible.

Efficient Crops for Different Regions

Different crops and cropping systems have been identified for fuller and more efficient utilization of rainfall and stored moisture. If crops are grown only on stored moisture, the depth of the soil and the available stored moisture in the profile are important for determining crop and variety choice. An example is given for Bellary region (Table 3).

Even in high rainfall areas, soil depth per se becomes important in selection of cropping systems. In the Indore region, with a high rainfall of 990 mm, shallow soils can support only a monocropping system; medium soils can support intercropping; and deep soils can support sequence cropping (Table 4).

Efficient crops and varieties have been identified for different regions (Tables 5, 6, 7). In

Table 3. Crop choice in relation to stored moisture in Bellary region.

Available moisture (cm)	Crops
20	Sorghum (M 35–1 or SPV–86) Safflower (A–300, 7–13–3) Gram (A–1)
15–20	Sorghum (CSH–2, CSH–3) Safflower Gram
10–15	Safflower Gram Sorghum as fodder
<10	Dolichos Lima beans *Phaseolus vulgaris*

Table 2. Length of effective cropping season at dryland research centers.

Category	Regional centers and effective cropping seasons	Cropping intensity
A. Less than 20 weeks	Bellary, Jodhpur, Anantapur (8)* (11) (13) Hissar, Rajkot, Bijapur (17) (17) (17)	Sole Cropping
B. 20–30 weeks	Jhansi, Kovilpatti, Hyderabad (21) (21) (22) Udaipur, Sholapur, Agra (22) (23) (24) Anand, Akola (25) (27)	Intercropping
C. More than 30 weeks	Bhubaneswar, Varanasi (31) (32) Hebbal, Hoshiarpur, Indore (32) (35) (36) Rewa, Samba, Ranchi Dehra Dun (36) (44) (45) (51)	Sequence cropping

* Figures in parentheses indicate the duration of cropping season in weeks.

Table 4. Efficient crops in relation to soil depth in Indore region.

Depth	Available moisture (cm)	Crops
Shallow	10	Sorghum (CSH–5, CSH–6) Maize (Ganga–5, Chandan–3)
Medium	15	Soybean (T–49) Sorghum + pigeonpea (150-day variety)
Deep	20	Maize-safflower (JSF–1) Soybean-gram (Ujjain–24) Sorghum-gram

some of the regions, however, inefficient crops continue to occupy large areas. Extension efforts are being intensified to substitute these with efficient and productive crops. Data accumulated in the various research centers show that the untapped yield potential is as high as 250 to 400%.

Sowing

Early sowing of crops has several advantages, both general and specific. The general advantage of early sowing is the possibility of obtaining good and vigorous seedlings. By early seeding, it is also possible to obtain better moisture and a longer growing season. Some of the results of the effect of sowing dates on the yield of crops are listed in Tables 8 and 9.

Advancing Sowing Time

Another important consideration is advancing the sowing time of *rabi* (postrainy season) crops in southern India, where the temperature changes between *kharif* (rainy) and *rabi* seasons are gradual. In such situations, moisture rather than temperature determines the sowing dates of postrainy season crops. The Deccan *rabi* region, comprised of Sholapur, Bijapur, and Bellary, is sown with *rabi* sorghum after the cessation of the rains, approximately the last week of September in Bijapur, the first week of October in Sholapur, and second week of October in Bellary. However, by advancing the sowing period by 3 to 4 weeks in these regions, enormous yield increases have been obtained (Table 9). The yield advantage due to advance in sowing time seems to be primarily due to optimized use of water.

Seeding Methods

In the recent past, the project attempted several innovations in existing seeding devices. In the

Table 5. Efficient crops and varieties for different regions (< 20 weeks' cropping season).

Region	Crop	Variety	Seasons averaged	Average yield (q/ha) Research farms	Average yield (q/ha) Farmers' fields
Bellary	Sorghum	CSH-8R	4	35	3
Jodhpur	Pearl millet	HB-3	3	18	3
Anantapur	Groundnut	Kadiri 71–1	5	15	5
	Castor	Aruna	3	8	3
	Pigeonpea	PM-1	7	7	
Hissar	Pearl millet	BJ-104	2	34	3
	Mustard	S-9	4	11	4
		T-59	4	14	4
Rajkot	Pearl millet	HB-3	3	18	5
Bijapur	Sorghum	M 35–1	2	21	5
	Safflower	7–13–3	6	12	
	Cotton	Suyodhar	5	16	2

Table 6. Efficient crops and varieties for different regions (20–30 weeks' cropping season).

Region	Crop	Variety	Seasons averaged	Average yield (q/ha) Research farms	Farmers' fields
Jhansi	Sorghum	CSH-5	2	23	9
	Pigeonpea	Hy-1	2	17	8
	Wheat	Kalyan Sona	3	20	11
	Barley	Ratna	3	25	12
	Gram	T-2	3	17	4
Hyderabad	Sorghum	CSH-6	4	36	4
	Castor	Aruna	3	15	6
Udaipur	Sorghum	CSH-5	6	29	6
	Maize	Ganga-5	6	18	9
	Wheat	Narbada-4	3	15	5
Sholapur	Sorghum	SPV-86	5	21	3
	Safflower	7–13–3	4	17	5
Agra	Mustard	RT-16	4	20	7
	Barley	Ratna	5	21	14
Anand	Pearl millet	NHB-5/BJ-104	3	14	10
	Castor	GCH-3	7	13	5
	Tobacco	G-4	4	11	4
	Cotton	Hy-4	5	8	3
Akola	Pearl millet	HB-3	3	16	4
	Sorghum	CSV-4	3	18	5

Hyderabad region where the *kera* method (seeding behind plow) is prevalent, the *pora* method (seeding through a tube) has been introduced by attaching a bamboo tube to the plow. The use of seed drills for sowing has become popular in the Bangalore region. In Hissar, the ridger-seeder developed through SIDA-ICAR collaboration has been well accepted by the farmers. Line-sowing has been accepted as an innovation in the tribal area around Ranchi.

Placement of fertilizers (up to 10 kg N/ha) along with the seed has been found to be safe and useful for promoting seedling vigor. Use of complex fertilizer to apply all the phosphorus and a portion (not exceeding 10 kg) of nitrogen has been suggested for wider adoption.

Crop Geometry

Crop geometry includes plant population and row widths.

Plant density. High-yielding cultivars of crops perform better only at ideal plant populations. In other words, in a community the high-yielding varieties and hybrids perform far superior to the existing local varieties. That ideal population is important to obtain higher yields has been well established for several of the experiments in the project.

Row width. Several studies of the project indicated that there could be enough flexibility in the interrow distance of crops. For example, sorghum can be planted as close as 30 cm and also as wide as 75 cm without reduction in yield, provided the ideal plant population of 0.18 million/ha is maintained. Increased row widths allow ease of interculture, particularly for weed control, facilitate sowing of large areas in a short time, and increase the scope for intercropping.

Cropping Intensity

The cropping intensity in semi-arid areas is generally 100, implying that only a single crop is

Table 7. Efficient crops and varieties for different regions (> 30 weeks' cropping season).

Region	Crop	Variety	Seasons averaged	Average yield (q/ha) Research farms	Farmers' fields
Bhubaneswar	Upland rice	DR-92	5	21	11
Varanasi	Rice	Cauvery	7	28	7
	Maize	Ganga-2	6	21	10
	Blackgram	T-9	7	13	6
	Wheat	C-306	5	24	10
	Barley	R-129	3	36	13
	Gram	C-130	5	35	8
Hoshiarpur	Maize	JML-603/607	4	40	20
	Wheat	PV-18/K-227	7	28	8
Indore	Maize	Ganga-5	5	43	12
	Soybean	Bragg	6	27	10
	Safflower	JSR-1	7	24	
Rewa	Rice	Cauvery	7	29	6
	Wheat	C-306	3	21	7
Samba	Maize	Ganga Safed-2	4	19	10
	Wheat	Kalyan Sona	3	33	15
Ranchi	Upland rice	Bala	6	30	8
Dehra Dun	Upland rice	RP 79-5	5	44	12
	Wheat	Kalyan Sona	3	27	10

taken during a year; however, research has provided ample evidence that the cropping intensity can be increased both by intercropping and sequence cropping. In areas where rainfall is inadequate, ranging from 375 to 625 mm, and soil moisture storage capacity is less than 100 mm, it is preferable to take a single crop during the rainy season; however, when the rainfall is between 650 to 750 mm, with a period of moisture surplus, intercropping has proved useful in increasing and stabilizing crop production. In regions of 750 to 900 mm rainfall, with soil moisture storage capacity of 150 mm and above, sequence cropping is possible. Beyond 900 mm and with soil moisture storage capacity of 200 mm and above, sequence cropping is assured.

Intercropping. In the Indian context, mixed cropping, intercropping, and monocropping are age-old practices. It is claimed that the system distributes risk due to vagaries of weather and incidence of pests and diseases; it also leads to better utilization of labor and material resources. Some suitable intercrops for different regions are listed in Table 10.

Intercropping of postrainy season crops, raised on limited conserved soil moisture, has not been found more remunerative than the sole crop. Even in the rainy season, only tested intercrops should be chosen.

Table 8. Effect of sowing date on the yield of pearl millet (Hyderabad).

1972		1973		1974	
Date	Yield (q/ha)	Date	Yield (q/ha)	Date	Yield (q/ha)
1/7	12.1	9/6	32.0	18/6	20.3
14/7	19.6	23/6	41.9	3/7	33.8
29/7	15.0	7/7	34.1	18/7	19.9
8/9	8.4	21/7	23.9	2/8	5.0
22/9	7.4	4/8	17.4	17/8	5.1
7/10	3.1	19/8	18.0	1/9	3.2

Table 9. Effect of advancing sowing date on sorghum yields (Bellary).

System	Grain yields (q/ha)						
	1971	1972	1973	1974	1975	1976	1977
Advanced sowing	15.4	33.7	30.1	10.7	16.5	12.5	12.3
Normal sowing	5.0	12.4	16.8	2.4	7.4	2.6	7.4

Sequence cropping. Some examples of sequence cropping are listed in Table 11. The data clearly indicate the immense potential for crop production in these regions and the scope for additional production of the most needed pulses and oilseeds.

Integrated Nutrient Supply

Experiments conducted by the project have conclusively proved that it pays to fertilize dryland crops. In the drylands, response to nitrogen is universal (Table 12), but varies considerably from season to season and place to place. The response to phosphorus is mostly limited to the semi-arid and subhumid red soil regions and the granitic black soil regions. Response to potassium is limited to light soils and high-level production.

In order to increase and stabilize the response to fertilizers, crop management needs to be optimized. Crops vary in their response to fertilizers. Cereals respond to both N and P, while quick-growing pulses respond to phosphorous and deep-rooted crops respond more to nitrogen. Further, fertilizer-use efficiency per se can be enhanced by the supply of other limiting nutrients as well. Sulfur enhanced yields of groundnut in the Bangalore region. Zinc deficiency was perceptible in Anantapur, Bangalore, Bellary, Bhubaneswar, Hyderabad, Indore, Rajkot, and Ranchi regions. Placement increased fertilizer efficiency. In drought-prone areas (e.g., Rajkot) set-line cultivation with lower levels of fertilizer was found useful. Split application of N for rainy season crops is a must to save fertilizer in case of aberrant rainfall.

Optimizing soil management increases water intake and storage, which consequently increases fertilizer efficiency. Increased soil depth, vertical mulch, and advance sowing are some methods of increasing the stored moisture in the profile.

Since much of the available fertilizer in the country goes to the irrigated areas, efforts should be made to supply much-needed plant nutrients through other means such as planting legumes and using organic residues. Thus, there is need for an integrated nutrient-supply system to reduce the use of chemical fertilizer and improve its use efficiency. This is especially relevant in the drylands, because the dryland farmer's capacity to invest is low and the risk involved is high.

The recent FAO/UNDP Consultancy on Tropical Agriculture points out that the contribution

Table 10. Some suitable intercrops for different regions.

Region	System	Base crop Yield (q/ha)	Intercrop Yield (q/ha)
Bijapur	Pearl millet	14.1	
	Pearl millet/pigeonpea	11.6	8.0
Ranchi	Maize	28.6	
	Maize/pigeonpea	28.2	6.2
Akola	Sorghum	33.5	
	Sorghum/greengram	30.8	7.3
Sholapur	Pearl millet	18.0	
	Pearl millet/pigeonpea	18.3	17.0
Hyderabad	Sorghum	34.4	
	Sorghum/pigeonpea	33.5	5.5
Rewa	Sorghum	25.4	
	Sorghum/pigeonpea	22.3	4.7
Indore	Sorghum	32.7	
	Sorghum/groundnut	28.3	7.6
Dehra Dun	Maize	38.8	
	Maize/soybean	38.7	1.8

Table 11. Suitable crop sequences in different regions.

Region	Crop sequence	Seasons averaged	First crop Yield (q/ha)	Second crop Yield (q/ha)
Samba	Bajra-wheat	3	21.5	24.0
	Fallow-wheat	3		33.3
Dehra Dun	Maize-wheat	4	38.5	31.8
	Rice-wheat	4	43.1	29.9
	Fallow-wheat	4		26.8
	Maize-gram	4	30.3	16.2
Varanasi	Rice-gram	2	30.2	25.4
	Fallow-gram	2		35.7
Hoshiarpur	Maize-wheat	7	27.3	27.2
	Fallow-wheat	3		23.2
	Maize-gram	7	27.3	15.3
	Fallow-gram	3		17.0
Bangalore	Cowpea-ragi	5	8.6	27.6
	Ragi (alone)	4	26.9	
Akola	Sorghum-safflower	3	45.4	14.1
Anand	Cowpea-tobacco	2	8.2	9.7
Bijapur	Greengram-safflower	2	7.5	10.6
Indore	Maize-safflower	3	29.5	10.8
	Sorghum-gram	3	32.1	13.9
	Maize-gram	3	35.5	14.3

of a legume in the cropping system would be about 9 to 15 kg/ha of nitrogen. Legumes are a component of several sequence and intercropping systems developed by the project. In fact, in the intercropping system, the association of a legume leads to an economy in nitrogen. In a legume-safflower sequence, data show that safflower benefits.

Table 12. Response of cereals to nitrogen fertilizer.

Crop	No. of trials	Level of N (kg/ha)	Response (per unit N)
Rice	17	40	20.3
Maize	5	40	15.5
Sorghum (*kharif*)	9	40	26.7
Pearl millet	3	40	19.2
Wheat	12	50	20.5
Barley	14	40	17.5
Sorghum (*rabi*)	8	30	14.4

In a study on incorporation of organic residues in red soils of Hyderabad, it was found that after 4 years the physical properties improved, leading to better yields.

Weed Control

Weed control is important in optimizing the use of various inputs by the crops. It is now well established by the project that weed control is particularly important within the first 3 to 4 weeks of the seeding.

Soil Management

The studies on soil management, though site- and location- specific, have a common goal: the improvement of crop production through better soil and water management. The soil problems are generally those that could potentially be ameliorated by tillage; water management problems include rainfall runoff collection, its storage and reuse, and management of in situ

stored water. The experiments on soil management include deep tillage, year-round tillage, vertical mulching, surface mulching, and some aspects of zero-till farming practices.

Deep tillage increased yields of many crops in different regions (Table 13). At Bellary and Sholapur, the benefits of vertical mulching were evident in the improved water intake into heavy black soil, this being most apparent in drought years (Table 14). Year-round tillage has been attempted at the Hyderabad, Rewa, Varanasi, and Bangalore centers with varying success.

Preliminary studies proved zero-till farming beneficial at Indore for safflower in a sequence, but not with wheat; however, at Anantapur, Bangalore, and Hissar the results were not encouraging.

Mulching has very little place in crop production during the rainy season, but where soil mulch is created as part of weed control practice, it may serve a purpose. However, postrainy season experimental data from many centers revealed that under moisture stress conditions, or where moisture can be carried over for a short time or can be conserved for a subsequent crop, mulching has been beneficial (Table 15). In alluvial soils, winter crops have benefited; the moisture seems to be a common causative agent. Mulches not only conserve moisture under proper circumstances but also influence soil temperature.

Farming Systems

The ICAR/ICRISAT collaborative Farming Systems study on soil and water management was initiated at seven centers in 1977 and has been taken up at 15 centers during 1979. This study is designed to determine how soil and water can best be managed on inter-terraced lands. Agronomic and physical land-treatment practices are being developed to improve soil and water conservation in situ by controlling runoff and erosion and facilitating infiltration of water into the soil uniformly over the watershed area. In the first experiment, the emphasis is on resources development, conservation, and utilization in rainfed areas. The second experiment on hydrological studies is aimed at improving land and water utilization in small agricultural watersheds.

The preliminary studies reveal that the

Table 13. Effect of tillage practices on yield of crops (q/ha).

Region	Crop	Year	Shallow (Country plow)	Deep tillage (Moldboard plow)
Jodhpur	Pearl millet	1	8.5	10.8
Dehra Dun	Maize*	3	39.1	47.3
	Wheat	1	14.1	16.1
Hoshiarpur	Wheat	1	6.3	12.9
	Maize	1	15.6	21.8
Agra	Barley	2	14.9	17.3
Bangalore	Maize	3	33.9	45.3
	Pigeonpea	1	3.8	9.6
	Groundnut	1	11.3	13.8
	Ragi	1	33.7	38.1
Sholapur	Sorghum	1	28.9	29.7
Anantapur**	Castor	4	8.7	11.4
	Pigeonpea	4	8.4	11.5
	Pearl millet	3	8.2	7.7
	Groundnut	4	7.9	9.9

* Postrainy season tillage
** Tillage first year and residual effect for 3 years

Table 14. Effect of vertical mulch on sorghum in Bellary.

	Grain yield (q/ha)				
Interval	1973	1974	1975	1976	1977
8 m	2.8	16.1	17.7	11.2	19.2
4 m	4.0	16.9	17.8	12.5	15.4
Control	0.2	11.2	11.0	10.8	14.5

benefit of bedding over flat on grade is only marginal (7%). The reasons for this marginal increase could be that the season was favorable during 1978, except in Anantapur. Land configuration may be more useful in critical years.

In the future, the introduction of equipment to monitor soil erosion and runoff will make it possible to measure the effectiveness of farming systems tested.

Runoff Management and Storage Structures

In a monsoon climate, where rainfall is concentrated in a 3- or 4-month period, the storage of excess water in the catchment is as important as the vegetative cover alone. This storage not only reduces soil erosion and controls flash floods but also changes the microclimate of the watershed area. In undulating terrain, the construction of small ponds and tanks in small watersheds of 5 to 10 ha augments the underground storage of monsoon flow by encouraging infiltration and recharging aquifers. The recycling of stored water not only ensures the success of the rainy season crop when the monsoon recedes earlier than expected, but also helps to harvest a good postrainy season crop by providing presowing irrigation and, later, life-saving irrigation during the crop growth period. The experiments on runoff recycling at various centers of the dryland project have given yield increases ranging up to 300% over the checks, which received no presowing or subsequent irrigation (Table 16).

Table 15. Effect of mulches on yield of crops (q/ha).

Region	Crop	Years	Control	Mulch
Hoshiarpur	Wheat	2	28.6	35.1
Dehra Dun	Wheat	3	23.3	29.3
Anand	Tobacco	2	13.3	18.4
Kovilpatti	Sorghum	1	5.3	9.4
Varanasi	Barley	1	17.5	19.1
Sholapur	Sorghum	1	9.8	16.4

Developmental Work

Operational Research Project

Sir Joseph Hutchinson, reviewing the work on dry farming in India, stated that it lacked the intermediate stage of pilot operational research, which is an essential element in successful transfer of results to village farming practices. Consequently, the Indo-UK project was started by ICAR in 1973 to test the dry-farming technology evolved at agricultural experiment stations and to study the operational problems involved in the transfer of research results to the farmers' fields. Subsequently, during Phase II of the Indo-Canadian technical collaboration, four more operational research projects at Hoshiarpur (Punjab), Ranchi (Bihar), Hyderabad (Andhra Pradesh), and Hebbal (Karnataka).

At Indore, in an operational project covering 2000 ha in three villages, nutrient use and intensity of cropping have increased from 2 kg to 49 kg/ha and from 103 to 130%, respectively. The introduction of improved varieties of sorghum, maize, soybean, wheat, and gram has contributed substantially to the yield improvement of these crops, the increases being several fold in sorghum and maize.

With an improvement in the managerial skills of the farmers and stability in agricultural production, farmers have gained the confidence to invest more on critical inputs, which have, in turn, resulted in higher net returns (Table 17). There has been a manifold increase in the construction of open wells, installation of pumpsets for irrigation, and purchase of power threshers.

Similarly, in the Hoshiarpur ORP started in 1976–77, covering two villages, an investment of about Rs. 400/ha for minor land leveling, bunding, and suitable structures for disposal of excess water on an area of 16 ha owned by 20

Table 16. Effect of critical irrigation on the yield of crops.

Region	Crop	Seasons averaged	Yield (q/ha) Without irrigation	Yield (q/ha) With one irrigation
Dehra Dun	Wheat	4	21.4	35.5
Varanasi	Barley	2	26.0	33.6
Ludhiana	Wheat	4	19.2	41.1
Agra	Wheat	2	21.9	27.4
Bijapur	Sorghum	5	16.5	23.6
Bellary	Sorghum	4	4.3	13.7
Sholapur	Sorghum	5	9.8	18.2
Rewa	Upland rice	4	16.2	27.8
	Wheat	4	5.7	18.8
Anand	*Bidi* tobacco	1	12.1	18.1

cultivators has resulted in 100 to 200% yield increases. The yields of maize, wheat, and fodder dry matter were increased from 13.6 to 22.3, 16.1 to 27.3, and 44 to 129 q/ha, respectively.

The cultivators in the villages covered under the operational research project at Bangalore and Hyderabad have been persuaded to adopt improved land and water-use practices on an agricultural watershed basis. The field plots demonstration on improved soil-, water-, and crop- management practices has shown consistent increases in yields.

Encouraged by our success, we propose to start four additional ORPs at Hissar (Haryana), Rewa (Madhya Pradesh), Anantapur (Andhra Pradesh), and Sholapur (Maharashtra) during the Sixth Five-Year Plan. The emphasis in these projects will continue to be on farmers' acceptance of new research-proven concepts and practices.

Pilot Projects

Another unique feature of the project is the attachment to each research center — except Dehra Dun, Hoshiarpur, and Dantiwada — of about 800 to 2000 hectares of land situated, on a catchment basis, over one to three villages. The scientists have to provide backup for developing an action program for crop production in drylands. To induce farmers to adopt the new systems of farming, subsidy was provided for inputs during the Fourth Five-Year Plan; in the Fifth Plan, this was reduced to a nominal amount (Rs. 20/ ha). Unfortunately, work on each watershed was planned only for 1 year, which was considered by the scientists as inadequate to spread the message of new dryland crop production technology and to develop the managerial skill of the farmer to a level that could be sustained after the termination of the project. Thus the adoption and diffusion of the technology has not been satisfactory in these projects.

However, an analysis of the impact of the programs revealed that for cash crops such as castor, groundnut, tobacco, etc., fertilizer use was adopted. On an average, 0.5 t/ha additional production could be achieved during the implementation of the program. This worked out to 100 to 200% additional production in the various project areas.

Future Research Needs

Runoff Management

Studies on runoff management should include runoff collection, storage, and recycling. Attempts should be made to develop models for future projections; such modeling would be helpful in determining the size and location of the storage tank. Further, while considering recycling, the use of various types of pumps to lift water from the ponds to fields and efficient methods of minimal water use need to be

identified. Naturally, this coincides with the critical stages of crop growth as well. Thus, while considering runoff management, the water so stored should be considered only for critical irrigation.

Table 17. Increase in investment and income (Rs./ha) Operational Research Project, Indore.

	1973–74	1974–75	1975–76	1976–77	1977–78
Investment	493	388	576	608	690
Gross income	656	560	1005	1127	1292
Net income	163	172	429	519	602

Seepage Control Methods

The success of water harvesting, storage, and recycling is determined by an effective seepage control technology. Several seepage control methods — for instance, the use of lining materials such as bentonite, polymer films, concrete, asphalt, and butyl rubber — have been used with varying degrees of success. Other materials — such as latex emulsions and resinous polymers — though not efficient at this stage, may, in the future, result in superior products that may be more suitable as well as economical. Chemical and gleization methods can be considered as low-cost methods that have scope for further research and field-scale application. In India, research efforts will have to be intensified to locate a cheap and dependable lining material for minimizing the seepage losses.

Optimizing Use of Natural Resources

Efforts must be made to increase in situ water harvesting by some kind of land configuration and/or shaping. Such efforts are in progress in the dryland project but they need to be fortified. While bunding is to be taken as an erosion control practice development of suitable land-shaping practices is equally important in the interbunded area for uniform distribution of moisture.

Land-use Capabilities

While considering land-use capabilities, agroforestry and silvi-pastural systems are important. Available information on land use is inadequate and more needs to be collected. As the marginal and submarginal lands come into cultivation, the cost of cultivation also will increase. In such instances, perhaps, pastural systems would be more meaningful.

Pulses and Oilseeds

Another area of research that needs attention by the dryland scientists is the place of pulses and oilseeds in cropping systems. The research information from the project has established the scope of pulses and oilseeds in intercropping and sequence cropping systems. More comprehensive planning and experimentation is required to obtain higher yields of these two commodities in drylands.

Organic Recycling

The principle of "chain recuperation" of energies is called for at the present juncture of the energy crisis. Conserving and improving the quality of the land through the use of organic wastes and better cropping systems and aiming at maximum economy in the use of fertilizers should be the basic principles for improving the rural environments. Use of symbiotic microorganisms for fixing nitrogen from the air would be an added advantage in cropping systems.

Socioeconomic Analysis

Another important area of research is economic analysis. The project is already working on the economics of various improved systems of farming as a whole and in components. Further, it is also attempting to study the adoption and diffusion of the various improved practices developed. Data must be based increasingly on real farm situations so that the new technology will be widely and freely accepted.

Training

Training the farmer and the extension worker is an important component in the project. Ad-

justments and judgment increasingly play an important role in crop production in drylands. Therefore, "guides for improved judgment," indicating the critical value and the range of the crucial factors concerned, need to be prepared urgently.

Further, the strength and weaknesses of practices developed by the project need to be tested by directly involving scientists in real farm situations, through operational research, and by other means.

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The Drought-prone Areas of Maharashtra

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Abstract

Maharashtra is the third largest state in India; of its cultivated acreage, one-third is proverbially drought-prone. The topography is undulating; the soils prone to erosion; the rainfall, ranging from 500 to 750 mm, is highly variable. About 30% of the soils are shallow to medium-deep. The Agricultural Research Station at Sholapur, established in 1933, has done considerable research on "dry-farming," the results of which are ready for transfer. However, the salvation for rainfed agriculture cannot come from technology alone; a concerted multidisciplinary, multiple-agency effort is necessary. This effort must be on the basis of integrated development of entire watersheds rather than on an individual farmer basis.

Geographically, Maharashtra is the third largest state in India; of the cultivated area in the state, one-third, covering 87 *talukas* or *tehsils*, is proverbially drought-prone and famine-haunted. This region receives scanty rainfall (500 to 750 mm annually) that is highly unpredictable and extremely variable both in timing and quantum. Most of the region has undulating topography, rendering the soil — predominantly Vertisols — moderately to highly erodible. The hills are severely denuded of vegetational cover, which greatly accelerates soil erosion. About 25 to 30% of the cultivated acreage comprises skeletal to shallow and medium-deep soils; these are generally left fallow, without any crop cover, during the rainy *kharif* season, thereby adding to the soil erosion. *Rabi* (postrainy season) farming is the predominant cropping system.

The farming community is largely illiterate, ekes out a miserable living from severely risk-prone farming and is predominantly under the so-called "poverty line." Consequently, the farmers are highly tradition-bound, not easily amenable to suggestions for changes in their farming methods, and are resigned to fate.

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Early Research on Dry-farming

Maharashtra (which was then known as the Bombay Presidency and comprised Sind, Gujarat, the present western Maharashtra, Khandesh, and northern Karnataka) was the earliest among the states in India to establish a research center for dryland farming. The first one was set up in 1923 at Manjri, near Pune. Later, in 1933, it was transferred to Sholapur, which lies in the heart of the drought-stricken region. Sholapur was among the earliest chain of dry-farming research stations[1] established in the country with financial assistance from the Indian (then Imperial) Council of Agricultural Research (ICAR). Sholapur is thus a pioneer and leading dry-farming research center of India.

Through the research endeavor spread over two decades or more, the well-known Bombay Dry Farming Method was developed at Sholapur, naturally in the context of the scientific background obtaining at that time. Broadly, the technology had two major facets: one, soil and water conservation by mechanical methods — such as contour-bunding, land-scooping, deep plowing once in 3 years, and manuring with organic manures — the other, improved crop production practices, such as

1. The others were Rohtak, located in what is now the state of Haryana, and Bellary and Hagari, both now in Karnataka.

wider row spacing (45 cm) for *rabi* sorghum, limited plant density per unit area of land, and interculturing two or three times during the crop season. Based on these researches, the state government undertook an extensive soil and water conservation program, which included contour-bunding, in about 12 districts; this program has served all over India as a useful model.

All India Coordinated Research Project for Dryland Agriculture

During the late 1960s and the 1970s the scope of dry-farming research at Sholapur (and also at the ancillary stations at Mohol, Jeur, and Chas) was considerably broadened to include soil and climatological studies, selection of a wider range of crops and new crop varieties, development of suitable agronomic practices, and development of tools specially suited to rainfed farming. Valuable and utilizable results have emerged from these researches. Since 1970, the Sholapur station of the Mahatma Phule Agricultural University functions as an important link in, and an integral part of, the All India Coordinated Research Project for Dryland Agriculture sponsored by the ICAR; since the inception of ICRISAT at Hyderabad in 1972, it also enjoys close and fruitful cooperation with that institution of international repute. A technical bulletin, describing the results obtained from recent research on dry farming at Sholapur, has been prepared and will be published shortly.

Problems Facing Rainfed Farming

During the mid-1960s, India witnessed the historic "green revolution." The "miracle" varieties of wheat, and later of rice, were harbingers of that revolution. The areas in which it took place enjoyed the advantages of irrigation and assured rainfall, and the process was spearheaded mostly by resourceful, relatively well-to-do, "progressive" farmers. Transfer of the new technology from the experiment stations to the farmers' fields was remarkably rapid. The result was that India, which had eked out a precarious existence on the food front for about 18 years — since Independence in 1947 — and which had annually imported foodgrains ranging from 2 to 14 million tonnes during that period, built up within a matter of 6 years (by 1971) a gratifying national food grain reserve of around 11 million tonnes.

By contrast, dry-farming research technology is, by its very nature, painfully slow in its travel from the lab to the land, especially when rainfed agriculture has to be carried out, as in Maharashtra, under undulating topography and under drastically varying conditions of rainfall. The many problems (and some suggested solutions) include:

1. In contrast to irrigated agriculture, the research technology of rainfed agriculture does not produce immediate and dramatic results on the farmers' fields.
2. Rainfall and other weather conditions, and therefore crop harvests, vary considerably from year to year. Establishment of confidence in the new technology and its acceptance by dryland farmers therefore takes time. Research scientists and extension agents must therefore be constantly in touch with their farmer clients over a number of years.
3. The research station-extension agency-farmer link must be established on an enduring basis and a mechanism must be developed for sustained and efficient information exchange. Experiences must be exchanged frequently and on a personal basis. From this standpoint, the present extension system needs to be strengthened in terms of numbers of scientists and extension workers and also of the diversity of technical specialization needed. Linkages between the research system and the technology delivery system must be made far closer and stronger than they are at present; that is, agricultural universities and extension agencies must work together in close harmony.
4. The extension agent, as well as the farmer, needs to be trained and retrained systematically and frequently. The research scientist also learns a great deal during this training process.
5. The training of both the extension agent and the farmer must take place on the farmers' fields. Experiment stations can only be used as centers of exposure to the new technology, research being oriented and reoriented to meet actual farming

situations, which are locale-specific, and in recognition of the success or failure of the new technology out on farmers' fields. It must be remembered that research centers generate technology in an ethos quite different from that obtaining on farmers' fields, because human, socioeconomic, financial, administrative, and legal considerations weigh heavily on the farmer in his day-to-day life and occupation.

6. Soil and water conservation and management are extremely critical factors in dry farming. For reaping even reasonable harvests, these two resources must be managed very efficiently. Field demonstrations are necessary as a first step to catch the farmers' imagination and gain their confidence. But it must be pointed out here that the process of research technology transfer takes us into avenues other than, and in fact far beyond, the farmer's field.
7. Apart from timely, on-the-spot technical advice, the dryland farmer must be given, more or less at his doorstep, the crucially needed physical and financial wherewithal. Some or all of these may not be available to him at all, or may be available only partially. Tools, implements, water-storage structures (percolation tanks, dug wells, farm ponds), and animal or mechanical power are his primary needs for soil and water conservation and management; these must be followed by other inputs such as improved seeds, fertilizers, and pesticides. If he does not, as many poor farmers do not, own these essential physical prerequisites, he should be able to rent them in his village at the right time. Alternatively, some form of cooperative and collective system would have to be designed, organized, and put into practice in the village. This means the rural society and the government must both make a concerted and cooperative effort to evolve a benevolent, yet economically viable, social organizational system.
8. Financial assistance is, patently, even more crucial. Most of the farmers in the region are illiterate and ill-fed and they live below the "poverty line." Farming is terribly risk-prone and harvests highly variable from year to year. Hence, major policy decisions must be taken by governments and financial institutions with regard to the organization and operation of credit supply. The terms of credit may even need complete overhaul — i.e., low interest rates, longer duration of loan repayment on the basis of actual annual harvests, and slackening of conditions for credit-worthiness. This means the setting up of a rural financial security system geared to farmers' needs, yet operating within the framework of economic viability.
9. Where dryland farming is practiced as in Maharashtra — not on flat or more or less even land, but on undulating topography — it is beyond the ken of the individual farmer to do all that is needed for soil and water conservation even on his own plot of land. Public agencies must step in here. Soil and water conservation measures must be taken on the basis of an entire watershed. The soil survey and land-use planning and advisory agency must take detailed topographic and soil surveys and analyses and execute the soil conservation works. The groundwater survey and development agency must make geological, geohydrological, and geophysical surveys of the entire watershed. Based on these, appropriate sites for percolation tanks and dug wells must be located in relation to the natural aquifers, before such tanks and wells are actually dug. Such surveys should also be used for predictably quantifying the availability of water at the various levels on the watershed and the scope for recharging existing and new dug wells.

Very importantly, then, the rural community, the people's institutions, and the local administrative machinery must pull together and identify and execute measures for people's participation in this program, taking into consideration the human, social, technical, legal, and administrative aspects of the problem. *Zilla parishads* and *taluka panchayats* can, and should, give the lead. Water is a very precious resource, but it must also be

recognized that if its conservation and utilization are not done wisely — on a physico-geographical and economic rationale and on the basis of social distributive justice — the same water can become a source of the worst of rural feuds. Finally, as major, medium, and minor irrigation projects are executed by governments from public funds, so should soil and water conservation and management projects be taken up, watershed by watershed, and executed from public funds.

The food the farmer produces on his land in 1 year, he generally uses for 2 years. In this sense, increasing crop productivity on such lands not only raises farmers' incomes but, more importantly, acts as an insurance against recurring famines. When famine strikes, the government spends millions of rupees in a single year. Such massive financial expenditure could be significantly reduced, perhaps even eliminated, if a sustained endeavor is made, over the years, in the drought-prone areas on the lines indicated above.

10. The continual pressure of human population makes the land:man ratio precarious in India, as in many other countries of southern and southeastern Asia. The result is that rainfed farming is practiced even on skeletal and shallow soils and on slopes of land on which farming should indeed be forbidden. Land use on watersheds receiving scanty rainfall must therefore be diversified to include:
    - Pasture-sheep farming
    - Agro-forestry for fuel, fodder, and other economic uses (for instance, the growing of *neem; karanj*; acacia or *babul; Casuarina; Ipil ipil* or *koo babul;* mesquite or *vilayati babul*; ficuses such as *banyan, pipal, pimparni*; the fodder-yielding *anjan* tree, *Hardwickia binata*, etc.)
    - Dryland horticulture (jujubes or *ber*, custard apple, tamarind, *jambool* or *jamun*, jackfruit).
    - Cultivation of *sisal, agave,* and other economically useful xerophytic species.

    Such diversified use would perhaps be more worthwhile and economic on these lands than even foodgrain farming.

    Among oil-yielding cash crops, castor and sunflower would be the most promising. At Sholapur, intercropping of pasture grasses with pearl millet (*bajra*) has also been tried with a reasonable degree of success. Thus, every bit of land and every drop of rainwater received on the watersheds must be utilized in the best and most economical manner. Such judicious land utilization would also stave off soil erosion, apart from yielding a wide array of economic plant wealth. The vast expanses of barren lands and denuded hills painfully visible all over drought-prone Maharashtra today could really be transformed, in the not-too-distant future, into a pleasing green mantle valuable to humans and animals alike. The crucial concept in rainfed farming, we must appreciate, is not just of increasing food production, but really one of increasing the incomes of the farmers in more than one way.

11. While food is the most basic need of man, an equally important problem at the rural level is that of fuel with which to cook the food. For his daily fuel, man has foolishly and mercilessly cut down trees and bushes and every kind of vegetation over the last several decades, without caring about the soil erosion which such denudation engenders. Systematic afforestation of watersheds is therefore essential, not only for soil and moisture conservation and control of erosion, but because trees are also important sources of fuel and timber. However, trees take time to grow whereas rural energy needs for domestic cooking and lighting are everyday needs. In this context, a concerted biogas campaign for full utilization of animal dung and human night soil at the rural level becomes most crucial. It is important to remember that this is ever-renewable and the cheapest source of energy; as long as man and beast exist, we should never be short of this source of energy. Besides supplying combustible gas, biogas plants, equally importantly, yield organic manure, which has a valuable role to play in farming in general and

in rainfed farming in particular. The biogas movement is therefore essential if deforestation leading to desertification is to be prevented.

12. If rainfed farming and the lifestyle of the dryland farmer are to be transformed, diversified and judicious use of land and rainwater on a watershed basis is inescapably necessary and diverse agencies, in addition to those directly and immediately concerned with research technology generation and its transfer, must be brought in to play their respective roles, fully and in unison. These include agricultural universities as generators of research information, the state departments of agriculture, animal husbandry, and forestry as vehicles of technical development; government and banks as policy-makers, planners, and suppliers of finance; state administrative machinery as the controlling and regulating authority; benevolent public and private agencies and individuals; people's institutions such as the *zilla parishads* and the *taluka* and the *gram panchayats*, and, above all, the farmers themselves. All of these must come together to think, plan, and act to accomplish this complex task.

Compared with the magnitude and the wide range of the task, the present technology-delivery system is quite slender, weak, and utterly uncoordinated. The trouble is that numerous departments are operating, more or less in isolation from one another, on such programs as Drought-Prone Areas Program (DPAP), Intensive Cattle Development Program (ICDP), *Vanamahotsav* (tree-planting program), small farmers' development programs, landless laborers programs and what not — all in bits and pieces.

The Government of Maharashtra has pioneered unique ideas and bold programs of rural and agricultural development, such as the Employment Guarantee Scheme (EGS) and Command Area Development Authority (CADA) for every irrigation command area in the state, which governments elsewhere can well emulate. It should not be difficult — indeed it should be a high-priority matter — for the Government of Maharashtra, or for any government anywhere, to launch composite, multidisciplinary, multiple-agency, well-coordinated integrated watershed development projects on the lines indicated above, without which dryland farming cannot be lifted out of its present bleakness.

A time-bound, district-by-district program has to be taken up systematically. Such integrated endeavor will immediately generate large-scale rural employment sustained over a considerable period of time, as these programs are made operational, watershed by watershed, all over the state. It will indeed radically transform rainfed agriculture and significantly increase crop and animal (sheep, goat, cow, buffalo) production, thereby increasing meat and milk production on lands that today are hopelessly unproductive. It will stave off famines, and it will generate newer avenues and opportunities for rural employment and thereby stem the colossal tide of rural-urban migration of human population.

Conclusion

It will perhaps be argued that we have taken up a much-too-large canvas and have attempted to paint a rather complex picture in trying to deal with the problems of rainfed farming technology and its transfer. We may even appear Utopian. We do concede that first things must come first and also that the "better" should not be allowed to become the enemy of the "good." ICRISAT, Sholapur, and many research institutions in India and abroad have already developed useful dryland farming technology that can and must be taken up straightaway for its transfer to rainfed lands. No one can deny that the development of appropriate research technology and its urgent transfer to farmers, who are waiting for it around the corner, constitute the kingpin of this task. Nevertheless, we must make bold to emphasize that transformation of dryland agriculture is a complex and multi-faceted affair; full and substantial success cannot come from technology alone, but only through the adoption of a multidisciplinary, multiple-agency, and well-orchestrated strategy such as we have ventured to outline here.

Experience from Nigeria

M. B. Ajakaiye*

Abstract

Agricultural technology, to be practicable and acceptable, must take into account the socioeconomic factors influencing its users. The Nigerian program, based on this premise, attempts to solve the SAT farmer's problems by developing short-season varieties to fit the growing season; devising simple tools to reduce farm drudgery; controlling pests and diseases through preventive measures; and ascertaining that new farm practices developed will be both acceptable and profitable to the farmer. The Agricultural Extension and Research Liaison Service (AERLS) plays a key role in linking research and its ultimate user, the farmer.

The development and transfer of technology in agriculture must take into account the socioeconomic factors influencing users of the technology.

This is particularly so with the farmer in the semi-arid tropical zones operating under rainfed conditions, because of his environment, especially the short duration of the rainy season.

The transfer of the technology developed must also take cognizance of the social and economic status of the farmers if the package of practices developed is to be practicable and acceptable.

The semi-arid tropics are already well defined. In Nigeria, the Sahel and Sudan savanna zones fall into the semi-arid tropical region.

Development of Agricultural Technology

The general considerations for the development of technology here include:

1. The level of management skill of the farmer. Practices are developed at different levels — advanced, intermediate, and low — so that each farmer can benefit at the level on which he operates.
2. Habit or tradition, which determines what farmers prefer. For example, maize is a higher yielder than sorghum in the savanna zones of Nigeria, but because farmers traditionally have been used to sorghum, maize is not a priority in the cropping system.
3. Pest and disease resistance. Breeding for resistance to pests and diseases is a main thrust of the crop-protection program.
4. Labor-saving devices. These must be simple enough to be within the reach of the farmer.

These semi-arid zones are connected with the northern part of Nigeria and are characterized by:

- short-duration rainy season of 3 months or less,
- long dry season,
- sparse vegetation,
- mainly sandy soils, susceptible to wind erosion, and
- soils with low organic matter and low phosphorus content.

Farmers in the Nigerian semi-arid zones are peasant farmers cultivating on the average about 1 ha each. They practice mixed cropping, which is the popular system, growing as their main crops millet, sorghum, groundnut, and vegetables of all sorts. Labor is expensive at peak seasons of planting, weeding, and harvesting, and the farmers lack suitable machinery — simple devices or hand tools — to reduce the drudgery of farm operations.

The above problems are taken into consideration in the development of agricultural techno-

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logy for the Nigerian farmer of the semi-arid zones. For example:

1. Short-duration rainy season. Efforts are directed to developing short-season varieties of sorghum and groundnut to produce a good crop in the short season. We have learned our lessons from the droughts of 1973–74 followed by the rosette epidemic of 1975, which wiped out our groundnut crop, and we are working hard on meeting future drought hazards.
2. Profitability and social habits. The agricultural economics section looks at the socioeconomic aspects of farm practices developed. This is to ascertain that they are practical, acceptable, and profitable to the farmer. For example, we have found that the maize/cowpea combination gives a greater gross return per unit area than each grown as a sole crop. As most farmers practice mixed cropping, there is a farming systems research program that looks at the different practices of the farmers and tries to evolve definite cropping patterns of crop combinations. The most common crop combinations farmers use are millet/sorghum, groundnut/sorghum, groundnut/maize, and maize/cowpea, but there are numerous others.
3. Mechanical devices. The agricultural engineering section tries to design simple tools — for example, hand maize-shellers, groundnut decorticators, and grain planters. Prototypes are produced and it is hoped that some commercial concerns will be interested in producing them on a large scale. Also, the Institute for Agricultural Research, Samaru, has decided to set up a small-implements production unit. This will develop and produce our prototypes for distribution initially to stimulate interest in them and subsequently to popularize the implements and devices. Animal-drawm implements have been developed and been in use for a long time in ridging, weeding, and even in groundnut harvesting. These are mainly ox-drawn, but investigations into the use of donkey power have been recently started.
4. Microclimate and physiology. The physiological aspects of mixed cropping have been looked into; nutrient utilization and solar energy distribution and absorption in the canopy are studied with a view to modifying populations and planting configurations for best effects. Pest incidence in mixed cropping has been found to be less than in crops grown sole.
5. Pest and disease control. Close attention is paid to preventive measures, such as seed dressing and cultural practices. These involve mainly crop hygiene and timeliness of operations. However, for farmers who can handle and afford chemical control, spraying schedules have been developed for some crops, such as cotton and tomatoes.

Transfer of Technology

The transfer for agricultural technology involves extension, which may be defined as an agency of change that teaches new or appropriate technologies so that clients can adopt them for their own benefit. This has been the responsibility of the states, which have institutional arrangements in the form of Field Services Divisions of the Ministries of Agriculture and Natural Resources. These ministries have field extension staff who work in the villages; through the normal extension methods of demonstrations, meetings, visits, agricultural shows, field days, movies and slides, and, recently, the minikit method of demonstration, they persuade farmers to use improved practices. The minikit involves the farmer in the decision of which variety to use. He grows promising varieties developed by research, evaluates them, and decides which suits him best.

This method, based on the experience of the "green revolution" countries, reduces the time lag between the development of a new variety and its adoption by the farmer.

The Case of the AERLS

In Nigeria, as in most developing countries, the flow of information from research direct to farmers is not quick and smooth. This is partly because of the background of the farmers, who are largely illiterate. Also, institutional arrangements have not really made it possible for research results to get to the extension workers and farmers in a form that is readily usable. To

solve this problem, in the northern part of Nigeria, an organization has been formed to act as a link between extension and research: Agricultural Extension and Research Liaison Service (AERLS).

The Research Station in Zaria was established about 1920. With the establishment of the Ahmadu Bellow University in 1962, the research station was appropriately transferred to it and named the Institute for Agricultural Research. By 1960, it was realized that most of the information from the activities of the station did not reach the farmers — the ultimate users of the information — to improve their practices. The Extension and Research Liaison Section (ERLS) was therefore established in 1963, based in Samaru but part of the Field Services Division of the Ministry of Agriculture. Its primary function was to serve as a link between the research institute and the Ministry's extension services. Upon the dissolution of the then Northern Region Ministry of Agriculture (as a result of the creation of states) the ERLS was merged in 1968 with the Institute for Agricultural Research (IAR).

In 1975, ERLS was separated from IAR and made a separate organization, known as the Agricultural Extension and Research Liaison Service.

Its functions may be summarized as:

- Interpreting, publishing, and disseminating to farmers and extension workers research results and other appropriate information in agriculture and related disciplines such as animal husbandry, animal health, agricultural economics, rural sociology, etc.
- Providing systematic training for states' extension staff, such as regular short in-service training sessions, specialized short courses, or workshops.
- Identifying problems in the field that need research and communicating these to the appropriate research institutions, so that research projects initiated are relevant to farmers' problems.
- Assisting in the organization of state extension demonstration units and organization of agricultural shows.
- Providing advisory and consultancy services, e.g., disease control programs, poultry management, etc.
- Conducting urgently needed applied research or surveys, especially where the research institutes lack the staff to undertake them or where attention needs to be focused on developing problems likely to become economically significant in time.
- Organizing seminars and conferences.

The AERLS has two main sections — the subject matter specialists section and the audiovisual unit.

Staff of the subject matter specialists section are trained in specific agricultural/livestock disciplines — e.g., poultry science, agronomy, veterinary medicine, agricultural engineering, etc. — and are responsible for extension work in their respective areas. This section puts out publications and assists in upgrading technical competence of the states by conducting in-service training courses and workshops.

The audiovisual unit provides backup in the transfer of agricultural technology through teaching materials for all grades. The specialists in this unit are trained in communication techniques and agricultural journalism. They produce slides and films and organize radio and television programs. AERLS has encouraged the states to carry out vigorous extension programs in order to realize our national goals.

Posters and leaflets are produced in large numbers of about 90 000 in each of nine selected local languages for use of farmers and extension workers.

Other publications — guides and bulletins — are produced to inform and educate extension workers and serve as a basis for their extension educational programs.

Some problems facing transfer of technology or extension include gross inadequacy of extension staff; inadequate training or skill of most of the extension staff in direct contact with farmers; poor working conditions of extension workers; bad attitude by some extension workers toward their work; and illiteracy and general povery of farmers, which render them incapable of procuring the necessary inputs for increased agricultural production.

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Reflections on the Transfer of Technology

Joseph Kabore*

Abstract

A code or framework for the transfer of technology should be developed to strengthen the capacity of developing countries for organizing and receiving new techniques and improving access to technology at prices that can be borne by all. Establishment and development of facilities for technical and in-service training in the countries themselves are prerequisites for an efficient and durable transfer of technology. New techniques must be assimilated, modified, and adapted to conditions peculiar to each country. Agricultural research carried out in developed countries such as the USA or in Europe involves means of production having nothing in common with those of the small farmer of Upper Volta. Scientists are needed who can assimilate the people's everyday problems and work out a realistic research program that will raise the technological level of the farmer.

The enormous gap between the "developed" countries and the so-called "developing" countries — particularly those of Africa, including Upper Volta — compels the latter to rely heavily on the technology or know-how of the former. This is not without critical problems, the most serious being the dependence and heavy expenditure forced on the still fragile economies of the developing countries. Therefore, a suitable framework must be found for controlling the transfer of technology.

In this matter we largely subscribe to the proposals made by the UNCTAD Group of 77 at the 1975 and 1976 meetings in Nairobi.

Technology is part of the universal heritage of mankind and all countries have a right to it, at least to alleviate if not to eliminate the intolerable economic inequalities within the new international economy.

A "code for the transfer of technology" should be developed with these main objectives:

- To strengthen the capacity of developing countries for organizing and receiving new techniques;
- To improve access to technology and to have reasonable costs and prices that can be borne by all;
- To promote unspecified transactions with regard to choice of different elements of technology, estimation of costs, organization, and institutional facilities and channels.

This code will apply to all types of technology and will guarantee profitable transactions to the developing countries without perpetually "enslaving" them.

Transfer of Technology

Training

Transfer of technology implies the presence of adequate and suitably qualified personnel in all sectors of the economy. They should be capable of assimilating simple to complex technologies and techniques so that the so-called developing countries get the greatest benefit from imported technologies.

This also implies that all persons, to the lowest level, involved in building the economy should be trained so that each person is able to carry out the necessary technical work.

This training, which we believe should include both adults and children — the architects of today and those of tomorrow — should above all be conducted in the developing

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NOTE: This paper is an edited translation of the original French text, which appears in Appendix 1.

countries. However, some further training and reorientation in developed countries is essential for completing the know-how.

Training Children

A child is the future architect of the economy. Opening his mind to scientific knowledge from an early age will more easily make of him a high-level confirmed technician. Suitable facilities should be planned and established for opening the child's mind at this age.

Practical Training for the Working Masses

In order to be more efficient, the farmer, the agricultural worker, needs a minimum amount of training, further training, and reorientation; all the measures likely to improve practical training of the worker should be encouraged. A bad farmer is of no benefit to the economy. Agricultural fairs, demonstrations, and shows, courses for further training of farmers, etc., are some of the means for improving their technical ability and making them more efficient.

Structures for Technical and In-service Training

The establishment and development of facilities for technical and in-service training in developing countries are prerequisites for an efficient and durable transfer of technology.

Technology should be transferred through competent persons who have not only assimilated but can modify and adapt the new techniques to conditions peculiar to their country. There should be a sufficient number of such authorized individuals in all sectors of the economy. If an expert needs to be brought in, this should be temporary and only for the time required to train the local people. The expert should play the role of a technical consultant till the national technicians acquire minimum experience.

If technical and in-service training facilities are required to provide the economy with senior personnel, it is the same for the medium and lower categories, as these are indispensable links in any economy.

Thus, we believe that in any sector — such as agriculture, industry, and commerce — suitable training facilities are of primary importance, and these facilities cannot be established without technical and financial support from the developed countries.

Further Training and Reorientation Abroad

In most sectors of the economy, scientific development has raised the level of technology so that the developing countries cannot afford the luxury of having very specialized training institutions in all the sectors. Consequently, they have to arrange with the developed countries for further training and reorientation of their technicians in some of the very specialized areas. This collaboration is essential for an efficient transfer of certain technologies and should be taken into serious consideration.

Scientific and Technical Research

Situations and conditions often exist that are peculiar to developing countries regardless of the sector of the economy — agriculture, agroindustry, or industry. Scientific and technical research will enable those countries to find solutions to their specific problems. Therefore, training of scientists is another problem which greatly preoccupies the developing countries.

We believe that the developing countries should be able to increasingly provide training in their own country to scientists who have assimilated the problems to be solved, and then establish the means for finding the solutions. For example:

Agricultural research as it is carried out in the developed countries (Europe, USA) aims to solve problems of farmers or agricultural undertakings. The solutions are intended for educated and literate farmers, often at engineer level as in the USA, with the means of production having nothing in common with those of the small farmer in Upper Volta for manually cultivating an average of 5 ha of land. Financial and material means are not limiting factors to the large farmers, whereas in the developing countries they are the main limiting factors. Therefore, agricultural research will not have the same concerns and objectives. In the developed countries, only the identification of techniques — even sophisticated ones — and varieties is required; these countries do not lack the financial means and all the farmers have the required training.

In developing countries like Upper Volta, the farmer's level must be taken into account; he is often tied to ancestral customs, illiterate, not very open to new ideas, with poor means and no access to the almost nonexistent loans for agriculture. It will be difficult to make him leap from the Middle Ages to the twentieth century.

Although he does not have the necessary means or facilities, there are more chances of success if we seek to improve his technological level in stages. For this purpose, scientists are needed who are able to assimilate the problems that the people of Upper Volta face every day, in order to produce a research program that "sticks" to reality. This research will be more effective than that giving good results but which cannot be applied due to lack of technical capacity and means.

Transfer of Patents and Techniques

Patents, know-how, and manufacturing processes form the greatest wealth of the developed countries, and these belong to them 90%. Their transfer is subject to complicated and onerous laws. One of the first measures to be taken is to partially raise the exclusive rights to property and to decrease the cost of use. The second is the possibility for adaptation, but strictly for internal use. The third is the promotion in developed and developing countries of appropriate technology that is to be made available to developing countries.

Each case raises the question of the type of technology to be transferred for particular cases and the context.

In the developing countries, while eighteenth century technology is not adequate in some sectors, it is not possible to optimize twentieth century technology in other sectors. We believe that for advanced technology requiring abilities that are not yet available in the developing countries, caution is indispensable and regional integration is desirable.

For the other types of technology, preference will be given to that enabling maximum use of local human and physical resources; industrialization which will help to raise the standard of living of most of the people and is or will be completely controlled by national staff before long.

Training should be provided for large numbers of technicians and engineers who will gradually change the technology since experience shows that, whenever possible, people prefer products of very advanced technologies.

The Senegalese Experience

Djibril Sene*

Abstract

For many years now, Senegal has had a well-established agricultural research infrastructure as well as a large number of trained scientists. However, the Senegalese farmer has not profited much from the research findings, and the difficulty of passing them on to the farmer has been one of the major constraints to rural change. Agricultural research has two main defects: first, it is highly intellectual and not pragmatic enough; second, much of it is developed without sufficient understanding of the rural world. The creation of the multidisciplinary Regional Experimental Units (REUs) has been a decisive element of progress in research, but the REUs have been less successful in helping extension agencies. The objective of research in Senegal should be to develop innovations that will be acceptable to farmers and to facilitate the adoption of these innovations as part of the national agricultural policy.

Let me begin by congratulating ICRISAT, whose work is directed toward the development of progressive technologies for agriculture, for having organized a symposium that is not confined to the sole aspect of developing its own technologies, but also deals with the problem of transferring technology developed through research to the rural world.

Senegal has had an important agricultural research infrastructure for many years now, as well as a large number of scientists, especially when compared with the situation existing in other countries of the Sahelian zone.

This is due to the fact that at independence, Senegal was fortunate in inheriting a large system of agricultural, zootechnical, and veterinary research formerly established by France to meet the needs not only of Senegal, but of the entire western part of the African semi-arid tropics north of the Equator: from the Cape Verde peninsula in the west to Niger in the east. This is how the Senegalese Agricultural Research Center at Bambey, established more than 50 years ago, served for many years — until the Francophone West African States obtained their independence — as the Federal Agricultural Research Center for the entire Sahelian and Sudanian part of West Africa formerly under French rule.

Even though valuable achievements have been made in science and technology by agricultural research in Senegal, it is nonetheless true that as far as the Senegalese farmer is concerned, his world has evolved only very slowly — too slowly in the opinion of the country's leaders — if the farmer's income over the last few decades is used as a criterion.

Experience shows us more and more each day that one of the major constraints to changes in the rural areas arises from the inability to pass on most of the research findings to the farmer.

Does this mean that the message or messages sent by research to the rural world are mainly defective and unacceptable to the farmers, and if so, why?

Or does this mean that the normal extension services responsible for conveying the message and introducing it into the farmers' world have not, until today, known how to play the role entrusted to them, and in this case, why?

These questions must be answered and it is for this purpose that a few months ago in Senegal, we started reexamining the relationship between research and development and the operation of the rural extension agencies.

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NOTE: This paper is an edited translation of the original French text, which appears in Appendix 1.

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I shall confine myself to sharing with you here a few of my own thoughts about the messages that agricultural research is currently delivering to the farmers of Senegal, deliberately setting aside the second aspect of the situation — the operation of the rural extension agencies.

My thoughts focus on two points:

- First, how research has formulated its messages to the farmers.
- Second, how these messages have been conveyed from the laboratory or field at the research center to farmers' fields.

The Formulation of the Message by Research

Having been involved in research for a long time and now having the responsibility for overall rural development, it seems to me today that the agricultural research in Senegal has two defects which, moreover, we shall try to correct. This is true even though it is a serious research effort, carried out by scientists — both national and international — who for the most part are very competent, each in his own field of specialization.

First, it seems to me that this research is often too intellectualized, too sophisticated, might I say, and not pragmatic enough. This often gives the impression that the scientists are inclined to do research purely for the pleasure of doing research rather than to help satisfy the most urgent needs of the rural world. Perhaps this is actually because these scientists are more concerned about a distant future than the immediate future.

Second, it seems to me, moreover, that until today many of these scientists have either not known how to, or have not wanted to, adequately understand the rural world while developing their research programs.

It appears to me that for both these defects, it is a question of outlook related mainly to the type of training that is given these scientists:

- A training that is too university-oriented, so that scientists prefer to acquire higher degrees or to publish reports and scientific papers on theory rather than meet the most urgent practical needs of our agriculture.
- A training in a school of thought that, I feel, is more suited to the industrialized nations than to the developing countries; with the idea that it is up to research and research alone to decide the path of rural progress; hence, to determine the content of the message that the extension agencies will then be responsible for disseminating in rural areas. And that it is ultimately up to the government and rural extension agencies to bring about the social and economic conditions where the innovations recommended by research are accepted, regardless of their nature or cost.

I admit that, strictly speaking, such an approach could be followed for the remote future. I cannot, on the other hand, subscribe to it for the short and middle term. That would only widen the gap that we are forced to witness at present in Senegal between the research departments and the rural extension agencies. These agencies are already overinclined to undertake studies or trials that do not concern them, under the pretext that they will provide answers to problems that research either did not want to, or did not know how to, consider up till now.

It seems to me that the technical innovations proposed by research for the short and medium term should be truly suited to the changing rural scene as predicted for this period in terms of psychological, sociological (type of farm, family structure, etc.), and economic (credit, marketing, cooperatives, etc.) aspects according to the government policies in this respect.

It must not be forgotten that it will undoubtedly be very difficult for the present to change the outlook of scientists who are already working, though some effort to change can be seen. I am, on the other hand, more confident for the future, since we decided to establish a national institute of rural development responsible for training here, in Senegal, all the high-level personnel required for administration and in rural extension agencies, or for research. This does not exclude the possibility of further training abroad for our scientists, but this would only be for specialized training. This new training system should commence next year.

Transferring the Message to Farmers' Fields

The dialog between research and the rural

extension agencies in Senegal over the last few months reveals that a major concern, especially of the agencies, is the need for:

- First, findings that can be applied in the medium or short term with specifications about space (an accurate indication of the different areas where these results can be applied) and time (variation of these results according to the characteristic long-term conditions of a determined area of application and the probability of these variations in order to calculate risk).
- Second, information for evaluating the social and economic constraints to the adoption of the proposed development techniques.

How has research attempted to respond to this dual concern until today, and to what extent has it succeeded?

It must be understood that no matter how the message of agricultural research has been conceived thus far, scientists in Senegal have always been very careful to evaluate the worth in time and space of each of the technical findings obtained on the research stations; this answers the first of the two concerns voiced by the rural extension agencies.

This was initially accomplished by setting up a network of multilocational trials covering the entire territory of Senegal, and later, by establishing supplementary structures called the PAPEM (benchmark locations for preextension work and multilocational trials). Besides being part of the regular system of multilocational trials, the PAPEM are also able to play a demonstrative role for the farmer by setting up other trials combining all of the different innovations that research considers promising for the rural areas.

These experiments do not, however, meet the second concern of rural extension agencies — that they be supplied with information for evaluating the social and economic constraints to the adoption of the recommended development techniques.

This led, in 1969, to the establishment by research of a third type of intermediary structure between the central research station and the rural world — the REU (Regional Experimental Units). Much has been written about the REUs since they were established, giving somewhat ambitious definitions of their role:

"A unit for prospective research on production systems and farm models," according to Rene Tourte who was one of those directing the planning that led to the creation of the units; or again, according to the same author, "an example of the use by agricultural research of the systems approach."

"A limited socio-geographic entity where the results of agricultural research are tested in real situations in order to develop and constantly perfect technical systems, while also considering the link between the physical and human environment and the objectives of the regional development plan" (J. Killian).

"A unit where a controlled developmental process is implemented by research and concerns a set of socioeconomic conditions viewed as a whole" (L. Malassis).

These definitions give a good idea of the spirit in which these units are conceived, so that we do not have to dwell any further on this point. I shall merely point out that they were conceived as a result of a reexamination of the situation mainly by general agricultural scientists who are, therefore, closer to the realities of the rural world than most of the other scientists such as specialists in crop improvement, conservation and improvement of soil fertility, crop protection, etc., who are more inclined to confine themselves to their own area of specialization.

This reexamination originated from the relative failure of most of the rural development projects operated in Senegal since Independence and the difficulties in disseminating some of the recommendations of agricultural research, in particular, those that aim at the creation of a more favorable physical environment for traditional or new crops; among these proposals, deep tillage and burying of organic matter should be cited in particular.

I shall not describe here how these Experimental Units operate; I would only like to point out that the observations cover the entire environment; all the consequences — technical, economic, and sociological — of the introduction of an innovation in this environment are studied, and it is, consequently, a truly multidisciplinary approach.

What can be said about the work of these Experimental Units, which have now been in existence for 10 years? The answer is not easy, because the evaluation differs depending on whether it is made from the point of view of research or the rural extension agencies.

From the standpoint of research, I believe — keeping in mind the idea I have of the role of agricultural research and its operation — that the creation of the Experimental Units has been a decisive element of progress in the operation of agricultural research in Senegal. This is because the problems encountered by scientists within these Experimental Units make them increasingly aware that for agricultural research to be meaningful in Senegal, it is necessary to:

- Determine the areas and priorities of research from the environmental data;
- Aim to develop integrated techniques and systems that are compatible with existing systems before recommending them for extension and aim to identify the constraints.

I regret that, in spite of the change in outlook that has already begun to follow this line of thought among certain scientists, there are still too many who continue to conduct their research away from these principles. This is particularly true of breeders, especially those involved in improving cross-pollinated plants (millet breeders, for example) who, it seems to me, are often more concerned with the identification of a maximum heterosis in an absolute situation rather than one that is used within a cropping pattern and in a rotation. This is also true of the technological use of harvest products, which imposes different constraints on the plant, such as pest and disease resistance, crop duration, plant structure, crop management, and grain quality.

From the standpoint of development, the Experimental Units have provided the rural extension agencies with little information up till now, apart from certain technical data (fertilizer applications, sowing dates, spacing of plants, maize crop development, animal-powered farming, etc.), which really does not require a structure like that of the Experimental Units to show their advantages and their possibilities.

It is rather astonishing to discover that, in spite of the considerable studies to provide an in-depth understanding of the environment in which the units operate (studies of land tenure and availability, family and seasonal farming operations, work relationships, time of operations, and setting up farm budgets), the scientists have not been able to tell the rural extension agencies how to better organize this environment, even after these Experimental Units have been operating for 10 years. The same problems are found within the Experimental Units as outside in terms of credit operations and repayment of debts, organization and management of cooperatives, and use of agricultural implements within the traditional social units defined by those living in the same compound.

It is just as surprising to note that it was not possible to obtain a better dissemination of the recommended techniques within these Units, in spite of these studies and a far better education program for the farmers than that set up by the rural extension agencies. Nonetheless, scientists consider these techniques essential to achieving the crop-intensification policy recommended by them and considered by all as the only possible way for the rural world and agriculture in Senegal to actually progress.

This well shows that the objective of research in Senegal should be to develop innovations that will first of all be acceptable to farmers — changing the environment should only be a necessary corollary. Research should be aimed solely at facilitating the adoption of these innovations as part of the national agricultural policy.

I feel that there is perhaps a lesson to be drawn from here for ICRISAT while determining its policy for work in Africa.

I do not think that this Institute can truly conduct an effective operation for Africa from India, especially for developing cross-pollinated crops. But I could be mistaken.

Moreover, it seems indispensable to me that the work scheduled for Africa should be carried out in close collaboration with the different national programs of the African countries. These programs are, in my opinion, the only ones capable of indicating to ICRISAT the direction of its work in Africa if it is to be of real use to the African farmer.

The Sahelian Region of Africa

Nalla O. Kane*

Abstract

The Sahel Institute was created in 1977 at the instance of the Permanent Interstate Committee for Drought Control (CILSS). Its functions include collection, analysis, and dissemination of scientific and technical research results; adaptation and transfer of technology; and training of researchers and technicians. The Institute determines technology packages appropriate to local socioeconomic conditions and helps plan rural radio programs in the national (vernacular) languages of the Sahelian countries. On farms, "model" farmers demonstrate the effectiveness of new techniques to their neighbors. However, this paper stresses, the Sahelian farmer should not be regarded merely as a passive recipient of technology. He has proved his astonishing adaptability, and the traditional techniques he himself has evolved —peculiarly suited to local conditions —also deserve careful study and dissemination.

Before dealing with the problem of linkages in the Sahelian region I would like, first of all, to place it in the framework of the Sahel Institute's responsibilities. This institution was actually created in December 1977 during the Banjul meeting of Heads of State. Its creation was desired by them since the constitutive summit meeting of the Permanent Interstate Committee for Drought Control (CILSS) held at Ouagadougou in September 1973. This agency for subregional cooperation, entrusted with applied research and coordination of research and training activities in the Sahel, was, through resolution No. 3253, to call the attention of the United Nations General Assembly to the need for such an institute.

This is how, in May-June 1975, a joint UNDP-UNEP preparatory mission had to define the main orientations of the future Sahel Institute. These were discussed in Bamako in April 1976 and resulted in the immediate creation of the Sahel Institute in December 1976 at N'Djamena. In October 1977, a larger meeting on the Sahel Institute was held to study the Institute's statutes, as well as the initial and first-generation programs. The programs and statutes were adopted at the conference of the Heads of State held in Banjul on 19 December 1977.

The Institute's functions as adopted at that conference include:

1. Collection, analysis, and dissemination of scientific and technical research results.
2. Transfer and adaption of technology.
3. Coordination of scientific and technical research.
4. Training of development researchers and technicians.

The theme of this present symposium is included in the framework of item 2 of the Institute's responsibilities — transfer and adaptation of technology. Although the transfer of technology at farmer level falls within the competence of the countries, the Sahel Institute — through its functions of promotion and coordination of research and training activities and collection, analysis, and dissemination of scientific and technical research results — contributes significantly to the improvement of techniques at farmer level.

As a matter of fact, the Sahel Institute has to indirectly participate in the transfer of technology at farmer level, through:

- the training of extension and development agents;
- the determination of suitable technological

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NOTE: This paper is an edited translation of the original French text, which appears in Appendix 1.

packages to be transferred to farmers on the basis of scientific and technical information obtained at the Sahel Institute;

- the exchange of experiences between extension officers in the Sahelian countries; and
- the improvement of conditions for dissemination and of rural radio programs, as well as programs of other media in the CILSS member states.

The conditions for a successful transfer of technology in the Sahelian rural areas can be summarized by three main points:

- the training of extension and development agents and of farmers;
- the determination of technology packages suited to the socioeconomic conditions of the farmers, and
- for the masses, a well-planned rural radio program, based essentially on item 2. This program is of course transmitted in the country's national (vernacular) languages.

In each country of the CILSS region, extension services are established either within the traditional agricultural structures or the more operational framework of development institutions, such as:

- the Company for Agricultural Development and Extension (SODEVA) in Senegal's groundnut basin,
- the Regional Development Institutions (ORD) in Upper Volta,
- the development operations (the Mopti millet operation in Mali),
- the zonal projects within a country (project 3M in Niger).

In most cases the transfer takes place according to the spreading dissemination technique, mainly by means of demonstration. In the intervention area, a certain number of "model" farmers are selected to whom these techniques are taught. These farmers serve either as instructors to the others, or as an incentive for their neighbors to use the same techniques in order to obtain the same yields.

Audiovisual techniques are often used for mass communication. These are undoubtedly important but they cannot replace the direct experience that farmers can gain from visits to the fields of "model" farmers; after this on-field experience, they benefit more from a film promoting these techniques.

Technological packages to be transferred should be determined keeping in view the important factor of the farmer's socioeconomic conditions. Any technique that is not easily integrated within the target rural areas, or surpassing their financial capacity, has little chance of success. This is also true of a technological package comprising complex themes and sophisticated techniques.

This observation, however, is not a panacea, since we often find farmers with an extraordinary capacity for adaptation. For instance, at the start of the OMVS program, people said that the farmers of the River Senegal region would never master the technique of rice cultivation with complete water control. As everyone knows, this is a very complex technique. This apprehension was contradicted by the facts. Although the farmers of the River Senegal basin are not traditional rice growers, they showed themselves to be as competent as Asians, thanks to an astonishing ability to adapt.

There is still a lot to be done in the field of transfer and adaptation of technology in the Sahelian region.

It is well known that both national and international research have obtained satisfactory results in the region, but these have not always had the desired applications, not only for lack of sufficient financial means, but also for lack of really adequate methods for applying the results. For this reason, the recent project on millet, sorghum, and cowpea improvement planned by the Sahel Institute has emphasized, besides training and experience exchanges between researchers, the transfer — through multilocational trials — of varieties selected and tested in some CILSS states.

The Sahel Institute will endeavor in these trials to find the right methods for controlling various techniques related to the dissemination of these varieties in rural areas.

We have discussed the transfer of technology as if the farmer was only to receive and not create techniques. Undoubtedly, this means that people do not fully appreciate the capabilities of the Sahelian farmer. There are several traditional techniques relating to cultivation methods suited to different soil types, to breeding and seed conservation, as well as control of parasites and other crop pests. Although these traditional techniques have a local character, they are truly suited to the farmers' socioeconomic conditions.

Research and development authorities should study further these techniques and improve them for dissemination, which will certainly be more rapid and less expensive, because they are produced by the farmers themselves.

The Brazilian Experience

A. Blumenschein*

Abstract

Brazil has invested substantially in agricultural research in the Northeast, where most of the semi-arid areas of the country lie. Besides the irregularity of rainfall and the impoverished soils, a real obstacle to development in this area is the land distribution, with 8% of the farmers owning 67% of the cultivated land. The research program began by analyzing the constraints to increased production and has undertaken four main projects: an inventory of natural resources, the development of production systems for rainfed areas, production systems for irrigated areas, and farming systems for the special conditions that exist in the Northeast. The program is so structured as to facilitate the quick transfer of technology from the IARCs to Brazil.

Most of the semi-arid areas of Brazil are in the northeast of the country. This region also includes some areas where rainfall is regular and that are therefore not semi-arid; however, for purposes of development, the Northeast is considered one socioeconomic unit.

Agriculture is the most important support for the regional economy. Nevertheless, the increased production of the last years has come from an expansion of the cultivated area, not from higher productivity per unit area. If the present ratio of expansion to population growth rate is maintained, all cultivable areas will soon be occupied. The only solution therefore is to adopt appropriate technology to enhance productivity.

Brazil therefore decided to invest substantially in agricultural research this year in the Northeast; $20 million was made available for that purpose, and 550 people are involved in agricultural research in the region. The research center for the SAT (Centro de Pesquisa Agropecuária para o Trópico Semi-Árido), located in the Northeast, is responsible for generating technology for this region and for coordinating development by other institutions. Three other centers, also located in the Northeast, specialize in research on cotton, cassava and tropical fruits, and animal production. Each state in the region also has a local program, carried out by state institutions, universities, and private institutions. We have structured our national research program so as to facilitate a quick transfer of technology from international centers to our country. The relationship of our national to state-local centers is similar to that of IARCs to national programs.

The climate in the northeast of Brazil is characterized by a rainy season covering a single period of 3 to 5 months. The rainfall distribution is very irregular, with average ranging from 25 to 252 to 1000 mm. In some areas, the distribution is so irregular that we can classify these as the very arid regions. The annual average temperature ranges from 23 to 27°C. The insolation is very strong, averaging 2800 hours a year and the relative humidity is low, averaging about 60% a year. Evapotranspiration is very high, averaging 2000 mm/year.

The soil has a low and medium depth and very low fertility. It is rich in potassium but very poor in calcium, phosphorus, and organic matter. It is a sandy soil and the erosion can be very intense in this area. The vegetation — with the exception of some small spots of dense evergreen forest — consists of xerophytic species that characterize the region, which we call *Sertão* or *Caatinga*.

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NOTE: This was not presented as a formal paper at the Symposium but is an edited transcript of Dr. Blumenschein's extemporaneous remarks.

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The total population is 18.5 million; or 3.7 million families. Of those, less than 2.2 million families have incomes equivalent to $100. About 58% of the farmers have less than 24 ha, corresponding to 6% of all the area used for agriculture in this region. Long periods of drought, frequent in this region, most affect these small farmers. Only 8% of the farmers own more than 100 ha each, but they own 67% of the cultivated area. Thus land distribution is the real problem in this area.

In order to establish its research program, the regional center analyzed the development of agriculture in the region and identified the following main constraints to development:

1. Lack of sufficient knowledge of natural and socioeconomic resources
2. Harvesting deficiences
3. Inadequate soil
4. Small land holdings

The research program is now oriented toward overcoming those constraints; it considers the property as a whole and looks for production systems appropriate to each ecological situation, trying to show the producer the advantages of improved technology over the traditional one.

The program is based on four main projects:

1. Inventory of natural and socioeconomic resources. This project will allow us to collect information about the climate, soil, and other physical factors, as well as socioeconomic factors, that affect agriculture. The Northeast can then be divided into analogous subregions.
2. The development of production systems for rainfed areas. The main objective here is to develop technology that will increase and stabilize agricultural production in areas with low and very low rain. This technology must be appropriate for adoption by the small and medium farmers, with a limited number of cattle.
3. The development of production systems for irrigated areas. The objective here is to develop an improved technology that will allow the rational use of area with water reserves, on surface and underground, and soil with potential to be exploited continuously under irrigation.
4. Management of the *Caatinga*, the special conditions in the Brazilian Northeast. The main objective of this project is to develop technology that will make viable the economic potential of agriculture, especially in areas with very low precipitation, while preserving the ecological equilibrium.

The regional center has a specially structured program. Because its purpose is to generate farming systems technology, its work program must be comprehensive and allow the flow of information from one experiment to another. The research in the center involves basic studies, both at experimental field levels and at the farmers' level. Results obtained on conventional experiments and knowledge of regional conditions are integrated in a synthesis experiment, where the benefits can be evaluated as a whole, based on important production factors. For example, for crop production, the factors are grouped into varieties, fertilizers, soil and crop management, and water management. The best results for synthesis experiments, such as crop rotation, are tested on an operational scale, which allows economic analysis and enables the multidisciplinary team of researchers at the centers to compare the performance of alternative systems with traditional systems. The most promising of the new systems are tested by them for acceptability. If the systems prove efficient at the farmers' level, they will be thoroughly diffused with the help of the extension people.

Under the dryland farming systems research, 3 systems of cultivation have been studied: runoff, watershed, and *vasante*. These research programs are associated with studies of drought-resistant plants and are conducted simultaneously by multidisciplinary research teams consisting of specialists in agroclimatology, cultural practices, animal production, ecology, economics, agriculture, mechanization, hydrology, soil and water management, plant breeding, soil fertility, plant nutrition, soil physics, and soil- and water-plant relationships.

One objective of the runoff studies is to develop a system of cultivation by runoff that could be applied to the region of the *Sertao*, where average rainfall ranges from 250 to 600 mm per year. A second objective is to determine the efficiency of water collected in the areas without vegetation to define the relationship between the water collected and the irrigated areas in a given region and to identify the importance of soil better in the irrigated areas.

The watershed farming systems research aims at developing a watershed planting system that could be used in the region called *Agrestes*. Another aim of this research is to compare the traditional cultivation system with the watershed system and to compare the traditional cultivation system with the ridge planting systems.

The *vasante* farming systems research studies a type of agriculture peculiar to the northeast of Brazil: the practice of using dry river beds for agriculture during the dry part of the year. The *vasante* studies are meant for developing technology suited to this kind of agriculture.

The drought-resistance research seeks to identify the adaptation of plants to their environment. Various biometers are taken into account, climate parameters such as rainfall, evaporation, relative humidity, maximum and minimum temperature, light, intensity, solar radiation, and wind velocity; characteristics of the soil; and characteristics of the plant.

For the management of the *Caatinga* farming systems research, the objectives are: to develop an economically feasible technology for areas of the *Caatinga*, preserving their ecological equilibrium through the rational use of natural resources, and to increase the supply of food in the northeast division, where there is a large gap between food production and consumption.

Several projects compose this study. Among them is a study of goats, to obtain basic information on the productive and reproductive performance of the herb under existing conditions, and to identify the factors limiting a better performance. The effects of variables such as food and medical supply on performance during critical times of the year are measured. An identical study with the same objective and methodology is also being conducted with sheep.

In two other related projects, germplasm banks have been established to maintain, multiply, and assess native and exotic pastures, so as to encourage optimum use of natural resources for animal feeding.

Development and Transfer of Technology for Rainfed Crop Production in Thailand

Ampol Senanarong*

Abstract

Of the four geographical regions of Thailand, the Northeast is where the problems of rainfed agriculture are most evident. Low and unstable yields of all crops – especially rice – in this region, underutilization of land, and low soil fertility combine to make per capita income of farmers the lowest in the country. Until recently, research focused more on varietal improvement than on cultural practices or soil and water conservation and management. Multidisciplinary research needs to be emphasized and long-range programs developed to maintain continuity. Researchers, extension personnel, and practicing farmers should be enabled to work together to develop technology that the farmer can adopt profitably. A first step would be to accept existing farming systems and introduce simple, low-cost innovations that will result in visible increases in yields.

Thailand occupies a geographical area of 51.4 million ha, of which 18.5 million ha are used for agricultural purposes. Rice is the major crop, accounting for 11.7 million ha. The area under upland crops is 3.3 million ha; under fruit and tree crops 1.8 million; under vegetable and ornamental crops 95 thousand; and others 85 thousand ha.

The kingdom is divided into four regions: North, Northeast, Central, and South. The per capita income is highest in the Central region, followed by the South, the North, and the Northeast.

Only about 20% of cropped land is irrigable. The largest irrigable area (2 million ha) is in the Central region and only about 0.4 million ha in the Northeast. Much of the irrigation is during the rainy season and is chiefly used for rice. Water resources for irrigation in the dry season are limited; only the Central and the North regions are benefited. The major agricultural exports are rice, cassava, corn, sugar, rubber, jute, kenaf, tobacco, and castor.

The present paper confines itself to the Northeast, which is the poorest region, where farming is the most precarious.

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The Region

The region accounts for 34% of Thailand's population and 40% of the agricultural households. Per capita income of the farmers in the Northeast is the lowest in the kingdom; although the region occupies one-third of the country's area, it contributes only a sixth of the gross national product.

Cropped area in the Northeast is 5.2 million ha (from latitudes 14° to 18° N and longitudes 101° to 105° E). Rice occupies the major area (4 million ha) and is grown mostly rainfed in the Lowlands as well as in the Upper (Paddy) Terraces. The Lowlands are generally assured for rice except for flood damage. The Upper Terraces can grow transplanted rice only if the rainfall is heavy early in the season; otherwise, they are either transplanted late or remain fallow. It is estimated that even in normal years only 75 to 80% of the rice area in the Upper Terraces is transplanted, and of the planted area 80 to 90% is harvested; that is, only 60 to 72% of the Upper Terraces produce rice.

Upland crops occupy an area of 1.3 to 1.4 million ha, the principal crops being corn, cassava, and kenaf — which account for more than 90% of the area — followed by peanut and, to some extent, cotton, tobacco, and jute. Nearly 80% of the rice grown in the area is consumed within the region; hence, farmers

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attach greatest importance to rice. Cash income is largely from the sale of upland crops, vegetables, and livestock.

The region receives a mean annual rainfall of about 1200 mm (range 1000 to 1600 mm). The rainy season is from May to October. Except in areas bordering the Mekong river, rainfall is bimodal, with peaks in May and September. Rainfall in June and July is uncertain. Mean temperature is not less than 20°C in any month.

The soils are light textured, poor in fertility, and have a tendency to form crust. Topography is undulating to rolling. Land forms are Uplands, Upper Terraces, and Lowlands. There is subsurface movement of moisture from the Uplands to the other two land forms.

Based on the rainfall and humidity, the region falls into the seasonally dry semihumid category; however, because of light soil and free drainage, the Uplands and Upper Terraces adjoining them are, in reality, semi-arid rather than semihumid.

The Problems

The major problems of the Northeast are low and unstable yields of all crops, particularly rice; the underutilization of land; and low soil fertility.

The low and unstable yields are traceable to the unpredictable rainfall of the region. Moreover, present crop varieties and cultural practices are not ideal for rainfed conditions. This is most noticeable in the case of rainfed rice. The increased production — and therefore increased exports — of agricultural commodities has been due to expansion of cropped area; yields have remained static and, in certain crops, have decreased.

Underutilization of land is most obvious in the Northeast. Out of 8.5 million ha of croppable land, only 5.2 million ha are cropped; that is, 61% compared to 72% for the kingdom. Another aspect of underutilization of land is the low cropping intensity, that is, the present practice of raising a single crop of rice of upland crops. Cropping systems appropriate to the three land forms are vet to be identified.

Soil fertility problems are accentuated by lack of soil and water conservation practices, either on a catchment basis or at the farm level. This, together with the practice of growing crops without the addition of either organic manures or fertilizers, rapidly depletes soil reserves that are already small because of light soil texture. Legumes are obviously absent in the presently practiced cropping patterns.

Development of Research

Until recently, research on rainfed agriculture received little attention in Thailand, as in other developing countries. Funds were small and opportunities so scarce that only a few scientists were willing to work in this difficult area of research. Those few who persisted were insufficient to form teams strong enough to make significant contributions. The result was a discipline-oriented research which is too inadequate to find solutions for the varied and complex problems of rainfed agriculture.

Even today, much-needed multidisciplinary, area-based, and resource-based research aimed at solving field problems is either absent or is not given its due priority in research programs.

In Thailand, the first attempt to focus on rainfed agriculture was through the Pioneer Rainfed Rice Research Project, initiated in 1974, and the Upland Crops Improvement Project, in 1976. Both these projects are financed by loans from the World Bank and are in operation in the Northeast. While they succeeded in generating some useful information, continuing research on a long-term basis is needed.

Review of Research

As a rule, varietal improvement has received more attention than cultural practices (agronomy). Cropping systems research is still in its infancy; on-farm testing was initiated a couple of years ago. Research on soil and water conservation, utilization, and management is yet to be initiated.

Varietal improvement was aimed largely at increasing yields and resistance to pests; breeding varieties suitable for specific local conditions of soil and rainfall remained secondary. Practically no attempt has been made to develop varieties suitable for cropping systems.

Agronomy research was strongly crop-based. The objective was more to establish the yield potential of the elite varieties and their significance than to optimize resource use. The

range of information was insufficient to develop cropping systems. Attempts to superimpose the recommended practices of one crop over another did not result in efficient cropping systems.

On-farm testing was more for the benefit of researchers than farmers. It is still at the stage of understanding the farmers and their practices and appreciating the problems as farmers see them.

Development of Technology

Agricultural technology is appropriate when the farmers can adopt it and, if need be, adapt it. Rainfed agriculture in developing countries is practiced by small farmers on small holdings, with limited resources and inputs. To be appropriate, the technology should require only low energy and low monetary inputs. It follows that experiment station research is rarely directly useful (Fig. 1).

Technology should not only state what should be done but also how it should be done with the limited resources available to the small farmers who constitute the majority. Research of a different kind — call it adaptive research, operational research, verification trials — is needed. The first step is to accept the farmers' systems and introduce simple innovations capable of giving visible increases in yield. It is not enough to list what the farmer has failed to do; one must understand the reasons behind the failures in order to introduce innovations. The most fruitful and low-cost innovations concern variety, date of sowing, stand establishment, and weed control.

It is implicit that researchers, extension personnel, and practicing farmers should work together in developing appropriate technologies. The most difficult thing, it appears, is to find mechanisms to make this possible within the present institutional structures.

Transfer of Technology

There are two stages in the transfer of technology: first, from research to extension and, second, from extension to farmer. This is because in most countries research and extension organizations are separate and independent, and research will never be able to serve directly the large number of farmers. It must be emphasized that at every stage of transfer all three parties are involved, namely, researchers, extension personnel, and farmers. In the first stage, farmers serve as "observers" and in the second stage research provides backstop and

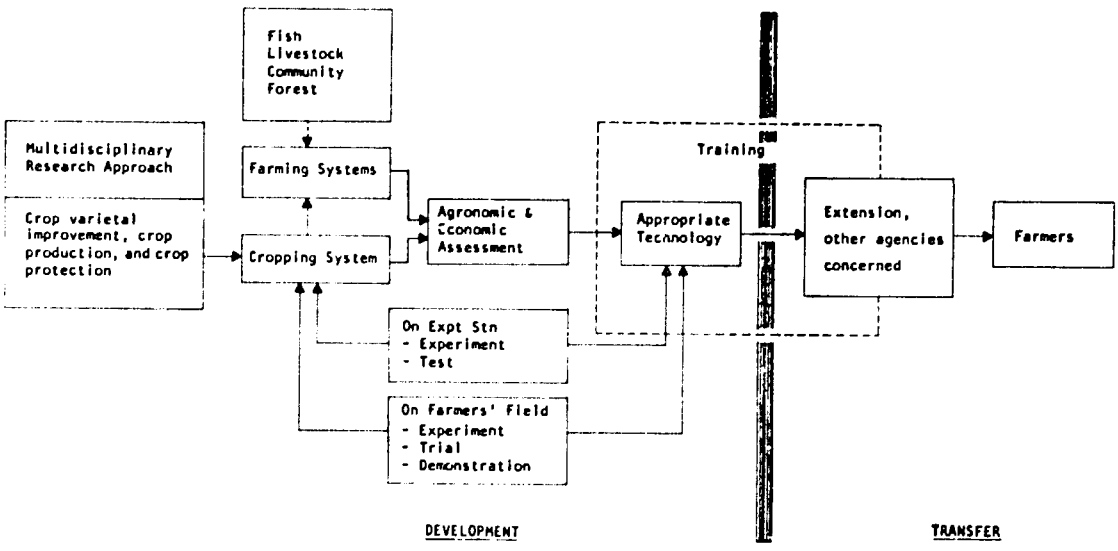

Figure 1. Development and Transfer of Technology Process.

monitors the programs. At both stages, feedback is invaluable (Fig. 2).

Maintaining Continuity

Research generates new knowledge. Some of this knowledge which is useful and utilizable would be incorporated into technology and in time would be transferred to extension and farmers. Hence long-term institutional relations are necessary to maintain continuity. The author would like to see operational research, on-farm testing, and pilot projects as permanent features comparable in effort and investment to those on crop improvement.

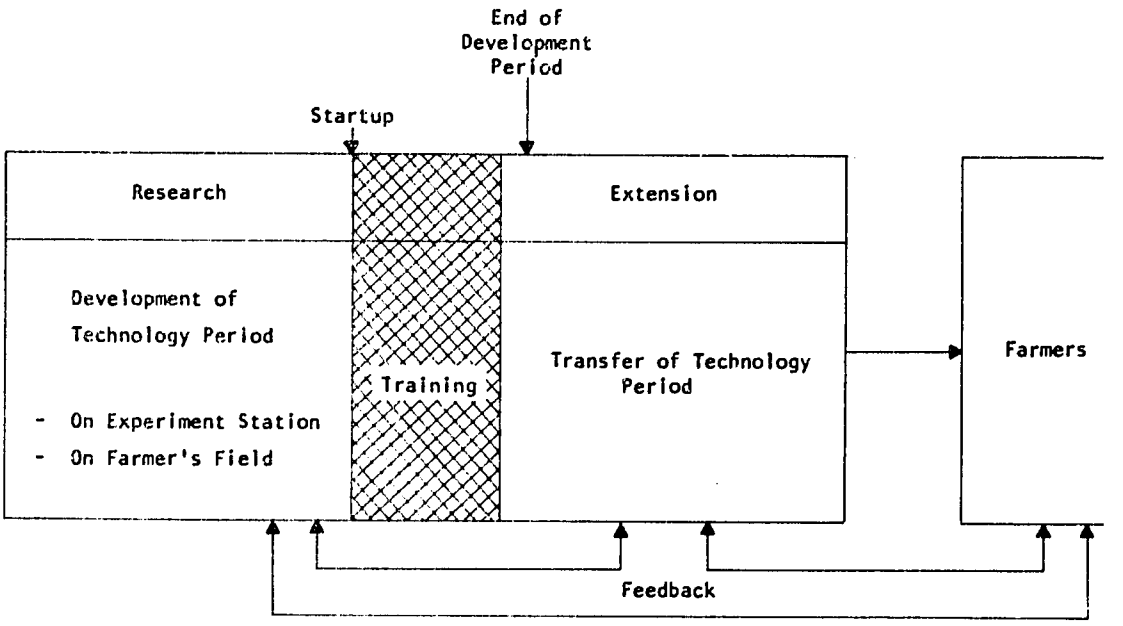

Figure 2. System of Transfer of Technology.

Philippine Experience in Crops in Dry Areas

J. D. Drilon, Jr. and Ed. B. Pantastico*

Abstract

The Philippines, though a typical wet country with an average annual rainfall of 253 cm, has dry areas from November to April. The trend of crop production in the wet, wet-and-dry, and dry areas reflects the influence of environmental parameters, e.g., amount of rainfall, temperature, relative humidity, soil fertility and texture, and market situation. To introduce cropping patterns in these areas with old-established cropping practices, applied research trials were conducted to gain and establish confidence that the new package of technology will be adaptable to actual conditions. The trials stress the selection of the testing site, design and testing of the cropping system in the farmers' fields, and series of data evaluation. The KABSAKA technology – i.e., two rice croppings and one upland crop for the rainfed areas – developed from these activities, has given excellent results and, with appropriate modifications, can be adopted for other areas.

This paper presents some crop production experience in dry areas in the Philippines. It also compares crop production in the *wet*, *wet-and-dry*, and *dry* areas.

The arbitrary grouping of the regions of the country is based on the duration and amount of rainfall received throughout the year. Dry areas have at least 5–6 dry months; wet-and-dry, 2–4 dry months; and wet, two dry months within a year. Dry months are those with 100 mm or less of rainfall and wet months, those with 200 mm or more of rainfall.

In this respect, the environmental parameters, e.g. , amount of rainfall, temperature, relative humidity, soil fertility and texture, and market situation determine to a great extent the trend of crop production in different locations.

Agroclimate and Geography

Climate

The Philippines comprises about 7100 islands and islets, which have an average annual rainfall of 253 cm (Baradas 1978).

The annual precipitation in the three largest island groups, Luzon, Visayas, and Mindanao, is 272, 239, and 235 cm, respectively, distributed in a typical rainfall pattern as shown in Figure 1. The island of Mindanao, though having the lowest annual mean rainfall, has a uniform distribution of rainfall throughout the growing season of the crops. Being the least affected by typhoons, it is an ideal place for crop production (Table 1).

Most of its islands are climatically influenced

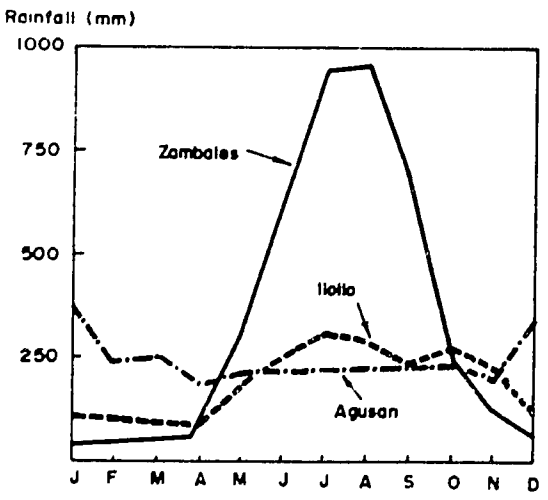

Figure 1. Typical rainfall patterns for three areas of the Philippines — Central Luzon, Visayas, and Mindanao.

* Director General and Director, Crops Research Division, Philippine Council for Agriculture and Resources Research.

Table 1. Grain yield (t/ha) of some rice varieties/selections used in the IRRI-PCARR cropping systems trials for two crops in 1975 (Haws, 1978).

Region	1975 (2 crops) IR1561–228	IR30
Luzon	7.4 c* (10)	5.9 c (10)
Vizayas	7.5 b (5)	7.4 b (5)
Mindanao	9.1 a (3)	8.8 a (3)

* Means followed by a common letter are not significantly different at 5% level. Figures in parentheses ( ) indicate number of locations.

by the southeast monsoon, which divides the year into well defined wet and dry seasons, with the cropping season for the annual crops generally determined by the wet season. Many areas in the country have rain from May to November, the peak being August to September. During the wet periods, typhoons and floods in the lowlands caused by intermittent heavy rainfall are the greatest hazards to crop production. However, during the dry months, particularly December to April, there is rainfall deficiency and some places approach the semi-arid condition.

Most of the agricultural lands suited to rice and other upland crops is rainfed (Table 2 and Fig. 2), cultural operations depending heavily

Table 2. Approximate distribution of rainfed areas in the Philippines (ha x 1000).

Region	Lowland rainfed	Upland rainfed	Total
Ilocos	61.8	4.3	66.1
Cagayan Valley	137.9	29.1	167.0
Central Luzon	318.8	7.0	325.8
Southern Luzon	122.2	131.2	253.4
Bicol	114.9	40.0	154.9
Eastern Visayas	148.0	13.9	161.9
Western Visayas	281.5	22.2	303.7
Northern and Eastern Mindanao	96.2	110.3	206.5
Southern and Western Mindanao	155.1	76.5	231.6
Total	1436.4	434.4	1870.8

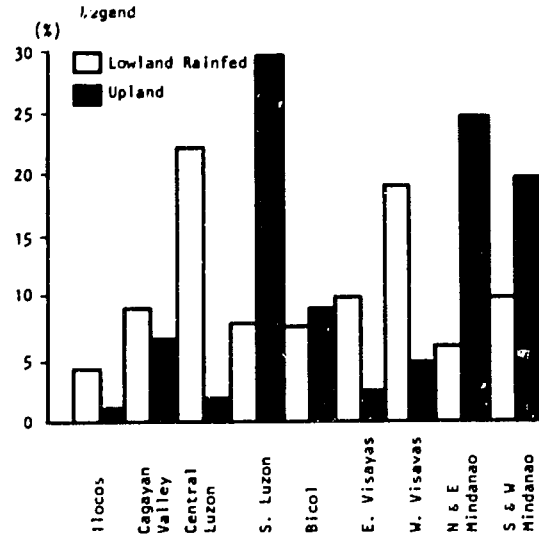

Figure 2. Percent distribution of rainfed areas in the Philippines.

on the stability of rainfall. As a consequence, the intensity of cropping, especially in dry areas like La Union, is mainly limited by the availability of the water throughout the duration of the crop.

The common cropping patterns in La Union, located in the north, are rice-tobacco and rice-vegetables. Tobacco or vegetables such as squash, tomato, eggplant, sweet pepper, beans, garlic, and onions are planted on a limited scale after the rice harvest. Rice is planted in May to July and harvested in October to November. Seedlings of transplanted vegetables/tobacco are raised in seedbeds, while melon, watermelon, ampalaya, squash, and beans are directly seeded in the field.

Situated in the tropics and surrounded by warm seas, the Philippines is generally expected to have high temperature as indicated by its mean annual air temperature of 27°C. The maximum temperature observed at 1 and 3 p.m. of the months of April, May, and June is 31.3°C, and the minimum temperature at 5 and 7 a.m. in December, January, and February is 22.8°C. The high air temperatures are usually observed in the dry areas with mean annual air temperature ranging from 26.8°C–27.6°C.

The high mean annual relative humidity (81%) observed in the country is brought about by the extensive evaporation from the seas surrounding the islands, the rich vegetation, the

moist air stream affecting the Philippines and the large volume of rainfall.

The distribution of the relative humidity follows the pattern of rainfall distribution. During northeast monsoon, high relative humidity is expected over the eastern portion, and low relative humidity is prevalent in the interior areas.

Soils

Soil texture is perhaps the most important soil property that determines the suitable cropping pattern in a vertain environment. The predominant soil types in the dry areas are the moderately fine texture, e.g., silty clay loam, clay loam, and sandy clay loam; medium texture, e.g., loam silt, loam, silt; and coarse texture, e.g., sandy loam and loamy sand.

The water-holding capacities of these different soil textures are presented in Table 3. A medium-textured soil provides better root penetration at the lower layer of the soil than the fine-textured types. However, immediate drying of the surface, more evident in light than in heavy soils, is relevant to the growing of crops during the dry months. Table 4 shows crops found suitable for growing during the dry season, as reflected by their low water requirement throughout the growing season.

Development of Technology on Cropping Systems

In essence, the technology on cropping systems in the country is developed through a series of activities: basic research in experiment station, preproduction phases in farmers' fields, and finally, adoption as regional/national programs.

Table 3. Water retention capacity of the different textures of some soil types in the Philippines.

Soil texture	Centimeter of water per 30 cm of soil
Sandy	2.5
Sandy loam	3.6
Loam	5.1
Clay loam	5.8
Silty loam	6.4
Clay	6.9

Table 4. Water requirements of crops suited for planting during the dry months (International Rice Research Program Review, 1979).

Crop	Crop requirement: During growing (cm)	Crop requirement: Period duration (days)	Yield response to water (kg)
Rice	35–70*	70–190	High
Corn	50–80	85–115	High (1.25)
Mungo	30–50	60–75	Med. High (1.15)
Cowpea	30–50	55–65	Med. High (1.15)
Soybean	45–70	60–75	Med. Low (0.85)
Sorghum	45–65	95–120	Med. Low (0.9)
Peanut	50–70	100–110	Low (0.7)

Values are higher for the Philippines.

The universities/colleges, different bureaus of the Ministry of Agriculture, and the International Rice Research Institute generate viable technology for cropping systems, e.g. varieties, cropping patterns, insect and weed control methods. This information is assembled as a package of technology for testing in the rainfed areas of the country. Testing is done on the farmers' fields to identify the constraints and reduce the risks involved before massive adoption in the region or entire country. This means that the technology should be screened in specific environments whose magnitudes are specified in the planning of research activities.

Collaborative Planning

Interested research entities form working groups that will develop plans of activities for the preproduction phase, composed of applied research and pilot extension. For instance, IRRI and PCARR collaborate with the Bureau of Agricultural Extension (BAEx) for the transfer of the new technology to farmers in different locations.

Applied Research Trials

Selection of the Testing Site

The testing sites are chosen principally on the basis of agroclimate. For example, in 1976, the IRRI-PCARR cooperative applied research pro-

jects on rainfed rice conducted trials on 17 locations of 12 provinces exhibiting different rainfall patterns and soil texture and types. Most areas in the Philippines have rain from May to November, with August–September as the peak months.

Among these 17 locations, 3 are classified as wet, 10 as wet-and-dry, and 4 as dry areas. The wet areas were located in southern Luzon and parts of Visayas; wet-and-dry, distributed in some parts of Luzon, Visayas, and Mindanao; and the dry areas, mostly in northern Luzon which, incidentally, is about the same latitude as Hyderabad, India (21° 25′ N).

The water-holding capacity of the soil is well considered. This soil property would indicate its capability to support rice and other short-duration crops during the dry and wet periods.

Design of the Trials

Two rice croppings of 3 months' duration could easily be grown within the rainy season. An upland crop following the second crop of rice is also a strong possibility, which can be tested in both dry and wet areas.

The design of the experiments ·idered the following factors: (1) land and soils, (2) rainfall distribution, (3) crops usually grown by farmers, (4) marketability of crops, (5) crop adaptability, (6) farm resources (i.e. labor and credit) available in the locality.

Five basic questions served as guidelines in deciding the applicability of the technology to be introduced:

1. Are the patterns highly productive?
2. Are the patterns stable over time and space?
3. Of the sets of patterns for a given environmental complex, which are the most promising?
4. Are the pattern requirements within the limitations of the farmer's resources?
5. Are the various management components at optimum level?

Strategy of Testing

The farmers' fields served as the testing sites. The experimental sites were approximately 1000 sq m so that data could be computed on a per ha basis. The farmer-cooperator was selected based on the following criteria: (1) he must reside and farm on the site, (2) farming must be his principal source of family income, (3) he must have finished at least elementary education or its equivalent training, (4) he must own a work animal and basic farm implements, (5) he should have good standing in the community, and (6) his farm should be accessible.

The cooperators were provided with all necessary inputs and component technology and management. The inputs were made available through supervised credit.[1] The component and management technology were extended by the researchers and the technician at the credit institution. However, the labor portion was left to the farmers' responsibility. Contracts were arranged so that the produce was channeled to the local markets or to the National Grains Authority.

Pilot Extension Phase

When most of the possible constraints in the applied research trials were identified and solved, the size of the testing site (50–100 ha or more) and the number of cooperators increased. When pilot-testing the promising technology, the cooperation of the local government was also solicited to ensure the efficient transfer of technology. Basically, the steps employed in the applied research trials would be followed. However, in the selection of the pilot-testing sites, the following points are also considered:

1) Is there leadership in the area?
2) Is the rainfall stable, as revealed by data collected by the project?
3) Is there organization and cooperation among agricultural agencies or can these be obtained?
4) Are there indications that farmers are cooperating voluntarily in activities?
5) Will the technology greatly change the working habits of the farmers in the area?

In all areas considered, the yield also had to be 8 t/ha or above, for the two crops of rice.

Station Barbara, Iloilo, was selected as the first pilot-testing site of the IRRI-PCARR project

1. Under the Integrated Farming Scheme, the farmer-cooperator could borrow approximately ₱ 2000 – ₱ 3000 (U.S. $270–405) based on two croppings of rice and an upland crop.

on cropping system. It was known as KABSAKA ("Kabusugan sa Kaumahan" or bounty on the farms).

Results and Discussions

The applied research trials of IRRI-PCARR on cropping systems covered the wet, wet-and-dry, and dry areas of the country. The cropping patterns differed with locations. Generally, two rice croppings are quite possible in areas with sufficient supply of water during the growing stages of the rice crop. A third crop of corn, sorghum, soybean, peanut, mungo, cowpea, or sweet potato may follow the second crop of rice in some locations. These crops are generally planted in wet-and-dry, and dry areas where water is very limited during the dry months of the year. Table 5 presents the yields of crops in the three environments. The profitability of the different crop combinations in the various locations is shown in Appendix Table 1.

Wet Areas

Samar (Region VIII), Albay (Region V) and Aklan (Region VI) represent the wet areas of the country. Samar and Albay have similar rainfall patterns of less than 2 dry months and 7 to 9 wet months, and are often visited by typhoons. There are at least 16 to 19 typhoons visiting the country every year.

However, the yield response of the crops in these locations differed. Samar is found most suited to rice, while Albay may grow upland crops from January to April. In fact, sorghum and mungo yielded the highest among the locations tested.

Aklan, which lies outside the typhoon belt area, outyielded Samar.

Wet-and-dry Areas

Iloilo (Region VI), North Cotabato (Region XI) and Quezon (Region IV) representing Visayas, Mindanao, and Luzon, respectively, have 2 to 4 dry months and 5 to 6 wet months. The viable cropping patterns in these places reflect the influence of the climatic and economic factors.

The effect of typhoons on the yield of the first crop of rice was very evident in some of these areas. Mindanao is more favorable for rice growing during the wet season than Visayas or Luzon. Towards the dry months, however, Luzon is most favored because of clear skies. Solar radiation, favorable to photosynthesis, is higher in Luzon than Visayas or Mindanao during this time.

The third crop probably indicates the local market situation. In Visayas, corn is the staple crop and sorghum is a potential substitute for corn as feedgrain. Cotabato is considered the rice bowl of Mindanao. Lucena, being an urban place near Manila, can readily dispose of the produce in local markets or in Manila. Palawan is an isolated island of Luzon and produces primarily for local consumption. Sweet potato can substitute for rice during lean months and legumes are possible cheap sources of protein.

Despite some constraints to production, it was in this type of rainfall that the new technology was found most suitable. For instance, results of the Iloilo Pilot Extension Project on Cropping Systems at Station Barbara, Iloilo (KABSAKA), demonstrated the possibility of growing two rice crops and an upland crop in rainfed areas. Transfer of technology was well facilitated, as indicated by the spontaneous adoption by farmers of the technology. An economic analysis showed that the net income from 148 ha of rice was ₱ 2679 (U.S. $ 344).

Prior to adopting the KABSAKA technology, a farmer grossed only ₱ 6000 ($800) per annum for a 35-cavan harvest (1.75 t/ha) from a single wet-season crop of rice. After joining the Project, he was able to harvest two rice crops amounting to 500 cavans (25 t/ha) valued at ₱ 21 000 ($2800). Immediately after his second crop of rice was harvested, he planted mungo (1 ha), peanut (1 ha) and corn (2 ha). He harvested them in February, all for ₱ 4750 ($633), broken down as follows:

Mungo (5 cavans)	–	₱ 1500 ($200)
Peanut (5 cavans)	–	750 ($100)
Corn (30 cavans)	–	₱ 2500 ($333)

In a span of 10 months, he grossed about ₱ 25 750 ($3433), which is ₱ 19 750 ($2633) higher than his previous income of ₱ 6000 ($800).

KABSAKA as a rainfed cropping technology has caught the attention of farmers and policy makers alike. In fact, at least four external agencies (World Bank, FAO, the Australian Government, and the Japanese Government) have been cooperating with Project KABSAKA in different parts of the country.

Dry Areas

The dry areas are mostly ... d in northern Luzon. The first two crops in these locations are planted to rice. Among the upland crops that serve as cash crops are corn, sorghum, peanut, mungo, cowpea, soybean, and sweet potato. The selection of the third crop is primarily based

Table 5. Yield of first, second and third crops in wet, wet-and-dry, and dry areas in the Philippines (IRRI-PCARR Annual Report, 1976).

Location	Rainfall type*	Crop yield (t/ha) First	Second	Third		Total
Wet areas						
Catarman, Samar	1.2	Rice 2.3	Rice 4.2			6.5
Guinobatan, Albay	1.2	Rice 2.7	Rice 1.2	Corn	2.3	6.2
				Sorghum	6.2	10.1
				Mungo	1.1	5.0
Kalibo, Aklan	1.3	Rice 3.8	Rice 6.0			9.8
Wet-and-dry areas						
Sta. Barbara, Iloilo	2.3	Rice 5.6	Rice 4.6	Corn	3.1	13.3
				Sorghum	3.5	13.7
Kabacan, North Cotabato	2.3	Rice 8.7	Rice 4.4	Rice	5.3	18.4
Lucena, Quezon	2.3	Rice 3.6	Rice 5.1	Corn	2.4	11.1
				Sorghum	4.4	13.1
				Mungo	0.7	9.4
				Soybean	2.0	10.7
				Cowpea	1.2	9.9
				Sweet Potato	5.1	13.8
Puerto Princesa, Palawan	2.5	Rice 2.8	Rice 3.6	Soybean	1.4	7.8
				Peanut	0.5	6.9
				Cowpea	3.0	9.4
				Sweet Potato	7.0	13.4
Dry areas						
San Fernando La Union	3.3	Rice 3.3	Rice 4.9	Sorghum	3.3	11.5
				Corn	1.8	10.0
Echague, Isabela	3.3	Rice 2.4	Rice 1.7	Soybean	0.7	4.8
				Cowpea	0.3	4.4
				Sweet Potato	2.4	10.6
Dry areas						
Sta. Maria, Bulacan	3.3	Rice 2.9	Rice 2.4	Corn	1.5	6.8
				Sorghum	1.8	7.1
				Soybean	1.0	6.3
				Peanut	1.9	7.2
				Sweet Potato	3.6	8.9
Sta. Maria, Pangasinan	3.4	Rice 1.5	Rice 3.7	Corn	4.7	9.9
				Sorghum	6.7	11.9
				Mungo	0.6	5.8

* 1.2 – <2 DM (dry months) and 7–9 WM (wet months)
1.3 – <2 DM and 3–4 WM
2.3 – 2–4 DM and 5–6 WM
2.5 – 2–4 DM and <3 WM
3.3 – 5–6 DM and 5–6 WM
3.4 – 5–6 DM and 3–4 WM

on the versatility of the crop. A market is readily available because these areas have greater access to Manila than Visayas or Mindanao.

Corn can be planted through November for dry grain. Cowpea is the most versatile and can be planted any time during the growing season. Sorghum can thrive even in drought conditions. Mungo can be grown only at the end of the rain. It cannot be harvested wet because of its low seed dormancy. Peanut can tolerate heavy rain early in the season but must have less than 100 mm/month at harvest time to prevent rotting. Sweet potato will tolerate heavy rain for the first 60 days but will rot if harvested early during the wet periods. Soybean is planted late October to early November because it is photoperiod-sensitive.

Comparative yields of the first, second, and third crops in wet, wet-and-dry, and dry areas in the country are presented in Figure 3. Rice as first and second crop and corn as third crop grow favorably in wet-and-dry areas. The dry areas could not support as well as the other environments did rice or an upland crop of either corn, sorghum, or mungo.

However, crop production in the dry areas seems to have bright prospects, too. The applied research trials verify the possibility of growing two crops of rice and an upland crop under light soils (Fig. 4).

Potential Crops

Based on a series of applied research trials, the

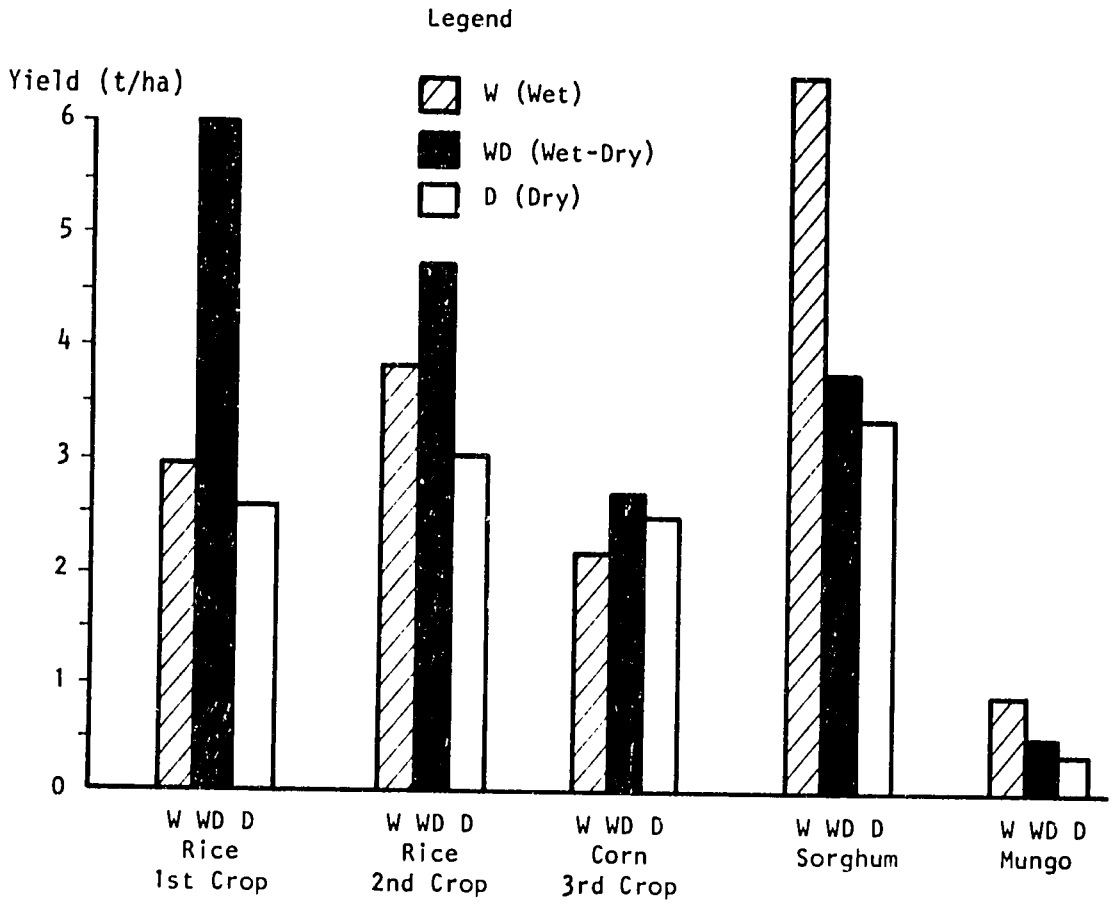

Figure 3. Comparative yield of first, second, and third crops in wet, wet-and-dry, and dry areas in the Philippines.

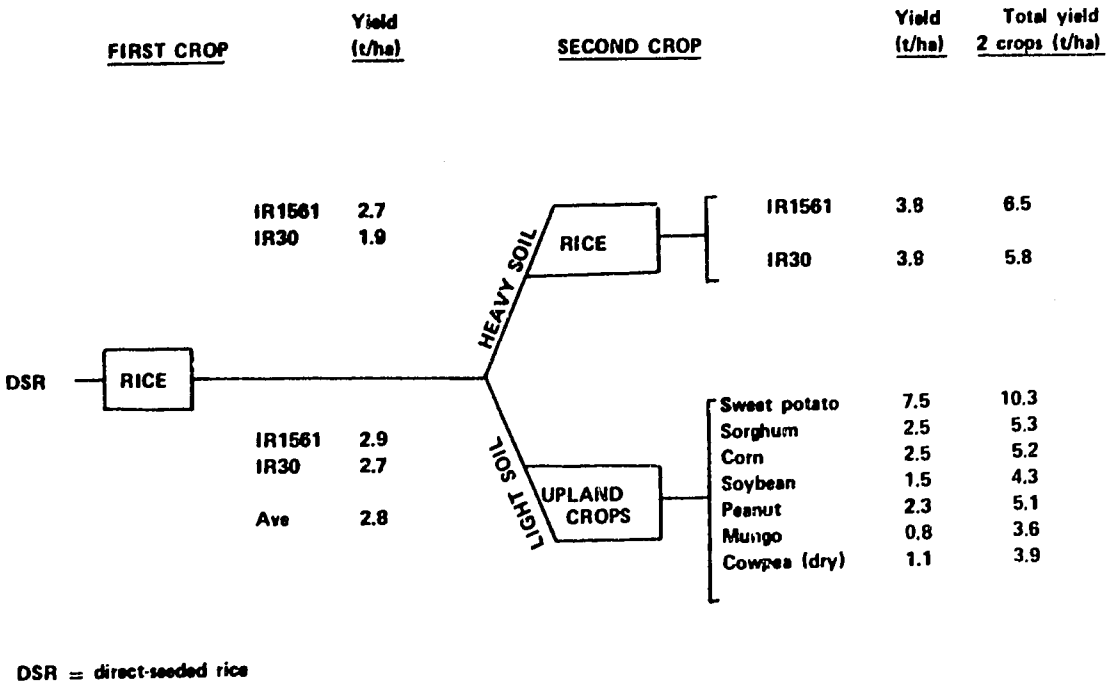

Figure 4. Production potential for growing two crops of rice in heavy soils or one crop of rice and one of seven crops on light soils under rainfed conditions in areas with five dry months.

potential upland crops that can be grown after the first crop of rice are sweet potato, sorghum, corn, peanut, soybean, cowpea, and mungo in the dry areas (Fig. 5).

The first crop of rice is planted at the onset of rainfall in May or early June. The rice harvest can either be domestically consumed or sold. If rice is intended as a cash crop, sweet potato with its high caloric value and vitamin A content can supplement rice as the main source of daily energy food. The rest of the sweet potato is channeled to makers of native delicacies, direct consumers and to swine raisers. Cowpea and mungo, considered as poor man's food, can substitute for expensive sources of protein. Cowpea can be used in the making of pork and beans, soysauce, and, possibly, texturized vegetable meat. Mungo commands high prices in the local market. Consumers have a high preference for mungo. It has potential industrial uses such as flour, textured vegetable protein, noodles, etc. Peanut, another popular seed legume, is in demand for snacks; edible oil, butter, confectionery, as a base for cosmetics, etc. Peanut shells could serve as fuel, too. Corn and sorghum are potential feedgrains, though corn finds many uses in the household. Corn is used in flour making, edible oil, explosives, paints, etc. Sorghum is popularized in the domestic household as a snack. It can be a source of flour, tannin, varnish, etc. Soybean, being rich in protein, is used mainly in the feeding of swine, poultry, and livestock. It is made into fermented food products such as soysauce, tofu, and textured vegetable products.

For heavy soils, which have a high capacity to store water, the rice-rice-upland crops combination is applicable. However, soybean, mungo, sorghum, peanut, and corn grow with difficulty in soils with high concentrations of clay. The yields of rice crops generally improve in the second cropping season, due, perhaps, to high solar radiation towards the Philippine summer months.

Light-textured soils having low water-holding capacity could not successfully support two rice crops, which are shallow rooted and need ample supply of soil moisture. Drought-tolerant upland crops with deep penetrating roots are

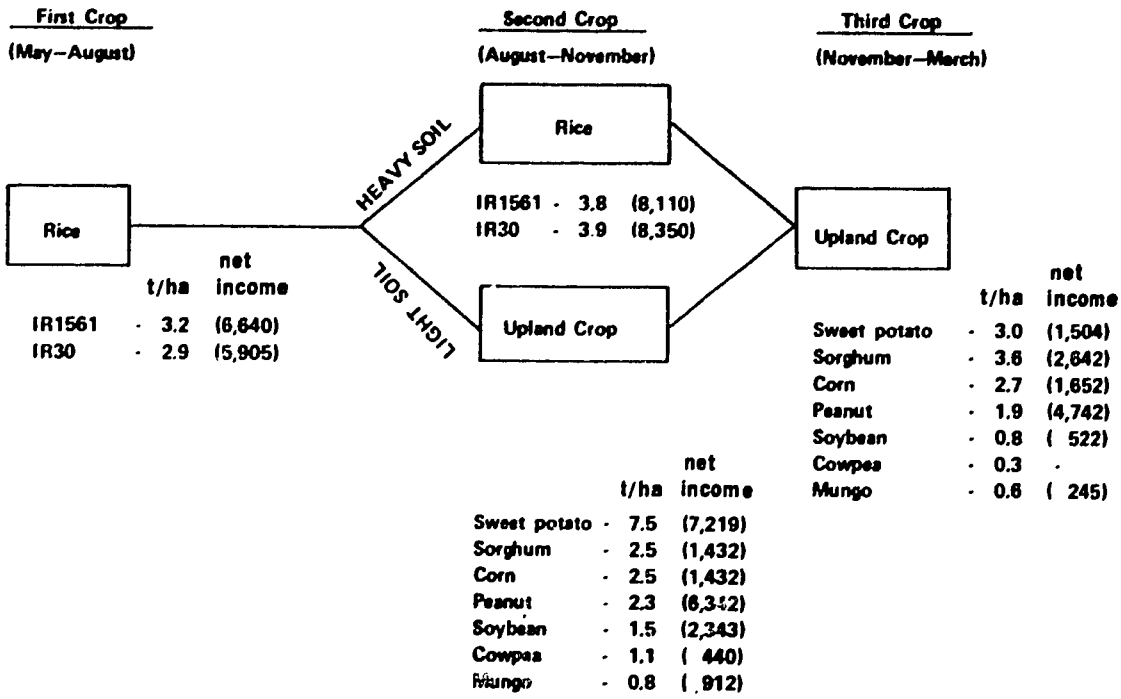

Figure 5. Alternative cropping patterns for dry areas.

best suited to follow after the rice harvest. Growing of the third crop would be limited to those capable of yielding satisfactorily under extreme water stress, like sorghum.

However, the local demands and possibly foreign markets primarily determine the choice of cropping patterns in the respective areas. For instance on the basis of the present price of the crop commodities listed in Figure 5, the most profitable combination in heavy soils was rice (IR1561), rice (IR30) and peanut, giving a total income for the year of ₱ 19732 ($ 2631)/ha. In light soils, the best crop combination was rice (IR1561), sweet potato, and peanut, yielding an income of ₱ 18601 ($ 2480) but for the same soil texture, rice (IR1561), peanut, and peanut with a total of ₱ 17724 ($ 2363) was not far behind.

Looking Ahead

In the country today, there are several ongoing national agricultural programs that aim to create sufficiency levels in food and feedcrops to improve the quality of life of small farmers and safeguard them from inflation due to the ever-increasing price of oil. Among them are Masagana 99 (M-99) for irrigated rice, Masagana Maisan (M-M) for corn, sorghum, and soybean, Gulayan sa Kalusugan (GK) for mungo, peanut, and vegetables, and National Mutiple Cropping Program for cropping intensification of the rainfed areas.

M-99, launched in 1973, extended financial and technical assistance to small rice farmers to boost rice production and attain a self-sufficiency level. Prior to this program, rice insufficiency was keenly felt during the lean months (August–September) because rice was planted only during the wet seasons. Today, the members of this program enjoy a prosperous life and can send their children to college.

Two years after the bumper harvests of rice were realized, the M-M program was pushed through to increase the production of feedgrains such as corn, sorghum, and soybean to reduce import costs and help local feedmillers, livestock, swine, and poultry growers, and, ultimately, the small farmers.

To improve the nutrition of these ordinary farmers, extensive vegetable production in the backyard and in commercial areas was encouraged through the GK and Green Revolution Program in 1976.

In the same year, the government launched a national multiple-cropping program specifically directed to the small farmers. Some researches have been conducted and are now being piloted in some project areas. One such example is KABSAKA, a technology developed and found most suitable for the wet-and-dry areas in the country. With modification of the technology and solution of the possible constraints to its adoption, there is a strong possibility of developing suitable cropping systems for the rainfed areas. In fact, some recommended multiple-cropping patterns after rice in dry areas with different rainfall patterns and soil texture are formulated (Appendix Table 2) to help the farmers especially in the dry areas to select suitable and profitable crop combinations.

With breakthroughs in research on cropping systems and the genuine interest of the government to improve the standards of living and morale of the marginal farmers, crop production in the dry areas has bright prospects.

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Appendix Table 1. Economic analysis of the different cropping patterns in wet, wet-and-dry and dry areas of the Philippines.

Location	Cropping pattern 1st	2nd	3rd	Total gross Income (₱)	($)	Total cost of production (₱)	($)	Net income (₱)	($)
Wet areas									
Catarman, Samar	Rice	Rice		15 925	2123	2400	320	13 525	1803
Guinobatan, Albay	Rice	Rice	Corn	9 145	1219	3718	496	5 427	724
			Sorghum	6 820	909	1318	176	5 502	734
			Mungo	3 674	490	1759	235	1 915	255
Kalibo, Aklan	Rice	Rice		24 010	3201	1200	160	22 810	3041
Wet-and-dry areas									
Sta. Barbara, Iloilo	Rice	Rice	Corn	28 422	3790	3718	496	24 704	3294
			Sorghum	3 850	513	1318	176	2 532	338
Kabacan, N. Cotabato	Rice	Rice	Rice	45 080	6011	3600	480	41 480	5531
Lucena, Quezon	Rice	Rice	Corn	23 955	3194	3718	496	20 237	2698
			Sorghum	4 818	642	1318	176	3 500	467
			Mungo	2 472	330	1760	235	712	95
			Soybean	5 572	743	1857	248	3 715	495
			Cowpea	2 400	320	1760	235	640	85
			Sweet Potato	6 477	864	2306	307	4 171	556
Puerto Princesa, Palawan	Rice	Rice	Soybean	19 600	2613	4257	568	15 343	2046
			Peanut	1 960	261	2858	381	898	120
			Cowpea	6 000	800	1760	235	4 240	565
			Sweet Potato	8 890	1185	2306	307	6 584	878
Dry areas									
San Fernando, La Union	Rice	Rice	Sorghum	23 720	3163	3718	496	20 002	2667
			Corn	1 980	264	1318	176	662	88
Echaque, Isabela	Rice	Rice	Soybean	11 921	1589	4257	568	7 654	1020
			Cowpea	680	91	1760	235	1 080	144
			Sweet Potato	3 048	406	2306	307	1 012	135
Sta.Maria, Bulacan	Rice	Rice	Corn	14 635	1951	3718	496	10 917	1456
			Sorghum	1 980	264	1318	176	662	88
			Soybean	2 688	358	1857	248	831	111
			Peanut	7 560	1008	2858	381	4 702	627
			Sweet Potato	4 572	610	2306	307	2 266	302
Sta.Maria, Pangasinan	Rice	Rice	Corn	17 910	2388	3718	496	14 192	1892
			Sorghum	7 370	983	1318	176	6 052	607
			Mungo	1 937	218	1760	235	177	24

* Yield data are presented in Table 5 of the text.

Appendix Table 2. Recommended multiple cropping patterns after rice for areas with different rainfall patterns and soil textures.

Locations	Rainfall pattern*	Soil texture**	Recommended crops***
Dry areas (5–6 or more dry months)	Low, Increasing	SL-SiL	Corn, mungo, peanut, sweet potato, cowpea, soybean
		SiL-CL	Mungo, cowpea, corn, peanut
		CL-C	Mungo, cowpea
		C	Cowpea
	Low, Decreasing	SL-SiL	Mungo, cowpea, sorghum, peanut, sweet potato
		SiL-CL	Sorghum, mungo, cowpea, sweet potato, corn, peanut
		CL-C	Mungo, cowpea, sweet potato
		C	Cowpea
Wet-and-dry areas (2–4 dry months)	Medium, Increasing	SL-SiL	Corn, soybean, cowpea
		SiL-CL	Cowpea, corn, soybean, intensive vegetables
		CL-C	Soybean, rice (direct seeded), cowpea, intensive vegetables
		C	Rice (transplanted), cowpea, intensive vegetables
		CL-C	Soybean, rice (direct seeded), cowpea, intensive vegetables
		C	Rice (direct seeded), cowpea, intensive vegetables
Wet-and-dry areas (2–4 dry months)	Medium, Decreasing	SL-SiL	Corn, cowpea, soybean, sweet potato, peanut, sorghum, mungo
		SiL-CL	Sorghum, soybean, mungo, cowpea, sweet potato
		CL-C	Rice (transplanted), cowpea, mungo, soybean
		C	Cowpea
Wet areas (less than 2 dry months)	Medium, Level	SL-SiL	Rice, cowpea (green), corn (green)
		SiL-CL	Rice, cowpea (green), corn (green), intensive vegetables, viny crops
		CL-C	Rice, cowpea (green), corn (green), intensive vegetables, viny crops
		C	Rice, cowpea, intensive vegetables, viny crops

Continued

Appendix Table 2. *continued...*

Locations	Rainfall pattern*	Soil texture**	Recommended crops***
	High, Increasing	SL-SiL	Rice, cowpea (green), corn (green)
		SiL-CL	Rice, cowpea (green), corn (green), intensive vegetables, viny crops
		CL-C	Rice, cowpea (green), corn (green), intensive vegetables, viny crops
		C	Rice, cowpea, intensive vegetables, viny crops
Wet areas	Medium, Decreasing	SL-SiL	Corn, cowpea, soybean, sweet potato, peanut, sorghum, mungo
		SiL-CL	Sorghum, soybean, mungo cowpea, sweet potato
		CL-C	Rice (transplanted), cowpea, mungo, soybean
		C	Cowpea

* Dry months have 100 or less mm of rainfall per month and wet months, 200 or more mm of rainfall per month. Low – 0–100 mm; Medium – 100–200 and High – 200 or more. Amount of rainfall increases or decreases as reckoned from planting to harvesting of the crops.

** SL – sandy loam, SiL – silt loam, CL – clay loam, C – clay. This is related to the water retention capacity of these soil types.

*** Soybean, mungo, sorghum and peanut grow with difficulty in soils with high clay concentration.

Summary of Discussion – Session 6

Chairman Sauger commented that the papers from this session fell into two groups — extension and research — with an important distinction between them. The first group expressed dissatisfaction at the existing state of affairs; the second group was fully or almost fully satisfied. Co-chairman Doggett summed up the afternoon's papers. He expressed concern that the papers contained few estimates of technology actually transferred. In more than 30 years' experience in the tropics, he said, he had not seen farmers near research stations take any interest in the activities of the station. How rapidly was technology being transferred? Did we have effective techniques for transferring technology?

He said the paper by Drs. Randhawa and Venkateswarlu gave an encouraging view of the impact made by the Indo-British and Indo-Canadian projects, with technology now beginning to be adopted in the project areas. The Nigerian paper gave the impression of slow adoption, citing the farmers' poverty as a major reason for the slowness. This is indeed cause for concern, Dr. Doggett said. He wondered if the technology being developed is within the farmers' reach. For example, he said, an experiment station recommendation for fertilizer in a cassava project was 100-100-100, whereas a 10-10-18 coconut fertilizer was the maximum actually, and effectively, used for 8 years.

The approach in Brazil appears very good and it sounds as though all aspects have been considered. There is plenty of financial input, too, and — perhaps a key factor — farmers' profits are increasing.

In Senegal, Dr. Doggett said, where there has been a series of efforts to find the best way of getting technology across to the farmer, Dr. Sene's paper implied that not a great deal of progress had in fact been made. This is a serious situation. At the IARCs, we are looking at some fairly advanced technology, and the big question in this: if we can't get even the simple stuff across to the farmer, what is the time scale for the more complex agricultural procedures?

It would be very helpful, Dr. Doggett said, to have some information on how much and how successful the technology transferred is proving to be. High-yielding varieties seem to be well accepted. But are they adopted alone or with a package of practices? Is this package substantially different from the one originally recommended?

The cropping systems approach in Thailand seems very relevant. This is a vital area. In the Philippines, the cropping system developed at IRRI, tested and modified on the farm with the farmer actually doing the trials, does seem to be well accepted.

Is the technology we are recommending really worth the farmer's while? The work of the international centers is worth nothing, Dr. Doggett concluded if we cannot get the technology over to the farmer.

Dr. Laxman Singh observed that techniques for transferring technology in rainfed areas must be radically different from those followed in the "green revolution" irrigated areas. The technique used successfully in irrigated areas has not resulted in adoption of new technology to support the technology in rainfed areas, even on adjoining fields after 10 years, he said. We have not created the infrastructure to support the technology we introduce. One solution is to organize the farmers to create and maintain an infrastructure to sustain the new technology. The farmer should be helped to process his crop so that he realizes greater benefits.

Dr. Govindaswamy described techniques used: to test findings in the farmers' fields for economic viability. On an experimental basis researchers were able to help farmers make spectacular gains — from 40 quintals (400 kg) to 4 tonnes. They also got feedback from the farmers so that research findings could be evaluated.

Dr. Sy from Mali said that Dr. Sene's description of Senegalese research as functioning in ivory towers was not accurate, that the fault was not with the research but with the organizational structure. It is not as if researchers invent their own problems and then try to find solutions for them — it is that the farmers don't constitute a strong enough pressure group and do not have adequate means of conveying their

problems to researchers. Extension workers are not able to take results from the lab to the small farmers. Perhaps, Dr. Sy said, there could be training programs to enable extension workers to draw on the published results of research work, digest them, and pass them on to the farmer.

Dr. Gill cited as a good example from Ghana the transfer of technology using only simple innovations — local improved variety of corn and locally available fertilizer and insecticide.

Dr. Avadhani observed that in studies he had been involved in, the 25- to 40-year old group of farmers and those who had a high school or higher education were more receptive to innovations than others.

Session 7

Linkages

Moderator: A. B. Joshi

Panel members: W. K. Agble
A. B. Joshi
N. O. Kane
B. A. Krantz
Michael Lipton
B. N. Webster

Rapporteurs: D. L. Oswalt
A. S. Murthy

Linkages for Transfer of Technology

B. N. Webster*

Abstract

The paper examines the more traditional concepts of technology transfer in agricultural development and points up the multidimensional nature of the linkages required to sustain a dynamic applied knowledge system. Considerable emphasis is given to the internal transfer of technologies and the greater relevance of those indigenously generated. The importance of the human element at all levels is stressed, and thus the cardinal role to be played by proper linkages with education and training institutions in the preparation of cadres of properly trained "human links" in the transfer chain.

Many papers on this subject during this last 10 years or so have stressed what I have always believed in. That is the importance of recognizing the farmer's field as the end goal of research and thus of the need for ensuring the strength of all the links in the technology transfer chain leading thereto. In examining these linkages we must also assume the existence of the structures to be linked — an institution, a service, and ultimately individuals, each of which is necessary to ensure a smooth flow of knowledge and its appropriate application.

We have heard during the last week from many speakers about individual examples and specific methods of technology transfer and about ICRISAT's own approach to its problems and concepts. I shall attempt to point out some specific problem areas in the process of transfer of agricultural technology that are generally considered to constitute "weak links," and to offer some solutions — not necessarily original ones — aimed at the shoring up of these weak spots.

The Network of Transfer

Traditional approaches to technology transfer tended to regard it strictly as a vertical process: from the developed to the less developed, from the international to the regional and to the national level, and thence through various stages (always regarded as downwards!) to the rural producer or entrepreneur. Also, such technology was usually of developed country origin and much of its transfer was prompted by the call of the first United Nations Conference on Science and Technology in 1963 for the rapid transfer of a vast bulk of "technology" from the more developed countries, in the erroneous belief that this would provide a panacea for the social ills of hunger, malnutrition, and poverty in the less developed countries.

A more enlightened view now prevails. The second UNCSTD meeting this last week has heard from many sources — including the UN itself, the Pugwash Council, and COSTED — of the importance of Technical Cooperation between Developing Countries (TCDC) as well as with the more advanced countries (TCAC). The importance of regional dissemination and sharing, and the ensuring of proper internal distribution of knowledge within each country (lateral transfer) have also been stressed at the conference. Thus, some regard the various components in the technology transfer process as having a two-dimensional relationship in the form of a network. However, as many of these components have relationships both with each other and with other correlated entities, a multidimensional network or matrix may better be envisaged. If, indeed, we were to regard the spatial distribution of components in a similar way to that of a complex chemical molecule, then the linkages that we are discussing — to continue the metaphor — could be regarded as the bonds. Inasmuch as a bond does not exist independently, so the linkages in our system should normally be an integral part of, or at

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least provided by, one or another of the components to be linked. On occasion, however, it is necessary to look to a third party to provide the desired contacts, and when so necessary, the third party could best be regarded in the form of a catalyst.

Components of the Network and Suggested Linkages

Major sources of agricultural technology external to the less developed countries are the transnational corporations, the international agricultural research centers, and international and bilateral aid agencies (which in turn have access to, and draw their knowledge from, research stations, universities, industries, learned societies, etc., in the developed countries and the more advanced less developed countries). A growing source is now from other developing countries with similar problems and resources.

Whatever the source of funding — transnational, international, foundations, or bilateral — one must distinguish the donor and the recipient components if the concept of technology transfer is to stand up. I shall retain the term and will examine some of the necessary linkages in the development of an agricultural knowledge system.

Each component has a diversity of linkages (indeed flexibility of linkages should be a key feature for consideration) and it would be invidious to single out any particular type of linkage for commendation. On the other hand, however, strong criticisms have been rightly leveled at the "lock, stock, and barrel" type of technology transfer (i.e., provision of capital, full financing, facilities, equipment, personnel, and recurrent expenditures, to make an "instant industry"), which is more typical of transnational corporations and major industrial exercises than of agriculture. The grounds for such criticism are, of course, that it gives little attention to the desirable creation of local conditions permitting technology absorption and generation.

More common in agriculture, however, is the provision of part of these services, with strong local counterpart contribution and considerable — and highly desirable — provision for the training of national staff through fellowships. All too often, however, those fellowships are linked strongly to the donor-country educational establishment and are not sufficiently often linked to the circumstances, ecological and social, in which the fellowship holder is going to have to work. This is but one example of a number of less appropriate linkages that have developed in aid activities. Some of the foundations, international agencies and centers, however, have long recognized the value of linking training to tasks to be performed, and have ensured the appropriateness of much of their training. That given at and by the IARCs is an instance, with the FAO/UNDP/CIMMYT Near East Wheat and Barley Training Project and the FAO/IITA Crop Production Technology Workshop providing good examples.

Each transfer system has a varying number of essential components, usually starting with the political will on the part of the government to acquire or to develop technologies for a specific purpose, running through negotiations with possible donors, program/project planning with or without donor/technical aid agency assistance; through technical/economic feasibility studies, government and local level approval, to final operations. This may again be conducted by the donor's own staff, by a contractor on behalf of the donor or the recipient country, or by the national institution utilizing its own staff. At all of these stages, specific linkages and bonds have to be forged or strengthened, and I propose we now examine a few of those necessary contacts and see how they may be improved.

First, initial contacts are normally made through diplomatic or international channels for which well-established, albeit often impersonal, linkages points exist. Following this, however, the subsequent development of a transfer process tends to be handled more and more at the personal level. Thus, the total process of technology transfer becomes more and more a person-to-person affair as we reach nearer and nearer to the "practitioner level."

The second level of involvement, especially in considering an "imported" technology, is likely to be between the senior planning and technical officials of a ministry or technical department on the one hand, and of the aid agency, company, or university, etc., on the other hand. The importance of sympathetic and understanding

ties at this level cannot be overestimated. Many otherwise excellent technical assistance/technology transfer schemes have foundered at this level, through inability on one side or the other (through language difficulties, lack of technical competence, etc.,) to fully achieve understanding. The selection of personnel at this level therefore begins to be important.

The next stage is active transfer. Diverse linkages need to be established at the several levels of implementation before a commodity, process, or technique reaches the farmer or small rural industrialist. Perhaps the most important are the linkages with the educational/training system of the country. Without the appropriate personnel available in sufficient quantity, the absorptive/generative capacity of any country for new technology is likely to remain low.

It is at this level of internal dissemination and implementation that the human resource gap is greatest, as, no matter how many personnel are trained, the brain drain overseas, losses to other public services, and to the private commercial sector, invariably decimate the trained "human links" in the transfer chain. The working contacts between agricultural and educational institutions, particularly where agricultural education is dependent on a Ministry of Education rather than a Ministry of Agriculture, leave much to be desired. Thus, stronger links through manpower planning boards, labor commissions, and agricultural research councils able to relate manpower supply to demand, are badly needed. We have already heard comments on the desirability of a rural, rather than an urban, background for workers in agriculture and would like to expand this recommendation to ensure inclusion of at least 1 year's farm level practice, or similar previous experience, as an indispensable requisite for all degree courses in agriculture. This used to be a sine qua non in most agricultural courses in the more developed countries; its reintroduction would do no harm. But it should be borne in mind that the practical work needs to be in an environment appropriate for the trainee.

I would like to reiterate what I have hinted at earlier, that the selection of personnel for training as the human links in the chain is just as important as the technology to be transferred. First, there must be a sense of *vocation*, at least as strong as that of the "vocational farmer," bearing in mind that "agriculture for millions of poor and the landless people the world over cannot be regarded as a vocation but rather as an inescapable way of life. Second, a fair degree of missionary fervor helps, provided it is rationalized into appropriate channels; third, understanding of, sensitivity to, and respect for, other peoples' ways of life are essential.

Our educational programs and curricula of today do not, I think, take sufficient account of these needs. Over the last 10 years, we have tended to create too wide a gap between the students training for research, and those for "other branches," including extension. Consequently, some of our research workers know little (and sometimes care less) of extension methods, and many of our extension methods, and many of our extension workers are not even taught how to lay out and run a simple field trial, let alone analyze its results! Thus, one of the most important linkages, that of research/extension, is in danger of being strained from the outset.

Linkages between technical and rural sociology and socioeconomic research institutions have also been generally weak in the past and this must have contributed to the widespread transfer of much inappropriate technology due to lack of understanding of the farmers' real needs and the circumstances that motivate a farmer to adopt a proffered new and improved technology. All too often, for example, the basic motivation of a functional marketing system serving a recognized demand has been lacking.

This lack has been fully recognized by the IARCs, and now the system as a whole has considerably strengthened its socioeconomic research, as an integral part of the Center's farming systems program. None has made better progress than the Village Level Studies program of ICRISAT, and we have heard what was to us a most exciting account of work at what I consider the most important level at which genuine constraints impede the process of transfer of both adapted and endogenously developed technologies.

Responsibility for ensuring appropriate linkages at the various levels differs from country to country and from system to system. In many, the linkages depend upon formal instruments of protocol, memoranda of agreement, etc., which usually serve to limit and define responsibilities of the contracting par-

ties. In aid agreements, these are probably essential. More informal associations, however, are often as fruitful and the Royal Society of London has stated, in material prepared for UNCSTD, that:

> "dissemination of scientific and technological knowledge depends heavily on personal acquaintance and correspondence between experts working in each particular specialist subject. Therefore, it is important that the . . . technologists in the developing countries are brought fully into the information networks of the developed world."

It further stresses the need, within developing countries, to establish the closest possible ties with professional societies elsewhere, between themselves, and between scientists, technologists, and educators in agriculture and in industry.

Arising from the strong bias towards the individual follows a recommendation for building up centers of excellence (i.e., internal linkage centers) around brilliant individuals and teams who have acquired an international reputation. This technique was used to great advantage in the UK in the buildup of the special research units of the Agricultural Research Council and has already been emulated elsewhere. Responsibility for this must be jointly government-professional societies.

Information and Communications

Internal communications and information exchange between the various components of a technology transfer system, the government policy makers, the scientific community, the academic and training institutions, the farmer cooperatives, credit and other institutions can only be properly maintained if appropriate institutional mechanisms such as agricultural research councils and technical committees are set up at all the necessary levels to ensure that all key personnel are kept adequately in the picture. An optimal arrangement at the field operational level is suggested later.

More formal international information networks are legion. The CARIS, AGRIS, and AGLINET projects of FAO are just three that serve the global needs of agricultural scientists, and numerous national abstracting and computer services have been established to increase the rate of dissemination of knowledge. Modern postal communications being what they are, and abstracting, printing, and posting taking even longer, it is encouraging that commodity information programs are proving of real value, and are certainly hastening that two-way interchange of knowledge between scientists with like interests that has received so much support. The newsletters supported by IDRC and the Centers are already proving to be most valuable linkages in the transfer process.

The role of FAO and other international agencies (CARIS, AGRIS, AGLINET, etc.) as essential sources of information on agricultural policies, the world food situation and its trends, and as disseminators of such information and technologies derived therefrom in its field programs, is likely to continue being strengthened. FAO's training activities have already been stepped up considerably, and mention will be made later of an interesting development in Asia that is taking a new look at the old process of "extension," which is essentially the final step in technology transfer. Cooperation is being stepped up between FAO and the IARCs in their complementary activities concerned with training research workers, and linkages here could be further strengthened. First, however, we should await the outcome of the current review of the Centers' cooperative activities, which may resolve some of the present problems regarding total off-campus responsibilities of the Centers.

At the same time, it may be worth considering whether we are yet training in the right way for optimum technology transfer and a further suggestion is made at the end of the paper.

Linkages Between Basic and Applied Research

Some of the international centers are increasing their own basic research on the grounds that closer interaction with their own applied programs can thus be assured. Furthermore, a fair amount of the more basic research needed is locale-specific. This approach, if extended to other international centers, as some believe it should be, would extend the role of the IARCs in basic research and, presumably, reduce their capacity (assuming no real growth) for applied research/technology generation and transfer. This also is surely commendable, provided again that, through regional advisers/monitors,

the Centers maintain close links with all the various developments of their materials (technologies) in order to provide feedback as appropriate to their core programs. As national capacities increase and national scientists take over more of the work, this should prove feasible.

Conclusions

Extension

One of the most promising solutions, if I may be cautiously optimistic, to the problem of the final linkages with the "voiceless majority," may be seen in the "field workshop technique" that has been used during the past 3 or 4 years in several Asian countries under the guidance of Cameron Clark of FAO's Regional Office for Asia in Bangkok. He recognizes one of the greatest challenges to communication as the "promotion of constructive dialog between national planners and administrators and representative farmers from diverse socioeconomic levels, on a scale large enough to produce a 'critical mass' able to influence public opinion and thus bring about institutional change." Clark's approach is based therefore on a multidisciplinary appraisal of the problem situation, with problem identification and solution involving representatives from all departments and levels of the bureaucracy concerned with area planning, from senior administrators to small-holder farmers, sharecroppers, and landless laborers. Each workshop lasts for 5 days and, if successful, results in an "integrated plan of action to which both farmers and government are fully committed."

This type of extension should help to avoid the many failures of the past in trying to transfer a sophisticated communication system that attempts to pass an inappropriate message to a community unwilling to accept it or simply incapable — through lack of basic resources — of accepting it. This then, I believe, may help to take whatever technology may be available for transfer to the people who really need it. I would therefore commend it for discussion to our panel, in the conviction that linkages for transfer of technology cannot be separated from linkages for the implementation of programs; one is simply the end point of the process and surely the most important and ultimate point.

Education

A few years ago I gave the opinion that we needed to develop a new type of agricultural graduate in tropical agriculture; or rather to resurrect an older breed–able to conduct and analyze straightforward field experiments, not aloof but able to mix with, talk with, and understand the small farmer. This needs practical experience in agriculture, a farm rather than an urban background, and proper training in sociological and communication skills.

So, if the panel that is to follow this address has a degree of agreement with me on the supreme importance of the human linkages in developing an applied knowledge system, it may also care to devote some time to the consideration of how best to select and train those most important human links.

Institutionalizing Linkages

All our speakers have agreed on the urgent need to ensure linkages between research and development agencies. Many methods and techniques have been pointed out, from the land-grant college system to the comprehensive listing of rather more ad hoc associations and contacts given by Dr. Cummings as available to and utilized by, the International Agricultural Research Centers.

The "technology transfer centers" recently proposed at the UNCSTD for both developed and developing countries might also contribute to the solution if established. Probably no blueprint can be established. However, I would like to hear the Panel's views on the best way to *ensure* the close and harmonious working of research and extension personnel. I believe a single campus is necessary, and a unified direction. International agencies such as FAO and the newer agencies are able and willing to assist countries in establishing the institution of their choice.

Should we all be prepared to tailor each individual system according to circumstances?

Linkages for Implementation of Programs

W. K. Agble*

Abstract

The most fruitful linkage for implementing programs would involve a triangular structure connecting research, extension, and the farmer. The major goals of such a linkage would be to transfer technology rapidly for the benefit of the largest number of farmers; such technology should not only be economically viable and acceptable to farmers but also meet the political, social, and economic needs of the country. This demands strengthening of both national research and extension systems. Most important, it requires farmers to group themselves into a strong force that can exert pressure on the country's political machinery to secure equitable pricing, funding, and tax policies, as well as other benefits for farmers.

Expected Goals for Establishing Linkages

In establishing linkages it is necessary to conceptualize certain targets, the major goals being:

a. That the processes (linkages) established would aim at transferring technology rapidly to benefit the greatest number of farmers and improve their earnings and standards of living.
b. That the new technology is proven to be economically viable, poses no serious risks, and is acceptable to farmers.
c. That the technology satisfies the political, economic, and social needs of the country.

Activity areas in the linkage structure can be described as a triangular structure involving (a) research (b) communications, and (c) production, all joined one with another; that is, research, extension, and the farmer.

Research

The transfer of technology is dependent on the existence of a national research system that is able to generate and validate its results and participate in the processes of the transfer mechanism. In the developing countries, particularly in Africa, the research capability of the national research systems is in most cases inadequate to meet the tasks, especially in the development of food crops. In such countries, the major problems deserving serious attention are:

1. Institution building to provide the structure and capability to conduct competent research.
2. Generation of new technology or adaptation of imported technology that can be introduced to replace traditional production systems.
3. Personnel requirements such as recruitment and training to build an indigenous high-caliber manpower to overcome the critical shortage of research personnel.
4. Adequate funding of national research programs by governments or other responsible bodies, both with national funds and sufficient foreign exchange to cover purchase of equipment and other imported research facilities.
5. Technical assistance by donors in bilateral and multilateral projects.

In order to tackle these problems and to improve the national research capability, the following measures are needed to form effective research linkages:

1. Effective coordination of the national agricultural research and that undertaken on specified projects or commodities in research institutes, universities, and other agencies, including the private sector and

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industry. Mixed farming is undertaken in the SAT area in Africa, and agricultural systems should encourage husbandry practices that are favorable to both crop and animal production.

2. Linkages between national research systems and the international research institutions, especially those sponsored by the Consultative Group IARCs such as ICRISAT and IRRI.
3. Linkages with international donor agencies, both bilateral and multilaterial.
4. Strategies for generating support for agricultural research and programs at the national level. The programs need the support of bureaucrats and politicians to obtain adequate local funding.
5. Development of programs aimed at technology transfer to farmers, which can be accomplished through
   - the conduct of on-farm trials and demonstrations;
   - participation in commodity production campaigns;
   - complementary activities with extension institutions and farmers,
   - engagement of liaison officers at research institutions to aid communications;
   - communications through informal channels by use of the media and formal methods by means of scientific literature reporting.
6. Provision of research components (funds and facilities) in defined-area development projects as well as rural and land-planning development schemes. Large tracts of the SAT in Africa are being reclaimed and freed from onchocerciasis and other endemic diseases and pests. Links should be established with the appropriate agencies to develop agricultural systems suited to these areas.

Communication and Extension

The linkages discussed under research apply also to the activities performed in communications and extension. The success of programs depends on the number of participant farmers. Linkages with farmers, adopter farmers, and farmer groups are therefore important in the processes of diffusion and transfer of technology. Such linkages should also establish a feedback system to benefit research. Training is an important component in the communication process, and training at different levels should be organized at appropriate institutions for the personnel engaged in these activities.

In most African countries, because of the absence of agrobusiness, which is only now developing, it is necessary in implementing programs to arrange directly for the delivery of required inputs such as fertilizers, seed supplies, breeding stocks, machinery, etc. In many cases, the personnel assigned to extension or general agricultural duties are responsible also for these assignments. Therefore, linkages with agencies engaged in supplies, and sometimes marketing and other support services, become important in extension activities.

The Farmer

The strongest linkage for farmers should be with the country's political machinery, in order to exert pressure for their needs to be satisfied. This assumes that farmers would develop linkages among themselves by forming various groupings and associations, such as cooperatives, to pursue their objections. Regrettably, farmers not only in the SAT region but throughout Africa have not used this means for much benefit. They have generally relied on the goodwill and good intentions of their governments. The benefit of such linkages would be manifest in government support policies, for example, price policies; policies regulating demand/supply situations for commodities; priority assignment to commodity production campaigns and their funding, tax reliefs, etc.

Farmers also need to forge linkages with agencies that serve their needs, for example, credit institutions; markets and devliery systems that would provide the required facilities for marketing produce; and agencies dealing in input supplies and offering direct services to aid their production.

Finally, farmers must link with institutions such as research and extension agencies; such linkages, as already discussed, are vital to the effective transfer of technology.

Summary of Panel Discussion – Session 7

A 6-member panel, consisting of Drs. Joshi, Agble, Webster, Kane, Krantz, and Lipton, discussed the subject of linkages for the smooth transfer of technology.

Moderator A. B. Joshi, in opening the discussion, stressed the importance of this session, which would tie together all the preceding sessions of the symposium.

It is not by technology alone, said Dr. Joshi, that the drylands can be lifted out of their present bleakness — the problems are also on the social, economic, and administrative planes. This does not mean, of course, that scientific research or technological development are unimportant; far from it. Research is the kingpin.

But it is necessary to be in the field with the SAT farmer to appreciate his plight. Where, for instance, does he get a continuing supply of fuel in a land denuded of all vegetation? Where does he get credit to buy needed inputs? Even in a drought year, when he suffers crop losses, he must still make payments on his loan. Is it possible to provide the farmer with alternative sources of energy? To provide "soft" credit based on a 7-year or 10-year cycle, with repayment to be made according to crop productivity? To set up some sort of crop insurance? Who should make the investment needed for all this development?

Citing the example of Maharashtra State, where only 10 to 11% of the farmland is irrigated, Dr. Joshi said that in the drought of 1972, the government spent Rs. 250 crores (U.S. $310 million) in a single year on famine relief. Is it possible, he asked, instead of such stopgap measures, to find long-range solutions to these situations?

Dr. Joshi asked the panel to consider these and related questions and invited all participants to describe any experiments that have successfully tackled these problems.

Dr. Agble noted that on the African continent the transfer of technology is hindered by a lack of:

- institutions with the structure and capability for doing competent research and developing new technology,
- indigenous, trained, high-caliber research personnel,
- adequate funding for national research programs, including foreign exchange for purchase of imported facilities,
- technical assistance by donors, both bilateral and multilateral, and,
- effective coordination of the national research program with specific projects at research institutes and universities.

Dr. Agble emphasized that linkages with farmers and farm groups are important in the transfer of technology. Perhaps the greatest need is for linkages among the farmers themselves and with the political machinery of the country — that is, a farmers' lobby that could exert pressure on government to meet farmers' needs in such areas as pricing policies, tax relief, and credit.

Dr. Webster emphasized the need to close the gap between research and extension at the highest level, recommending that both work from the same campus. He cited the Nigerian and Brazilian examples as encouraging. Early specialization has wrecked the old agricultural generalist training, he said, and what we need is not a new breed of cat but a reversion to an older type. Dr. Webster also described the work of an FAO representative in Southeast Asia, who brings together in field workshops bureaucrats, administrators, farmers, sharecroppers, and landless laborers to appraise problems and present solutions.

Dr. Krantz said that linkages should be considered at all levels and involve international, national, state, and local agencies, and — most important of all — the farmer. Linkages across all these levels would solve many major problems in the transfer of technology; for example, communication. Involving farmer groups in planning would automatically provide a feedback that would benefit research as well. It is not enough, Dr. Krantz said, to increase crop yields; it is also necessary to improve the income of the small farmer.

Dr. Krantz pointed out that improved seed is one of the best vehicles for the transfer of technology; a new seed may require new plant-

ing times, depth of planting, fertilizer, and other inputs that would vary with the locale — in short, it would encourage new management practices as well.

On the question of funding, Dr. Krantz said that a surplus of labor, such as there is in India, can be an asset rather than a problem, for the laborers can, by improving the resource base, actually create capital.

Dr. Lipton spoke on two kinds of linkage problems in the transfer of technology: linkage between countries and, within each country, linkages between the research organizations and the local agencies that must deliver technology to the poorest.

He gave four examples of linkages needed between countries: (1) Rural industry to manufacture simple farm implements to mill and process farm outputs should be developed in some countries of Africa where these are practically unknown. (2) Technology clearing houses should be set up so that technological know-how can be shared among the semi-arid countries. This would prevent both the importing of inappropriate equipment from developed countries — such as heavy moldboard plows for sandy soils — and unnecessary efforts to develop technology that already exists in other semi-arid areas. Similarly, a regional center for screening and breeding facilities could be set up to develop new varieties for a number of small countries, especially in central and southern Africa. (3) In areas of Africa where land scarcity is just now becoming evident, techniques to integrate crop and cattle production need to be imported from more densely populated areas where such intensive land use has long been practiced. (4) Training should be instituted, especially in recently decolonized countries, to dispel the old myth that the small farmer is an inefficient farmer, with low growth potential, and that the research worker always knows best. A basic training linkage is required with countries where this myth has been exploded.

The second issue, Dr. Lipton said, is to link research activities to the local capacity to deliver research outputs to the poorest farmer. ICRISAT's record is excellent in this direction because its research is aimed at improving "poor man's crops" and resists the temptation to cater to the "easy" big farmers or to stress maximum yield at the cost of stability.

In cases where technology recommended by institutes such as ICRISAT is labor-displacing, though efficient, it is necessary to involve economists and sociologists as well as technologists in planning research projects so that possible consequences can be considered from the very start. Certain social decisions must be taken. It is within the purview of a research institute, Dr. Lipton said, to see how these decisions work in practice. For instance, if a new facility for milling or threshing is labor-displacing, could this facility be cooperatively owned by the people it displaces? Otherwise the cost of increased efficiency may be to further deprive a number of the very poorest people in the world.

In his concluding remarks, Dr. Joshi stressed the need to have a strong will to do research and adopt technology at the local level. He cited the example of an engineer in Poona who, working on his own, developed a 45-acre farm enough to obtain yield increases of threefold or fourfold, within a period of 3 years. This resulted in annual support for 15 persons.

Dr. Dwarakinath stressed the need for dealing with marketing problems of the farmers. He also suggested that international institutions like ICRISAT should bring together national and state-level policy makers and top scientists for intensive study of technology available for adapting to local situations. Middle-level scientists should have the opportunity to study at the international centers so that they can develop locally applicable technology and transfer it to the extension services.

Mr. Melville stressed that the weakest linkage of all in the transfer of technology is between the extension worker and the farmer. One of the factors contributing to this weakness is the lack of funds to pay extension staff and provide support (and transport) for trials and face-to-face contact with farmers. He stressed the need to make the farm unit profitable, growing both food crops and cash crops; this will result in additional employment, shops, trade, transport, and industry in rural areas. However, increased production of a crop must have an assured market facility with a profit to the producer; otherwise, future suggestions for innovation will not be readily accepted.

Dr. N. D. Patil discussed the success obtained in the Integrated Development Project at Sholapur, which involves working with farmers in the fields and identifying the farm problems

with them. Crops are now being grown in more seasons of the year and increased livestock utilization for milk has greatly increased farm income.

Dr. S. S. Khanna described the successful transfer of technology in Haryana State, resulting in a twofold increase in food grain production. Close linkages have been developed between farmers, extension staff, and university personnel who are deeply involved in the rural development program.

Dr. Khanna stressed that rural women should also be a main target group, as home development chiefly depends on them. He also suggested that rural youth and university students should be actively involved in the transfer of technology. Dr. Joshi pointed out that women are major decision-makers in the rural community.

Dr. N. D. Desai said that the training and visits systems was an effective way to strengthen the presently weak extension link in the transfer of technology.

Mr. Russell cited examples of appropriate technology to suit local conditions. Ox-power is appropriate for South Asia, he said, but tractors may be more practical for Africa. Land-locked countries such as Sudan, Malawi, and Zambia, have problems transporting imported fertilizer; hence, instead of using chemical fertilizers, these countries should emphasize work on nitrogen fixation and recycling organic wastes. In India, forestry to save animal waste for use on land is important. For developing linkages, on-farm trials, adaptive research, and the training and visits extension system would be as appropriate for Africa as they are for India.

Dr. Blumenschein suggested that the function of research extension, and the farmer must overlap and interact. The economics of the potential results should be obtained and presented to the administrators as a package for research and development. In Brazil, the philosophy is that research work should be 20% extension, extension work 20% research, and the training of farmers 20% extension and 20% research.

Dr. Krishnamurthy made two observations:

1. Women are often more involved in agriculture than men and hence there is great need to train rural women in various aspects of agricultural production, processing, and storage, as well as in social aspects of rural life.
2. There is a need for agro-based industries to be organized so that rural areas develop through better marketing, utilization, and processing of farm produce. This would, encourage rural youth on the farm instead of migrating to urban areas in search of work.

Plenary Session

Chairman: William T. Mashler **Rapporteur: H. L. Thompson**

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Plenary Session

Dr. Bentley introduced the Chairman for the session, William T. Mashler, Senior Director of the UNDP's Division for Global and Interregional Projects. Dr. Bentley recalled Mr. Mashler's support of ICRISAT from its very beginnings and praised him as a farsighted administrator and friend of the international centers.

Mr. Mashler said that the IARCs represent one of the best international efforts ever made to improve agriculture around the globe. He said that one reason the centers have been able to accomplish so much is that they have steered clear of politics and kept in view their original purpose, giving the scientists the freedom to do their work.

Mr. Mashler then called on the rapporteurs to give their summaries of the seven preceding sessions. (These reports are incorporated in discussions in each section of this book).

The Chairman of the symposium, Dr. J. S. Kanwar, then thanked all the participants and summarized the findings of the symposium.

Chairman's Summary

J. S. Kanwar

Rainfed agriculture in the semi-arid tropics is fraught with uncertainties and risks, and the development of technology suited specifically to these conditions is relatively recent. In organizing this symposium, we at ICRISAT attempted to focus attention on all important aspects of this vital, but hitherto neglected, area of agriculture.

The main objectives of this symposium were:

- to appraise the efforts of ICRISAT and its cooperators in developing technology relevant to small farmers of the SAT;
- to discuss philosophical, technical, and practical aspects of transferring such technology;
- to share experience in the transfer of technology;
- to explore the interphase between research and development and find ways to bridge this gap; and
- to study ways of forging and strengthening linkages for smooth transfer of technology.

The general theme was what is relevant and excellent in technology and how it can be transferred. Although no formal recommendations were made by this symposium, several important points have emerged clearly from the papers and discussions. I will try to summarize these.

Generation and Development of Technology

It is the sense of this symposium that, because of the great risk involved in rainfed SAT farming, technology will be transferable only if it is low cost, high paying, and properly suited to the physical and social environment. The ICRISAT approach towards increasing yields — by attacking yield reducers such as pests, pathogens, and drought — appears sound strategy that will probably make a major contribution to reducing the risks of semi-arid farming. The development of technological options rather than a single package of practices is also to be recommended. Technological advance cannot be divorced from socioeconomic considerations. Thus, though the watershed management system developed at ICRISAT holds great promise for improving production while conserving scarce resources, it will need to be adapted to widely varying social and economic conditions.

The Economics Program has already broken new ground in studying the setting in which the technology is to be used. It would be valuable to

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have further studies that provide data to guide planners in formulating long-range investment policies, for governments must consider not only the cost-benefit relations of technology for individuals but the cost of social justice. For instance, governments spend vast sums of emergency drought and famine relief, but little information is available on potential costs and benefits of programs to avert or alleviate the effects of such disasters. Strategies based on long-term resource management-oriented plans for mitigating the effect of such calamities instead of emergency plans for famine relief are advocated.

Principles, Practice, and Problems in the Transfer of Technology

An important distinction exists between transfer of technology (horizontally, from one experiment station to another or from international to national programs) and the diffusion of innovations (vertically, from research station to farmers' fields). An international institute such as ICRISAT can develop concepts and methodologies for transfer and can facilitate exchange of materials and techniques. But only national and local agencies can adapt these to suit particular needs and conditions.

A wide network of research should be established to cover the whole range of environments in which research results must be applied. Climatological and soil data should be used to select such benchmark locations, and areas should be defined for testing in real-world settings such promising technology as ICRISAT's double cropping of deep versitols.

Seed-based technology — high-yielding varieties, for example — is far easier to transfer than site-specific farming systems or management practices. An important consideration in transferring complex technology is that farmers may not be ready or able to take an entire package. However, they may adopt a single component, and payoffs from that might induce adoption of other components.

Experience with Transfer of Technology

A critical appraisal of the experience of various SAT countries reveals that, despite promising beginnings in several countries, problems are overwhelming and examples of practices actually adopted are few. Transfer of technology in SAT areas is far more difficult than in irrigated or assured rainfall areas. This difficulty is compounded by the inadequacy of infrastructural support facilities such as credit, inputs, storage, and marketing, and by the weakness of extension agencies.

Farmers are not interested in marginal yield or profit increases. What is needed is a spectacular quantum jump in production, together with vastly improved facilities to help turn that production into profits.

Interphase Between Research and Development

Both international and national agencies have a role to play in developing research programs relevant to the needs of the small SAT farmer. To benefit from the work of the IARCs, national programs must be capable of and willing to receive and adapt the research results. This capability must be strengthened, and such agencies as the IADS and ISNAR can provide a valuable service in doing so.

Attention should be focused on policy issues, which are as important as the agricultural research itself, and national programs should strive to create government commitment to the cause of the small farmer. Most urgently needed are special provisions to overcome institutional bias against small farmers as well as ensure timely supply of quality seed and fertilizer, manufacture of suitable tools, marketing and credit-pricing structure for sale of produce, and training of local scientists and agents.

Linkages

Even the most promising technology remains merely academic unless its results can be put to use by the farmer. Often research scientists, extension agents, and policy makers function more or less in isolation from one another and from the farmer. A coordinated, multidisciplinary effort is essential to link all of them into a smoothly functioning network. Although this is primarily the task of the national programs, the IARCs, which have established excellent links

with their cooperators, may play a role in identifying weak links and suggesting means of strengthening them. Within national programs, it is vital to enable research, extension, and farmer to work together. It is also important to ensure that mechanization for improved efficiency does not displace labor but creates employment. The IARCs could also help establish linkages between SAT countries, which could benefit from one another's experience and avoid duplication of effort in developing suitable technology.

To sum up, ICRISAT and its cooperating national research organizations are fully committed to developing appropriate technology for the SAT; its transfer to the farmers, however, will be determined by the strength or weakness of the national research and extension agencies and the links between them. Despite the difficulty of the task, it can be accomplished if there is a cooperative effort and political will. We have a long way to go, but this symposium has indicated the direction we must take.

Appendix I

French Abstracts and Texts

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Résumés des Communications

Session d'Ouverture

Un Aperçu sur la Recherche à l'ICRISAT

J. S. Kanwar

Se rendant compte de l'urgence qu'il y avait à améliorer le bien-être des paysans des zones tropicales semi-arides, et à combler le fossé entre la production et la demande alimentaires, le Groupe Consultatif pour la Recherche Agricole Internationale (CGIAR) créa l'ICRISAT en 1972. L'Institut détient une responsabilité globale dans la recherche pour l'amélioration du sorgho, du mil, du pois chiche, du pois d'Angole et de l'arachide. Il détient également un mandat spécial pour la recherche de systèmes de cultures, de freins socio-économiques, et du transfert de la technologie pour les zones tropicales semi-arides à saison sèche, en vue de favoriser une percée dans la production agricole de la région.

L'ICRISAT a établi une banque de gènes de 48.000 accessions et échangé plus de 250.000 paquets de graines avec les chercheurs dans 67 pays. L'ICRISAT s'efforce d'améliorer le potentiel et la stabilité du rendement des récoltes, tout en maintenant une bonne qualité nutritive, et de mettre au point des concepts et des pratiques permettant d'optimiser la production et d'accroître les revenus des paysans. Nos chercheurs travaillent en coopération avec les chercheurs nationaux en Asie, Afrique et Amérique du Sud afin de mettre au point et diffuser une technologie plus efficace et plus rémunératrice destinée à changer sensiblement la production alimentaire des zones tropicales semi-arides.

Session 2 : Les Recherches de l'ICRISAT pour la Mise au Point d'une Technologie pour les Zones Tropicales Semi-arides

La Technologie de Recherche pour l'Amélioration des Cultures dans les Zones Tropicales Semi-arides : Les Céréales

J. C. Davies

Les principales céréales qui intéressent l'ICRISAT sont le sorgho et le mil, qui se placent respectivement au quatrième et cinquième rang de la production mondiale des céréales. Elles sont cultivées sur de vastes étendues des zones tropicales semi-arides en tant que cultures vivrières de base car elles sont assez tolérantes à la sécheresse. Elles ont une faible valeur monétaire et sont habituellement cultivées comme cultures de subsistance dans des situations où l'agriculture est pauvre; elles ne peuvent donc rentabiliser des apports importants de produits chimiques ou des technologies coûteuses. Le Programme sur les Céréales à l'ICRISAT a été établi en gardant à l'esprit ces considérations. La recherche dans toutes les disciplines s'est concentrée sur la production de semences possédant les caractéristiques nécessaires pour aider à diminuer l'impact des facteurs majeurs de la baisse de rendement : sécheresse, insectes nuisibles, maladies et herbes parasitaires. D'importants progrès ont été réalisés dans le domaine du criblage et de la sélection pour la résistance à ces facteurs. Bon nombre de ces techniques sont déjà largement utilisées en Inde et en Afrique.

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La Technologie de Recherche pour l'Amélioration des Légumineuses dans les Zones Tropicales Semi-arides

J. M. Green

Les légumineuses, avec leurs exigences nutritives plus importantes que les céréales, mais leurs réponses peu marquées, aux apports d'engrais, présentent de sérieuses difficultés aux chercheurs qui tentent d'augmenter la production. On a obtenu des résultats prometteurs dans l'accroissement du rendement des pois d'Angole en se servant d'hybrides, et dans celui des pois chiches en modifiant le type de la plante, ainsi que dans la stabilité du rendement pour les deux plantes, en incorporant une résistance génétique aux maladies. Des innovations en agronomie font espérer un accroissement de production en dehors des systèmes traditionnels.

La Technologie de Recherche pour l'Amélioration de l'Arachide dans les Zones Tropicales Semi-arides

R. W. Gibbons

Les arachides sont l'une des légumineuses les plus importantes des zones tropicales semi-arides et sont utilisées comme aliment, huile de cuisine, ou source de revenus en espèces. Les rendements, cependant, sont faibles dans ces zones, à cause principalement des pertes dues aux parasites, aux maladies et aux répartitions imprévisibles des pluies. L'objectif principal du programme est de produire un matériel sélectionné de haut rendement avec une résistance stable aux principaux pathogènes qui comprennent, entre autres, la rouille, les taches foliaires, et l'*Aspergillus flavus*. Les virus et les parasites sont la cause d'importantes réductions dans le rendement et des sources de résistance sont en cours de recherche. Des programmes de sélection à grande échelle sont en cours et des populations en ségrégation à des stades précoces et avancés sont distribuées aux sélectionneurs nationaux coopérants. Des efforts sont faits pour améliorer la capacité de fixation de l'azote des arachides. La culture associée des arachides avec le mil procure des avantages de rendement. Les espèces *Arachis* sauvages sont exploitées en tant que sources de gènes utiles.

La Recherche et la Technologie sur les Systèmes de Culture dans les Zones Tropicales Semi-arides

Jacob Kampen

La recherche sur les systèmes de culture à l'ICRISAT contribue à améliorer la qualité de la vie dans les zones tropicales semi-arides par l'intermédiaire d'efforts interdisciplinaires et coopératifs destinés à améliorer l'utilisation des ressources naturelles, humaines et en capital. Il a été trouvé que le semis en sec sur les Vertisols donne de bons résultats, là où l'on peut compter sur les pluies précoces; que l'introduction de porte-outils se traduit par un meilleur respect du calendrier cultural et une efficacité accrue dans l'utilisation des animaux de trait; que le système de planches larges et de sillons permet de maîtriser l'eau excédentaire et facilite les opérations de culture; que la culture double sur les Vertisols semble prometteuse; que la culture intercalaire augmente globalement les rendements de façon substantielle sur les Vertisols et les Alfisols; qu'une maîtrise efficace des

mauvaises herbes peut être atteinte grâce à l'intégration de moyens mécaniques, biologiques et chimiques. L'utilisation rationnelle des ressources et l'aménagement dans le cadre de bassins versants contribuent à augmenter et à stabiliser les rendements; l'effet combiné des différents facteurs de production appliqués globalement, dépasse de loin l'effet total de ces facteurs appliqués séparément; et les systèmes de culture améliorés expérimentés en bassins versants à une échelle opérationnelle, se traduisent régulièrement par des augmentations de trois à cinq fois des productivites en saison des pluies. Des études réalisées dans les exploitations agricoles ont débuté avec pour objectif de faire participer les paysans à la mise au point d'une technologie appropriée et de définir des formes efficaces d'action de groupe.

Les Contraintes Socio-économiques dans les Zones Tropicales Semi-arides et l'Approche Proposée par l'ICRISAT

James G. Ryan et Hans P. Binswanger

Cette communication traite de la façon dont les freins socio-économiques au développement de l'agriculture sont évalués à l'ICRISAT dans le but de mieux définir les priorités de la recherche dans un sens ex-ante et aussi de perfectionner l'efficacité avec laquelle de nouvelles technologies sont "vendues" aux paysans, après leur mise au point. Les contraintes étudiées comprennent les variations de densité de la population, l'hétérogénéité des ressources naturelles dans les zones tropicales semi-arides, le rôle du risque dans la décision du paysan, les organismes de commercialisation, les besoins humains fondamentaux et enfin, les préoccupations d'efficacité et d'équité dans la répartition des moyens de recherche.

Session 3 : Le Transfert de la Technologie Agricole

Les Problèmes et les Concepts du Transfert de l'Agrotechnologie dans les Pays Tropicaux

L. D. Swindale

Le transfert de l'agrotechnologie entre les pays ou entre les régions à l'intérieur des pays, comporte des contraintes et des problemes qui s'ajoutent a ceux associés a la diffusion des innovations. Les contraintes de la spécificité locale, l'applicabilité de la technologie transférée, les contraintes sociales, économiques et institutionnelles doivent toutes être reconnues et conceptualisées.

La technologie centrée sur les semences améliorees comporte le moins de contraintes et a été le moyen principal pour le transfert de l'agrotechnologie. Les nouvelles techniques d'aménagement du sol ou de systemes de cultures sont plus difficiles a transférer. L'élément essentiel est la zonation du milieu, par l'utilisation de classifications pédologique ou climatique.

Une recherche agricole compétente au niveau national constitue un autre élément essentiel. Les centres internationaux de recherche agricole aident a la recherche nécessaire au transfert, à la prise de conscience de l'existence de la technologie et a son acceptation.

Les Analogues Agroclimatiques dans le Transfert de la Technologie

Henry Nix

Les concepts et les méthodes de base se rapportant à la classification agroclimatique et à l'analyse des zones climatiques homologues sont passés en revue et discutés. Les raisons de la lenteur dans la mise au point, l'expérimentation et l'application des méthodes d'analyse agroclimatiques sont explorées et d'autres approches possibles sont examinées. Cet examen porte sur les concepts d'ensemble minimum de données, la définition de réseaux expérimentaux optimaux, la mise en œuvre de systèmes dynamiques d'interactions pour l'analyse et la synthèse des relations culture-climat a différentes échelles de temps.

Les Organisations de Recherche et de Transfert de la Technologie

Frederick E. Hutchinson

La recherche destinée à mettre au point des technologies qui puissent être transférées de façon appropriée aux petites exploitations des pays en voie de développement, est essentielle au succès du développement de l'agriculture. Le Congrès des Etats-Unis a stipulé que les futurs programmes de développement de l'agriculture financés par l'assistance américaine à l'étranger, auraient à mettre l'accent sur le transfert de technologie appropriée aux petites exploitations. Dans le passé, les organisations américaines travaillant au développement trouvèrent difficile de coordonner leurs efforts afin de rendre maximum leur efficacité, mais elles sont maintenant tenues de le faire en fonction de l'Article XII de la loi d'assistance à l'étranger de 1975. Cette loi fait participer universités agricoles, agences fédérales et organisations privées à des programmes de recherche liés aux stratégies de développement de l'agriculture. Il est discuté des éléments clef propres à créer et à maintenir cet effort de coopération.

Approche Climatique pour un Transfert de la Technologie des Systèmes de Cultures dans les Zones Tropicales Semi-arides

S. M. Virmani

Les rendements des cultures en zones tropicales semi-arides sont faibles en raison des variations, temporelles et spatiales, de la pluviométrie. Ces régions sont caractérisées par un besoin climatique en eau élevé, et la pluviométrie n'excède l'évapotranspiration que pendant 2 à 4 mois et demi par an. En raison de la large répartition spatiale des ressources naturelles, il existe une forte spécificité de l'emplacement en termes de ressources en eau pendant la saison de culture. Quelques techniques employées pour la quantification de la répartition de la pluviosité et de la disponibilité de l'eau du sol en relation avec les besoins en eau des cultures, sont décrites. Des exemples de l'applicabilité des analyses agroclimatologiques pour le transfert de technologie en matière de systèmes de cultures sont discutés.

Etudes sur Sols Représentatifs : un Moyen de Transfert de l'Agrotechnologie

Tejpal S. Gill

Une étude sur sols représentatifs constitue un effort de coopération de personnes travaillant avec des méthodes uniformisées de recherche agronomique sur des sols bien définis qui appartiennent à la même catégorie. Il s'agit, par définition, d'un réseau. La recherche effectuée sur sols représentatifs aboutit à des résultats à diffuser parmi les divers sites d'expérimentation, et aux agriculteurs exploitant les mêmes sols. Les résultats expérimentaux obtenus dans un pays peuvent être appliqués aux sols de la même famille dans un autre pays. A mesure que l'information s'accroît, il sera possible de perfectionner un modèle de transfert de technologie basé sur l'interprétation des sols, et leur classification. Un réseau international de sites représentatifs est déjà en opération à Hawaii, à Puerto Rico, au Brésil et aux Philippines; il peut être élargi à l'échelle mondiale pour accroître la production de cultures vivrières avec l'aide des centres de recherche internationaux et de leurs programmes de coopération ainsi que des projets de recherche agronomique conduits par les programmes nationaux à de nombreux emplacements dans chaque pays.

Aménagement de Bassins Versants et Transfert de Technologie dans les Zones Tropicales Semi-arides

Jacob Kampen

De fréquentes chutes dans la production alimentaire et une détérioration dans la capacité productive du milieu, sont devenues communes dans bon nombre des régions des zones tropicales semi-arides. La mise en valeur des ressources naturelles dans le cadre de bassins versants, qui implique une utilisation optimum de l'eau de pluie grâce à une meilleure utilisation de l'eau, du sol et des cultures, détient le potentiel nécessaire pour contribuer de manière significative à accroitre la production et conserver les ressources naturelles. La mise au point d'une technologie améliorée d'aménagement de bassins versants, qui soit adaptée aux besoins des paysans, est une tâche longue et complexe; toutes les utilisations de la terre, y compris les prairies et les forêts, doivent être prises en considération. Dans la poursuite d'un développement agricole réussi, la responsabilité de l'ICRISAT consiste en la mise au point de méthodes améliorées de recherche, en des investigations coopératives centrées sur la recherche d'opération, en l'intégration de nouvelles technologies, et en des programmes de formation.

Etudes au Niveau des Villages Considérées comme Bases pour l'Adaptation de la Recherche et de la Technologie

Hans P. Binswanger et James G. Ryan

Il est discuté en premier lieu dans cet article, de plusieurs traditions d'enquêtes socio-économiques en Inde. Il est démontré par la suite, comment l'étude au niveau des villages (VLS) de l'ICRISAT combine d'une manière nouvelle plusieurs des caractéristiques propres aux traditions antérieures. Les buts, la portée, et les résultats de cette phase d'observation socio-économique des VLS sont discutés par la suite, suivis par une description des recherches en cours et de la phase d'adaptation des études. Les

VLS sont considérées comme bases pour de nombreux types différents d'enquêtes socio-économiques, pour la mise au point d'une technologie adaptée et pour diverses recherches. Elles s'efforcent de fournir une approche allant du niveau des paysans à la mise au point de technologies à l'ICRISAT.

Session 4 : Les Programmes de Coopération de l'ICRISAT pour le Transfert de la Technologie

Vue d'Ensemble sur les Programmes Coopératifs de l'ICRISAT

R. C. McGinnis et C. Charreau

Un des buts principaux des programmes de coopération de l'ICRISAT est de renforcer les efforts nationaux de recherches, sans pour autant faire double emploi avec eux ou les concurrencer. L'Institut échange du matériel végétal avec plus de 40 pays coopérants; il aide à former le personnel de recherche; il organise des séminaires internationaux ainsi que des journées d'étude pour promouvoir l'interaction scientifique; il fournit une assistance technique adaptée aux besoins particuliers de chaque pays. C'est en Afrique — 66% de la zone tropicale semi-aride du monde — que les programmes de coopération ont bénéficié d'une haute priorité; des progrès satisfaisants ont été réalisés à la fois dans le domaine de la recherche et dans celui de la formation. En Inde, un excellent système de transfert à double sens a été établi. Des programmes de coopération ont également été établis dans d'autres pays d'Asie, de même qu'en Amérique Centrale et du Sud, une expansion ultérieure est envisagée, en conformité avec la responsabilité internationale croissante de l'ICRISAT.

Le Programme de Coopération de l'ICRISAT en Haute-Volta

W. A. Stoop et C. M. Pattanayak

Au cours de ces dernières années, la sécheresse a été fréquente en Haute-Volta, causant de faibles rendements et un sérieux déficit dans les productions de graines alimentaires. Les données de la recherche indiquent que, malgré cette sécheresse, des rendements plus élevés devraient être possibles. Cet article tente d'analyser pourquoi de tels rendements n'ont pas été réalisés, puis d'indiquer les moyens par lesquels le programme de l'ICRISAT en Haute-Volta pourra contribuer à améliorer cette situation.

Génération et Transfert de Technologie aux Amériques

Leland R. House

Les activités de l'ICRISAT aux Amériques ont concerné d'abord le sorgho, et dans une moindre mesure, le mil à chandelles, l'arachide, le pois chiche et le pois d'Angole. Les chercheurs travaillant à

ces différents programmes d'amélioration des plantes ont suivi de près l'évolution de ces programmes en Amérique Centrale et du Sud grâce à des visites personnelles et des échanges d'information et de matériel végétal avec les chercheurs locaux. L'ICRISAT a un sélectionneur sorgho en poste au CIMMYT, au Mexique, travaillant principalement sur l'amélioration du sorgho de haute altitude. Il y a eu un énorme accroissement de la production du sorgho au cours de ces dernières années en Amérique latine, principalement au Mexique, en Argentine et au Brésil. Le sorgho est utilisé principalement comme nourriture pour les animaux dans ces pays, et a contribué indirectement à la production alimentaire en rendant disponible une plus grande quantité de la céréale de base, le maïs, pour la consommation humaine. Mais le sorgho est aussi utilisé comme nourriture importante pour les humains au Honduras, au Guatémala, à El Salvador et au Nicaragua ainsi que dans bon nombre d'autres pays qui manifestent un intérêt croissant pour cette plante en tant que culture vivriere. Les priorités pour l'amélioration du sorgho en Amérique Centrale et du Sud prennent en compte la nécessité de sélectionner les variétés en vue de leur utilisation comme culture intercalaire avec le blé et les haricots, telle qu'elle est pratiquée par les paysans plus pauvres; elles prennent aussi en compte la nécessité de cribler les variétés pour la résistance aux importants parasites et maladies que l'on trouve dans ces pays, et celle d'intensifier la formation des chercheurs en Amérique latine ainsi que les échanges d'informations avec eux.

La Formation à l'ICRISAT

D. L. Oswalt et A. S. Murthy

Bourses internationales, programmes de formation universitaire et de chercheurs débutants, recyclage professionnel et contrats d'apprentissage constituent, au Centre ICRISAT, autant de possibilités offertes aux stagiaires pour développer leur compétence professionnelle et leur expérience pratique. Ces programmes de formation permettent d'établir des liens entre les programmes nationaux, régionaux et internationaux de recherche et de développement, d'une part, et les facilités de recherche et l'expertise scientifique disponibles à l'ICRISAT, d'autre part. Conçus de façon à convenir à des participants d'origines et d'expériences diverses, les programmes permettent a chaque individu de suivre un programme d'études personnalisé, adapté d'aussi près que possible à ses capacités et aux besoins exprimés par l'organisation qui le commandite. La durée des stages de formation est de quelques semaines à deux ans. Après le départ des anciens stagiaires, un programme de suivi permet de maintenir le contact avec eux, de les informer des progrès de la recherche et d'être tenu au courant de leurs activités et progrès.

Session 5 : Phase Intermédiaire entre la Recherche et le Développement

L'Aptitude d'un Programme de Recherche à Répondre aux Besoins des Petits Paysans dans les Zones Tropicales Semi-arides

Sir John Crawford

Pour qu'un programme de recherche puisse pleinement répondre aux besoins des petits paysans, il doit proposer une nouvelle technologie susceptible d'apporter une amélioration significative. Mais

cela ne suffit pas : il faut en outre une infrastructure fournissant des services dans des conditions telles que les gains escomptés puissent être effectivement réalisés. La neutralité des techniques mises en œuvre par rapport à la taille des exploitations est peut-être une condition nécessaire; mais elle reste insuffisante sans la distribution impartiale des services à l'égard des grands comme des petits paysans.

Le Rôle des Instituts Internationaux

Ralph W. Cummings

Le Groupe Consultatif pour la Recherche Agricole Internationale (CGIAR) fournit les moyens de travail à 13 instituts internationaux dont la fonction essentielle est la recherche en agriculture. La mise en œuvre pratique des résultats de cette recherche est normalement la tâche des agences nationales et locales; les instituts, toutefois, ont la responsabilité de détecter et aménager des interfaces ou domaines d'échanges avec les agences nationales de façon à garantir, dans de bonnes conditions, la mise à l'épreuve, sur une vaste échelle, des innovations technologiques potentielles et l'observation d'effets rétroactifs, positifs ou négatifs, fiables. Ceci a déjà été abordé dans bien des cas. L'établissement de l'ISNAR en 1978 est un pas important vers un renforcement des programmes de recherche nationaux, ce qui, en échange, rehaussera l'efficacité et l'utilité des instituts internationaux et contribuera à garantir qu'il n'y ait aucune rupture dans la chaîne allant de la découverte de la connaissance jusqu'à son application finale sur le terrain.

Le Rôle des Programmes Nationaux pour Lier la Recherche au Développement

M. S. Swaminathan

Une base dynamique de recherche nationale est essentielle au lancement et à l'entretien d'un programme de développement agricole visant au triple objectif de l'alimentation, du revenu et des emplois accrus par une exploitation des ressources disponibles. Si les instituts internationaux peuvent servir de catalyseurs au changement seul un programme national solide pourrait assurer un progrès soutenu. La recherche localisée a pour but de développer, pour chaque système de production, une technologie économiquement viable et son impact eventuel devrait être évalué afin d'éviter les problèmes nouveaux et inattendus associés aux ravageurs, aux maladies et au sol. A l'heure actuelle en Inde, les rendements réels des paysans sont inférieurs à 25% du potentiel disponible malgré le présent niveau de la technologie. La tâche immédiate est donc, pour les agences de recherche, de vulgarisation et de développement, de coopérer dans un effort pour combler le fossé entre les rendements potentiels et réels.

Le Rôle de l'ISNAR dans le Transfert de Technologie

Klaus J. Lampe

L'ISNAR (Service International pour la Recherche Agricole Nationale) est le dernier né de la famille des organisations patronnées par le CGIAR dans ses efforts pour améliorer la production agricole

dans les pays en développement. A la différence des centres de recherche internationaux, l'ISNAR est une organisation de services; il complètera les activités des autres programmes et instituts. Sa mission première est de renforcer les capacités de recherche agricole des pays en développement. Il servira de mécanisme de liaison entre les centres internationaux de recherche agricole et les institutions nationales, d'intermédiaire entre les partenaires intéressés à promouvoir une coopération bilatérale en recherche agricole et de lien pour garantir que la recherche, destinée à un groupe de populations donné, atteindra — par l'intermédiaire d'un service de vulgarisation efficace — la population rurale des pays qui feront appel à l'assistance de l'ISNAR.

Le Rôle des Programmes de l'IADS dans le Transfert de Technologie

D. S. Athwal

L'IADS (Service International de Développement Agricole) fut établi en 1975 pour fournir des services demandés par les pays en développement en vue de concevoir, organiser et renforcer les institutions de recherche et de développement en agriculture. L'IADS encourage la coopération entre les agences d'assistance, et aide à intégrer les ressources pour appuyer les efforts nationaux. Actuellement, les trois quarts des activités de l'IADS sont des services directs pour aider plus de 12 pays en Asie, en Afrique et en Amérique latine, à planifier et réaliser leurs programmes de recherche. D'autres activités concernent la formation de chefs et de gestionnaires, la préparation d'une littérature orientée vers le développement et la liaison avec les agences d'assistance et les institutions des pays en developpement. Alors que l'accent, jusqu'à ce jour, a été mis sur le travail avec des systèmes de recherche nationaux, l'IADS est maintenant prêt à participer à des projets plus orientés vers le développement en accord avec son mandat initial.

L'Intégration Agriculture-Elevage dans les Zones Tropicales Semi-arides

D. J. Pratt et C. De Haan

Dans cette communication, on a essayé d'isoler quelques-unes des interactions qui existent entre l'élevage et l'agriculture dans les zones semi-arides, et de discuter quelques-unes des tendances qui affectent ces interactions. On peut s'attendre à ce que davantage de systèmes de production intégrés voient le jour, grâce à un ensemble de mesures politiques et administratives, ainsi qu'à des innovations biologiques qui viseront essentiellement à accroitre, en qualité et en quantité, la nourriture du bétail en saison sèche. La recherche sur systèmes, propre à l'ILCA, suggère que la méthode d'attaque des problèmes de développement aura besoin de combiner un bon nombre de composantes pour être couronnée de succès. De par la nature même des systèmes de production, il se peut que l'élément clé pour améliorer la production de l'élevage consiste en actions destinées a accroitre le rendement des cultures de subsistance (même quand ces cultures n'ont pas d'intérêt direct pour le bétail); de la même maniere, une manipulation a l'intérieur de la composante "élevage" peut fournir les moyens d'améliorer la production des cultures.

Session 6 : Les Expériences dans les Zones Tropicales Semi-arides

Les Expériences Indiennes dans les Zones Tropicales Semi-arides : Perspectives et Rétrospectives

N. S. Randhawa et J. Venkateswarlu

En Inde, environ 75% des terres cultivées — fournissant 42% de la production alimentaire totale — sont cultivées sous pluie. Même après une utilisation complète des ressources en eau, environ 50% des terres continueront à dépendre des pluies. Les niveaux de rendement en culture sèche continuent à se situer autour de 0,5 t/ha, malgré les efforts de recherche antérieurs sur les systèmes de culture sous pluie dans les années trente, puis à nouveau dans les années cinquante. L'apparition de nouveau matériel végétal au milieu des années soixante fit espérer une amélioration de la production agricole en culture sèche. Le projet national sur l'agriculture sous pluie, avec ses 23 centres régionaux, fut lancé en 1970. Les centres de coopération ont engendré un nouvel ensemble de techniques permettant d'augmenter de 250 à 400% les rendements potentiels dans les stations expérimentales agricoles. La mise à l'épreuve de cette technologie dans les exploitations agricoles, sur de vastes zones pilotes à l'échelle opérationnelle, a fourni régulièrement des accroissements de rendement allant de 100 à 200%. L'intensité de culture, en culture sèche, peut être augmentée par des cultures associées et séquentielles dans les zones d'une pluviométrie de 650 mm et plus. De nouveaux systèmes de culture, spécialement adaptés aux diverses situations régionales, ont été mis au point, en y incorporant les oléagineux et les légumineuses. La mise en valeur de zones de culture fondée sur l'aménagement de bassins versants, ainsi que la collecte et le recyclage de l'eau de ruissellement, constituent d'autres caractéristiques importantes de cette technologie.

L'Elaboration et Transfert de Technologie pour l'Agriculture sous Pluie et le Paysan des Zones Tropicales Semi-arides dans les Régions Prédisposées à la Sécheresse du Maharashtra

A. B. Joshi, N. D. Patil et N. K. Umrani

Le Maharashtra est le troisième état de l'Inde en étendue; un tiers de sa superficie cultivée est proverbialement prédisposé à la sécheresse. La topographie est vallonnée; les sols sensibles à l'érosion; la pluviosité, de 500 à 750 mm, est extrêmement variable. Environ 30% des sols sont peu ou moyennement profonds. La Station de Recherche Agricole de Sholapur, instaurée en 1933, a effectué un travail de recherche considérable sur le "dry-farming": recherche dont les résultats sont maintenant prêts à être diffusés. Cependant le salut pour l'agriculture sous pluie ne peut pas venir uniquement de la technologie; un effort concerté et pluridisciplinaire, impliquant des agences multiples, est nécessaire. Cet effort doit se faire sur la base d'un aménagement intégré de bassins versants entiers plutôt que sur la base d'exploitations individuelles.

L'Expérience du Nigeria

M. B. Ajakaiye

La technologie agricole, pour être praticable et acceptable, doit prendre en considération les facteurs socio-économiques qui influencent ses utilisateurs. Le programme du Nigeria, fondé sur ce

principe, tente de résoudre les problèmes du paysan des zones tropicales semi-arides en créant des variétés de cycle court adaptées à la saison de culture; en concevant des outils simples pour réduire le travail ingrat de l'exploitation agricole; en maitrisant les ravageurs et les maladies grâce à des mesures préventives; et en s'assurant que les techniques de culture récemment mises au point seront tout à la fois acceptables et rentables pour le paysan. Le Service Agricole de Vulgarisation et de Liaison avec la Recherche (AERLS), mis en place en 1975, joue un rôle clef en établissant un lien entre la recherche et son utilisateur final, le paysan.

Réflexions sur les Problèmes de Transfert de Technologie

Joseph Kabore

L'élaboration d'un code de conduite des transferts de technologie s'avère nécessaire pour renforcer les capacités d'organisation et de réception des pays en développement et pour améliorer l'accès à la technologie à des prix abordables par tous. La mise en place et le développement des structures de formation techniques et professionnelles dans les pays en développement sont une condition préalable au transfert des technologies si ce transfert se veut efficient et durable. Les nouvelles techniques doivent être assimilées, modifiées et adaptées aux conditions particulières de chaque pays. La recherche agronomique telle qu'elle est menée dans les pays développés (Europe ou Etats-Unis) nécessite des moyens de production n'ayant rien de comparable à ceux dont dispose le petit paysan voltaïque. Il faut des chercheurs qui soient à même de s'imprégner des problèmes que vit quotidiennement la population afin d'être capables de sortir un programme de recherche qui "colle" avec ces réalités et éleve la technicité du paysan.

L'Expérience Sénégalaise

Djibril Sene

Le Sénégal dispose depuis déja de nombreuses années d'une infrastructure de recherche agronomique et d'un nombre de chercheurs que l'on peut qualifier l'une et l'autre d'importants. Mais le monde paysan sénégalais n'a pas beaucoup bénéficié des résultats de recherche, et l'inaptitude qu'il y a a les faire passer au niveau du paysan constitue un des freins les plus importants a l'évolution de ce monde rural. Cette recherche agronomique possede deux défauts importants : en premier lieu, elle est trop intellectualisée et pas assez pragmatique; deuxièmement, beaucoup de ces chercheurs ne se sont pas mis suffisamment à l'écoute du monde rural pour sortir un programme de recherche. La création des Unités Expérimentales Régionales (UER) de nature pluridisciplinaire a constitué un élément décisif de progres dans la conduite de la recherche, mais elles ont moins réussi a porter assistance aux sociétés d'encadrement technique du monde rural. L'objectif de la recherche doit être, au Sénégal, d'une part, la mise au point des innovations qui puissent être acceptées par le monde rural et, d'autre part, de faciliter l'adoption de ces innovations dans le cadre de la politique agricole nationale.

Transfert de Technologie en Agriculture Pluviale dans la Région Sahélienne

Nalla O. Kane

L'Institut du Sahel a été créé en 1977 a l'initiative du Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel (CILSS). Ses fonctions comprennent la collecte, l'analyse et la diffusion

des résultats de la recherche scientifique et technique; le transfert et l'adaptation des technologies; et la formation des chercheurs et techniciens. L'Institut définit des paquets technologiques adaptés aux conditions socio-économiques locales et étudie des programmes de radio rurale diffusés en langues nationales (vernaculaires) des pays sahéliens. Sur les exploitations agricoles, des paysans "modèles" démontrent l'efficacité des nouvelles techniques à leurs voisins. L'auteur souligne qu'il ne faut pas cependant parler du paysan sahélien comme s'il n'était appelé qu'à recevoir les techniques. Il a fait preuve d'une adaptabilité étonnante et les techniques traditionnelles que le paysan lui-même a produit — et qui sont d'ailleurs très adaptées aux conditions locales — devraient être étudiées et diffusées.

L'Expérience Brésilienne

A. Blumenschein

Le Brésil a investi substantiellement dans la recherche agronomique dans la région Nord-Est où est située une grande partie de la zone semi-aride du pays. Outre une pluviométrie irrégulière et des sols pauvres, le véritable obstacle au développement dans cette région est la distribution des terres, 8% des paysans possédant 67% des terres cultivées. Le programme de recherche a commencé par une analyse des freins à une augmentation de la production et a entrepris quatre projets principaux : un inventaire des ressources naturelles, la mise au point de systèmes de production, d'une part pour les régions sous pluie et d'autre part, pour les régions irriguées, et de systèmes d'exploitation adaptés aux conditions particulières de la région Nord-Est. Le programme est structuré de sorte qu'il favorise un transfert rapide de technologie des centres de recherche agricole internationale (IARC) au Brésil.

L'Elaboration et le Transfert de Technologie pour la Production des Cultures Sous Pluie en Thaïlande

Ampol Senanarong

Des quatre régions géographiques de la Thaïlande, le Nord-Est est la zone où l'agriculture sous pluie rencontre le plus de problèmes. Les rendements faibles et instables pour toutes les cultures — spécialement le riz — de cette région, la sous-utilisation des terres et la faible fertilité du sol se combinent pour faire du revenu individuel des paysans le plus bas du pays. Jusqu'à ces derniers temps, la recherche mit davantage l'accent sur l'amélioration variétale que sur les techniques de cultures ou de conservation et d'utilisation rationnelle du sol et de l'eau. Il est nécessaire d'encourager la recherche pluridisciplinaire et d'élaborer à long terme des programmes afin de maintenir la continuité. Les chercheurs, les agents de vulgarisation et les paysans exploitants, devraient être capables de travailler ensemble afin d'élaborer une technologie que l'exploitant puisse adopter avec profit. Un premier pas serait d'accepter les systèmes de culture existants et d'y introduire des innovations simples et peu coûteuses dont le résultat serait un accroissement visible des rendements.

L'Expérience des Philippines dans les Cultures en Zones Sèches

J. D. Drilon, Jr. et Ed. B. Pantastico

Les Philippines bien qu'étant un pays typiquement humide, avec une pluviosité moyenne annuelle de 253 cm, comportent des zones sèches de novembre à avril. La tendance de la production des cultures dans les zones humides, humides et sèches, et sèches reflète l'influence des paramètres du milieu, par exemple, la pluviosité, la température, l'humidité relative, la fertilité et la texture du sol et la situation du marché. Pour introduire de nouveaux systèmes de cultures dans ces zones où les pratiques culturales sont établies depuis fort longtemps, des essais de recherche appliquée furent conduits pour s'assurer que le nouvel ensemble de technologies soit adaptable aux conditions actuelles. Les essais mettent l'accent sur le choix du site d'expérimentation, sur l'élaboration et la mise à l'épreuve du système de culture dans les champs des paysans, et sur l'évaluation de l'ensemble des données. La technologie KABSAKA — c'est à dire deux cultures du riz et une culture pluviale pour les zones exondées — élaborée d'après ces activités, a donné d'excellents résultats, et avec les modifications appropriées, pourra être adoptée dans d'autres régions.

Session 7 : Les Liens

Les Liens pour le Transfert de Technologie

B. N. Webster

Cette communication examine les concepts traditionnels de transfert de technologie dans le cadre du développement agricole et elle fait ressortir le caractère pluridimensionnel des liens noués entre agents, caractère essentiel pour soutenir un système dynamique d'application des connaissances acquises. L'accent est mis sur le transfert de technologie vers l'intérieur de la région et sur l'applicabilité d'une technologie produite au niveau indigène. L'importance de l'élément humain à tous les niveaux est soulignée et par là, le rôle majeur que joue un lien adéquat avec les institus d'enseignement et de formation pour préparer les cadres bien formés servant de "liens humains" dans la chaîne du transfert.

Les Liens pour la Mise en Oeuvre des Programmes

W. K. Agble

Les liens les plus fructueux pour la mise en œuvre des programmes supposeraient une structure triangulaire liant la recherche, la vulgarisation et le paysan. Les principaux objectifs d'un tel système de liens seraient le transfert rapide des technologies au bénéfice d'un plus grand nombre de paysans; de telles technologies sont non seulement économiquement viables et acceptables par les paysans mais répondent en outre aux besoins politiques, sociaux et économiques du pays. Cela nécessite le renforcement des systèmes nationaux de recherche et de vulgarisation. Mais surtout, les paysans doivent s'unir pour exercer une forte influence sur la machine politique du pays afin d'assurer une fixation des prix, un financement et une politique fiscale équitables ainsi que d'autres bénéfices aux paysans.

Réflexions sur les Problèmes de Transfert de Technologie

Joseph Kaboré*

L'énorme fossé qui existe entre les pays "développés" et les pays dits en développement et plus particulièrement ceux d'Afrique, dont la Haute-Volta, impose à ces derniers de faire massivement appel à la technologie ou savoir-faire des premiers. Ceci ne va pas sans poser de délicats problèmes, dont les plus aigus sont la dépendance ainsi créée et les coûts importants que cela impose aux économies encore fragiles des pays en développement. Il s'agit de trouver un cadre adéquat qui règlemente les transferts.

En la matière, nous souscrivons, dans les grandes lignes, aux propositions, faites par le groupe des 77 de la CNUCED lors des sessions de 1975 et de 1976 à la conférence de Nairobi.

La technologie est une part de l'héritage universel de l'numanité auquel tous les pays ont droit pour, si non éliminer, au moins atténuer les intolérables inégalités économiques, dans le cadre d'un nouvel ordre économique international.

L'élaboration d'un "code de conduite des transferts de technologie" s'avère nécessaire; ses principaux objectifs seraient :

- Le renforcement des capacités d'organisation et de réception des techniques nouvelles des pays en développement,
- L'amélioration de l'accès à la technologie et des coûts et prix raisonnables et abordables pour tous,
- La promotion des transactions "non liées" quant au choix des différents éléments de la technologie, l'évaluation des coûts, l'organisation, les formes et canaux institutionnels.

Ce code qui intéressera tous les types de technologie sera le garant de transactions profitables aux pays en développement et qui ne les rendent pas perpétuellement "esclaves."

Les Transferts de Technologie

La Formation

Qui dit transfert de technologie dit présence de cadres en quantité et en qualité suffisantes dans tous les secteurs de l'économie, capables d'assimiler les techniques et les technologies des plus simples aux plus complexes, afin que les économies des pays dits en développement tirent le maximum de profit des technologies importées.

Cela implique également que tous les artisans de l'économie jusqu'à l'échelle la plus basse aient une formation qui les rende à même, chacun à son niveau, d'exécuter les tâches techniques obligatoires.

Cette formation qui doit à notre point de vue englober aussi bien l'adulte que l'enfant, les artisans d'aujourd'hui et les artisans de demain, doit pouvoir se faire avant tout, dans les pays en développement. Cependant certains perfectionnements et certains recyclages dans les pays développés sont nécessaires pour compléter le savoir-faire.

Formation de l'Enfant

L'enfant est le futur artisan de l'économie. Une ouverture de son intelligence à l'esprit scientifique dès le jeune âge fera de lui plus facilement un technicien confirmé de haut niveau. Il convient que des structures adéquates soient étudiées et mises en place pour donner cette ouverture d'esprit à l'enfant dans le même âge.

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Formation Pratique des Masses Laborieuses

Le paysan, l'ouvrier agricole pour être plus efficace a besoin d'un minimum de formation, de perfectionnement, de recyclage; toutes les manifestations, les actions qui peuvent améliorer la formation pratique du travailleur doivent être encouragées. Un mauvais paysan ne profite pas à l'économie.

Les fêtes agricoles, les actions de démonstrations, les concours agricoles, les stages de perfectionnement des paysans etc... sont autant de moyens qui peuvent augmenter leur technicité, et les rendre plus efficaces.

Les Structures de Formation Techniques et Professionnelles

La mise en place et pour le développement des structures de formation techniques et professionnelles dans les pays en développement sont une condition préalable au transfert des technologies si ce transfert se veut efficient et durable.

En effet le transfert doit se faire par des hommes compétents qui non seulement ont assimilé mais peuvent modifier et adapter les nouvelles techniques aux conditions particulières de leur pays. Ces hommes valables doivent être suffisamment nombreux et couvrir tous les secteurs de l'économie. Si l'importation d'un spécialiste est nécessaire et indispensable, cette importation devrait être temporaire et couvrir simplement le temps nécessaire à la formation des nationaux. Le spécialiste devrait jouer le rôle de Conseiller Technique le temps que les Techniciens du pays acquièrent un minimum d'expérience.

Si des structures de formation techniques et professionnelles sont nécessaires pour équiper les économies de cadres supérieurs, il en est également de même pour les techniciens des niveaux moyen et subalterne qui sont des maillons indispensables à toute économie.

Ainsi donc que ce soit dans les domaines de l'agriculture, de l'industrie, du commerce etc... des structures adéquates de formation sont, nous en sommes convaincus, des préalables et la mise en place de ces structures ne peut se faire sans concours techniques et financiers des pays développés.

Les Perfectionnements et les Recyclages à l'Extérieur

Le développement de la science a permis d'atteindre dans la plupart des secteurs une technicité telle que les jeunes pays en voie de développement ne peuvent se payer le luxe d'avoir des écoles très spécialisées dans tous les domaines de leur économie. Ils doivent par conséquent négocier avec les pays développés le perfectionnement et le recyclage de leurs techniciens dans certains domaines très spécialisés. Cette collaboration est nécessaire pour rendre efficient le transfert de certaines technologies et doit être prise sérieusement en considération.

La Recherche Scientifique et Technique

Que ce soit dans le domaine de l'agriculture, des agro-industries ou de l'industrie, les pays en voie de développement connaissent souvent des situations et des conditions particulières. Une recherche scientifique et technique permettra à ces pays de trouver des solutions à leurs problèmes spécifiques.

C'est-à-dire que la formation des chercheurs est un autre problème qui préoccupe beaucoup les pays en voie de développement.

Nous pensons que de plus en plus les pays en voie de développement doivent pouvoir former sur place des chercheurs qui soient imprégnés d'abord des problèmes qu'ils doivent résoudre et ensuite mettre en place ce qu'il faut pour la recherche des solutions.

On peut se permettre ici de citer un exemple :

La recherche agronomique telle qu'elle est menée dans les pays développés (Europe, Etats-Unis) cherche à résoudre des problèmes du fermier ou de l'entreprise agricole. Les solutions qu'elle préconise s'adresse à des fermiers bien cultivés, lettrés, souvent de niveau ingénieur comme aux

U.S.A. et qui disposent de moyens de production qui n'ont rien de comparable à ce dont dispose le petit paysan voltaïque, qui cultive en moyenne 5 ha manuellement. Les moyens financiers et matériels ne constituent pas un facteur limitant chez les grands fermiers tandis que dans les pays en développement c'est un des principaux facteurs limitants. Il en découle que la recherche agronomique ne peut pas avoir les mêmes préccupations et les mêmes objectifs. Dans les pays développés il suffit de trouver les techniques — même sophistiquées — et les variétés, les moyens ne manquent pas et tous les agriculteurs ont la même formation qu'il faut.

Dans les pays en voie de développement comme la Haute-Volta, il faut tenir compte du niveau où trouve la masse des petits fermiers souvent ancrés dans des habitudes ancestrales, illettrés, peu ouverts, disposant de moyens infimes et n'ayant pas accès aux crédits agricoles presque inexistants. Ce sera difficile de lui faire faire un saut qualitatif en voulant l'amener du Moyen Age au XXe siècle.

Il n'a ni les dispositions ni les moyens qu'il faut.

Par contre, si l'on réfléchit et l'on cherche comment par étape, et par palier on peut élever sa technicité on aura plus de chance de réussir.

Pour arriver à cela il faut des chercheurs qui soient à même de s'imprégner de ces problèmes que vit quotidiennement la population voltaïque afin d'être capables de sortir un programme de recherche qui "colle" avec ces réalités. Cette recherche-là sera beaucoup plus efficace que celle qui donne des résultats bons mais inapplicables par manque de technicité et de moyens.

Les Transferts des Brevets et des Techniques

Les brevets, le savoir-faire, les procédés de fabrication constituent une des plus grandes richesses des pays développés et leur appartiennent pour 90%. Leur transfert obeit à une législation complexe et onéreuse.

- Une des premières mesures à prendre serait de lever partiellement l'exclusivité de la propriété et de diminuer le coût d'exploitation .
- La deuxième mesure serait la possibilité d'adaptation, mais cependant pour des besoins strictement intérieurs.
- La troisième mesure est la promotion tant dans les pays développés que dans les pays en développement, de la technologie intermédiaire à mettre à la disposition des pays en voie de développement.

Dans tous les cas se pose la question de savoir quel type de technologie transférer, pour certains cas particuliers, dans quel contexte.

Les pays en développement ne peuvent pas se contenter de la technologie du XVIIIe siècle dans certains domaines alors qu'ils ne peuvent pas non plus rentabiliser celle du XXe siècle dans d'autres — la technologie étant de plus en plus sophistiquée, on est obligé de suivre son temps.

- Nous pensons que pour la technologie de pointe nécessitant des compétences dont ne disposent pas encore les pays en développement, la *prudence* est de rigueur et l'intégration régionale est souhaitable.
- Pour les autres types de technologie, la préférence sera donnée à celle permettant d'utiliser au maximum les ressources physiques et humaines locales; une industrialisation qui permette d'élever le niveau de vie de la majorité de la population, qui est ou sera entièrement *maitrisée* à court terme par les nationaux.
- Former en grand nombre des techniciens et ingénieurs qui feront évoluer la technologie sans trop d'à-coups car l'expérience montre que les populations, quand elles le peuvent, préfèrent les produits des technologies très avancées.

L'Expérience Sénégalaise

Djibril Sene*

Je commencerai par féliciter l'ICRISAT, dont l'action est orientée vers le développement de technologies de progrès pour l'agriculture, d'avoir organisé un débat qui ne se limite pas au seul aspect du développement de ces technologies particulières mais traite, aussi, du problème du transfert au monde rural des technologies mises au point par la recherche.

Le Sénégal est un pays qui dispose depuis déjà de nombreuses années d'une infrastructure de recherche agronomique et d'un nombre de chercheurs que l'on peut qualifier l'une et l'autre d'importants, surtout si on les compare à la situation qui est encore celle de la plupart des autres Etats de la zone sahélienne.

Ceci tient au fait que le Sénégal a eu la chance d'hériter, au moment de son indépendance, d'un important dispositif de recherches agricoles, zootechniques et vétérinaires, mis en place jadis par la France, non pour les seuls besoins du Sénégal, mais pour ceux de l'ensemble de la partie occidentale de la zone tropicale semi-aride de l'Afrique au nord de l'equateur : depuis la Presqu'île du Cap Vert à l'Quest jusqu'au Niger à l'Est. C'est ainsi que le Centre Sénégalais des Recherches Agricoles de Bambey, créé depuis maintenant plus de cinquante ans, eut à jouer de longues années durant, avant l'accession des Etats francophones de l'Afrique de l'Ouest à l'Indépendance, le rôle de Centre Fédéral des Recherches Agronomiques de l'ensemble des territoires de la partie sahélienne et soudanienne de l'Afrique de l'Ouest alors sous tutelle française.

Si l'on peut porter au crédit de la recherche agronomique réalisée au Sénégal de nombreux acquis scientifiques et techniques de valeur, il n'en reste pas moins vrai que le monde paysan sénégalais continue, quant à lui, à n'évoluer que très lentement, trop lentement au gré des dirigeants de ce pays si on prend comme critère de jugement la façon dont a varié le revenu des paysans au cours des dernières décennies.

L'expérience des faits nous prouve chaque jour davantage que l'un des freins les plus importants de l'évolution de ce monde rural provient de l'inaptitude qu'il a à faire passer au niveau du paysan une grande partie des produits de la recherche.

Est-ce à dire que le message ou les messages délivrés par la recherche en direction du monde rural sont pour la plupart des messages défectueux, non recevables par les paysans, et si oui, pourquoi?

Ou bien, est-ce à dire que les structures d'encadrement technique du monde paysan, chargées de véhiculer les messages de la recherche et de les faire pénétrer dans ce monde paysan n'ont pas su, jusqu'à présent, jouer le rôle qu'on leur a confié et, dans ce cas, pourquoi?

Ces questions méritent sans aucun doute des réponses, et c'est en vue de les obtenir que nous avons commencé à engager depuis quelques mois, au Sénégal, une vaste réflexion sur les rapports recherche-developpement et sur le fonctionnement des sociétés d'encadrement technique du monde rural.

Je me contenterai de vous faire part, ici, de quelques réflexions personnelles concernant les messages délivrés actuellement au Sénégal par la recherche agronomique en direction du monde paysan, laissant délibérément de côté le second aspect des choses : le fonctionnement des sociétés d'encadrement technique du monde paysan.

Mes réflexions porteront sur deux points :

- La façon dont les messages délivrés en direction du monde rural ont été, jusqu'a présent, composés par la recherche.
- La facon dont ces messages ont été véhiculés jusqu'à présent, depuis le laboratoire ou le champ situé au centre de recherche jusqu'au champ paysan.

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La Composition du Message Délivré par la Recherche

Ayant appartenu pendant longtemps à la recherche mais ayant, aujourd'hui la responsabilité du développement rural dans son ensemble, il m'apparaît, aujourd'hui, que la recherche agronomique conduite au Sénégal, bien qu'ayant la qualité d'être une recherche sérieuse et effectuée par des chercheurs (nationaux et étrangers) pour la plupart très compétents chacun dans sa spécialité, est une recherche qui n'en possède pas moins deux défauts contre lesquels nous tentons, du reste, de réagir :

- Il me semble que cette recherche est une recherche souvent beaucoup trop intellectualisée, sophistiquée, oserai-je dire, et pas assez pragmatique, ce qui donne souvent l'impression que les chercheurs sont davantage tentés de faire de la recherche pour le plaisir de la recherche plutôt que pour contribuer à la satisfaction des besoins les plus immédiats du monde rural. Peut-être, est-ce, en réalité, parce que ces chercheurs se préoccupent davantage d'un futur lointain que du futur immédiat.
- Il me semble, par ailleurs, que beaucoup de ces chercheurs n'ont pas su ou pas voulu, jusqu'à présent, se mettre suffisamment à l'écoute du monde rural pour bâtir leurs programmes de recherches.

Il s'agit, tant en ce qui concerne l'un et l'autre de ces deux défauts, d'une question de mentalité liée, me semble-t-il, en grande partie, au mode actuel de formation de ces chercheurs :

- Formation, d'une part, trop universitaire, conduisant préférentiellement les chercheurs vers la recherche de diplômes de plus en plus élevés ou à la publication de notes et mémoires scientifiques de portée théorique au détriment de la satisfaction des besoins pratiques les plus immédiats de notre agriculture.
- Formation conçue, d'autre part, dans un cadre de pensée plus adaptée, me semble-t-il, aux pays industrialisés qu'aux pays en voie de développement : dans le respect de l'idée que c'est à la recherche et à la recherche seule que revient le soin de dire quelles sont les voies par lesquelles devra se faire le progrès rural, donc de définir le contenu du message que les sociétés de vulgarisation seront ensuite chargées de diffuser dans le monde paysan. Au Gouvernement et aux sociétés chargées de l'encadrement technique du monde paysan le soin de provoquer, par la suite les conditions sociales et économiques qui permettront d'accepter les innovations proposées par la recherche quels qu'en soient la nature et le coût.

J'admets, à la rigueur, que telle puisse être la démarche de pensée suivie pour le futur lointain. Je ne saurais, par contre, y souscrire pour le court et moyen terme. Cela ne ferait qu'accentuer le fossé que nous sommes obligés de constater actuellement au Sénégal entre les services de la recherche et les sociétés d'encadrement technique du monde rural, déjà trop tentées d'entreprendre des études ou des essais qui ne sont pas de leur ressort, sous prétexte qu'il s'agit d'études ou d'essais destinés à apporter des réponses à des problèmes que la recherche n'a pas voulu ou pas su prendre en compte jusqu'à présent.

Il me semble indispensable que les innovations techniques proposées par la recherche pour ce court et ce moyen terme soient des innovations vraiment adaptées à l'état d'évolution du monde rural prévisible durant cet intervalle de temps dans les domaines psychologique, sociologique (nature de l'exploitation, structure familiale, etc...) et économique (crédit, commercialisation, coopératives, etc...) en fonction de la politique établie par le Gouvernement dans ces différents domaines.

Il n'ignore pas qu'il sera sans doute très difficile d'obtenir dans l'immédiat que les chercheurs déjà en place changent de mentalité, bien qu'un certain effort d'évolution puisse être constaté. Je suis, par contre, plus confiant pour l'avenir, depuis que nous avons décidé de créer au Sénégal un Institut National de Développement Rural chargé d'assurer, sur place, la formation de la totalité des cadres de haut rang dont nous avons besoin, tant au niveau de l'Administration que des sociétés d'encadrement du monde rural ou de la recherche, ce qui n'excluera nullement pour nos chercheurs la possibilité de stages complémentaires à l'étranger, mais ce ne seront que des stages de spécialisation. Ce nouveau système de formation devrait pouvoir entrer en vigueur au cours de la prochaine année.

Le Transfert du Message depuis la Station Centrale de Recherche jusqu'au Champ du Paysan

Lorsqu'on se réfère aux nombreuses discussions qui ont pu avoir lieu au Sénégal au cours de ces derniers mois entre la recherche et les sociétés d'encadrement technique du monde rural, on se rend compte que ce qui préoccupe essentiellement ces dernières est de pouvoir disposer :

- d'une part, de résultats applicables à court ou moyen terme dont la quantification soit connue dans l'espace (délimitation précise des différentes zones d'application possible de ces résultats) et dont la quantification soit connue dans le temps (variation de ces résultats en fonction des conditions pluriannuelles caractéristiques d'une zone d'application déterminée et probabilité de ces variations en vue d'une appréciation du risque).
- d'autre part, des informations qui permettront de juger des contraintes sociales et économiques à l'adoption des thèmes de développement proposés.

Comment la recherche a-t-elle tenté de répondre jusqu'à présent à cette double préoccupation et dans quelle mesure y est-elle parvenue?

Il faut reconnaître que, quelle que soit la façon dont les messages délivrés par la recherche agronomique au Sénégal ont pu etre conçus jusqu'à présent, la recherche sénégalaise s'est toujours montrée extrêmement soucieuse de juger quelle pouvait être la valeur spatio-temporelle de chacun des résultats techniques obtenus en station de recherche; ce qui répond à la première des deux préoccupations exprimées par les sociétés d'encadrement technique du monde rural.

Ceci a été fait, dans un premier temps, grâce à la mise en place d'un réseau d'essais multilocaux couvrant l'ensemble du territoire sénégalais; puis, ultérieurement, par la création de certaines structures particulières supplémentaires dites "Points d'Appui de Prévulgarisation et d'Expérimentation Multilocale" (PAPEM) qui associent à la caractéristique d'être un des éléments constitutifs du dispositif normal des essais multilocaux, la fonction de devoir jouer également un rôle démonstratif vis-à-vis du monde paysan en abritant d'autres essais synthétisant l'ensemble des différentes innovations jugées par la recherche comme étant des innovations intéressantes à introduire dans le milieu rural.

Ces expérimentations ne permettent toutefois pas de répondre à la seconde des préoccupations exprimées par les sociétés d'encadrement technique du monde rural : fournir des informations qui permettent de juger des contraintes sociales et économiques a l'adoption des thèmes de développement proposés.

D'où la mise en place par la recherche à partir de 1969 d'un troisième type de structure intermédiaire entre les stations centrales de recherche et le monde rural : les Unités Expérimentales Régionales (UER) qui ont fait l'objet depuis leur création d'une abondante littérature accompagnée de définitions plus ou moins ambitieuses sur leur rôle :

"Unité de recherche prospective sur les systèmes de production et modeles d'exploitations" selon René TOURTE, qui fut l'un de ceux qui conduisirent le travail de réflexion qui devait aboutir à la création de ces unités; ou encore, selon le même auteur, "exemple d'utilisation par la Recherche Agronomique de la démarche systeme."

"Entité socio-géographique limitée ou les résultats de la Recherche Agronomique sont testés en vraie grandeur, en vue de mettre au point et de perfectionner constamment des systèmes techniques, tenant compte des liens existant entre le milieu physique, le milieu humain et les objectifs du plan de développement régional" selon J. KILLIAN.

"Unité correspondant a la mise en œuvre d'un processus de développement contrôlé à l'initiative de la Recherche et concernant un ensemble socio-économique envisagé dans sa totalité" selon L. MALASSIS. Etc...

Ces definitions traduisent suffisamment bien l'esprit dans lequel ces Unités furent conçues pour que nous n'ayons pas à insister davantage sur ce point. Je préciserai seulement que leur conception est le fruit d'un travail de réflexion entrepris principalement par des agronomes généralistes donc plus proches des réalités du monde rural que la plupart des autres chercheurs : spécialistes de l'amelioration des plantes, de la conservation et de l'amélioration de la fertilité des sols, de la lutte

contre les ravageurs etc . . . plus facilement tentés de s'enfermer dans leurs spécialités.

A l'origine de cette réflexion est l'échec relatif de la plupart des projets de développement rural mis en œuvre au Sénégal depuis l'indépendance et les difficultés de diffusion de certaines propositions de la recherche agronomique, celles, en particulier, visant a la création d'un milieu physique plus favorable a l'expression des cultures traditionnelles ou nouvelles; parmi ces propositions, il faut citer en particulier le labour profond et l'enfouissement de la matière organique.

Je ne vous décrirai pas, ici, la façon dont fonctionnent ces Unités Expérimentales; je me contenterai de souligner le fait que l'observation porte sur l'ensemble du milieu, c'est-à-dire que l'on s'efforce d'etudier toutes les conséquences (techniques, économiques, sociologiques) de l'introduction d'une innovation dans ce milieu et qu'il s'agit, par conséquent, d'une approche véritablement pluridisciplinaire.

Que penser de l'activité de ces Unités Expérimentales dont la création remonte maintenant à dix années?

La réponse n'est pas facile à donner car, en fait, le bilan diffère selon qu'on se place du point de vue de la recherche ou du point de vue des sociétés d'encadrement technique du monde rural.

Si je me place du côté recharche, je suis convaincu, compte tenu de la conception que j'ai du rôle de la recherche agronomique et de son fonctionnement, que la création des Unités Expérimentales a constitué un élément décisif de progrès dans le fonctionnement de la recherche agronomique au Sénégal, en ce sens que les problèmes rencontrés par les chercheurs au sein de ces Unités Expérimentales les amènent a prendre conscience, un peu plus chaque jour, qu'il est nécessaire, si on veut donner a la recherche agronomique le sens utilitaire qui doit être le sien au Sénégal :

- d'une part, de définir les themes et priorités de recherche a partir des données du milieu;
- d'autre part, de viser a la mise au point de techniques intégrées et de systèmes compatibles avec les systemes existants, avant de les proposer a la vulgarisation, ainsi que de viser a identifier les contraintes.

Je déplore qu'en dépit de l'évolution des mentalités qui a déja commencé à se dessiner dans ce sens chez certains chercheurs, il y en ait encore trop qui continuent a conduire leurs recherches en dehors de ces principes, en particulier les sélectionneurs, surtout affectés à l'amélioration des plantes allogames (les sélectionneurs mil, par exemple) plus préoccupés souvent, me semble-t-il, de chercher un hétérosis maximum dans l'absolu qu'un hétérosis maximum dans le cadre de l'utilisation de ces especes à l'intérieur d'un assolement et d'une rotation, voire d'un usage technologique des produits récoltés imposant à la plante différentes contraintes de résistance aux parasites, de cycle, d'architecture, de culture et de qualité de graine.

Si je me place du côté du développement, je suis obligé, par contre, de constater que les Unités Experimentales ont fourni aux sociétés d'encadrement technique du monde paysan peu d'enseignements jusqu'a présent, en dehors de certaines données techniques dont il ne me semble pas évident qu'il y avait réellement besoin d'une structure du type Unité Expérimentale pour mettre en évidence leur intérêt et leur possibilité d'emploi (dosage d'engrais, dates de semis, écartements de plantes, développement de la culture de maïs, développement de la culture attelée, etc . . .).

Il est assez surprenant de constater qu'en dépit d'études très sérieuses permettant une connaissance approfondie du milieu sur lequel opèrent ces "Unités" (études sur la tenure foncière et les disponibilités en terre, le travail agricole familial et saisonnier, les rapports de travail, les temps de travaux, l'établissement de comptes d'exploitation) les chercheurs n'aient pas été capables, apres dix ans de fonctionnement de ces Unités Expérimentales, d'indiquer aux sociétés d'encadrement du monde rural comment parvenir a une meilleure organisation de ce milieu. On retrouve à l'intérieur des Unités Expérimentales les mêmes problèmes qu'a l'extérieur concernant le fonctionnement du crédit et les remboursements de dettes, l'organisation et la gestion des coopératives, l'utilisation des matériels agricoles au sein de l'unité sociale traditionnelle définie par la communauté de résidence.

Il est tout aussi surprenant de constater que malgré ces études et un encadrement du paysan très supérieur à celui mis en place dans les sociétés d'intervention en milieu rural, il n'a pas été possible d'obtenir, au sein de ces Unités Expérimentales, une meilleure diffusion qu'a l'extérieur de certains themes de la recherche considérés pourtant par les chercheurs comme essentiels pour la réalisation

de la politique d'intensification des cultures qu'ils préconisent, et jugée par tous comme étant, effectivement, la seule voie possible de progrès réel du monde rural et de l'agriculture sénégalaise.

Ceci démontre bien que l'objectif de la recherche doit être au Sénegal la mise au point d'innovations qui puissent être d'abord, acceptables par le monde rural, l'évolution du milieu ne devant être que le corollaire indispensable, orientée uniquement de manière à faciliter l'adoption définitive de ces innovations dans le cadre de la politique agricole nationale.

Il me semble qu'il devrait y avoir peut-être là une leçon à tirer par l'ICRISAT pour la définition de sa politique de travail en Afrique.

Je ne pense pas que ce soit depuis l'Inde que cet Institut puisse conduire un travail vraiment efficace pour l'Afrique, surtout en ce qui concerne le développement de la production des espèces allogames. Mais peut-être fais-je erreur.

Il me semble, par ailleurs, indispensable que le travail programmé pour l'Afrique, le soit en très étroite collaboration avec les différents services nationaux des Etats africains, seuls capables, à mon avis, d'indiquer à l'ICRISAT le sens dans lequel le travail conduit par l'ICRISAT pour l'Afrique doit être réalisé si on veut qu'il ait une utilité réelle pour le monde paysan africain.

Transfert de Technologie en Agriculture Pluviale dans la Région Sahélienne

Nalla O. Kane*

Avant d'aborder ce problème j'aimerais tout d'abord le situer dans le cadre des attributions dévolues à l'Institut du Sahel. Cette Institution qui a connu le jour effectivement en décembre 1977 à la réunion des Chefs d'Etats à Banjul avait été souhaitée par ceux-ci dès le sommet constitutif du Comité Permanent Inter-Etats de Lutte Contre la Secheresse dans le Sahel (CILSS) en septembre 1973 à Ouagadougou. Cet outil de coopération sous-régionale, chargé de recherches appliquées et de la Coordination des activités de recherche et de formation dans le Sahel, devait par la résolution n° 3253 attirer l'attention de l'Assemblée Générale des Nations Unies qui recommanda au Secrétaire Général de cette institution d'en accélérer les travaux préparatoires.

C'est ainsi qu'en mai-juin 1975 une mission préparatoire du PNUD conjointement avec le PNUE devait définir les grandes orientations du Futur Institut du Sahel. Celles-ci ont été discutés en avril 1976 à Bamako et devaient aboutir à la décision de création immédiate de l'Institut du Sahel en décembre 1976 à N'Djaména. En octobre 1977, une réunion élargie sur l'Institut du Sahel devait étudier les Statuts de l'Institut ainsi que les programmes de démarrage et de Première Génération. Les programmes et Statuts ont été adoptés à la Conférence des Chefs d'Etats le 19 décembre 1977 à Banjul.

Les fonctions de l'Institut telles qu'adoptées par la Conférence des Chefs d'Etats du CILSS à Banjul sont les suivantes :

1. La collecte, l'analyse et la diffusion des résultats de la Recherche Scientifique et Technique.
2. Le transfert et l'adaptation des technologies.
3. L'harmonisation et la coordination des recherches scientifiques et techniques.
4. La formation des chercheurs et des techniciens de développement.

Le thème du présent symposium s'inscrit dans le cadre du point 2 de l'attribution de l'Institut, a savoir : le transfert et l'adaptation des technologies. Bien que le transfert des technologies au niveau paysan soit plutôt du ressort des Etats, l'Institut du Sahel par son rôle de promotion et de coordination des activités de recherche et de formation ainsi que par le rôle qui lui est dévolu dans la collecte, l'analyse et la diffusion des résultats de la recherche scientifique et technique, contribue sensiblement à l'amélioration des techniques au niveau paysan.

En effet l'Institut du Sahel doit participer indirectement au transfert de technologies au niveau paysan par :

- La formation des agents de vulgarisation et de développement.
- La définition de paquets technologiques adéquats à transférer aux paysans (par le biais d'informations scientifiques et techniques obtenues de l'Institut du Sahel).
- L'échange d'expériences entre les différents encadreurs des pays sahéliens.
- L'amélioration des conditions de diffusion et des programmes de radio rurale ainsi que des autres média dans les Etats membres du CILSS.

On peut résumer les conditions de succès du transfert de technologies en milieu paysan sahélien en trois points principaux.

1. La formation d'excellents encadreurs et l'alphabétisation fonctionnelle des paysans.
2. La définition de paquets technologiques adaptés aux conditions socio-économiques du paysan.
3. Pour la large masse un programme bien étudié de radio rurale se basant essentiellement sur le point 2 ci-dessus. Ce programme est bien entendu diffusé en langues nationales du pays (ex. langues vernaculaires).

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Dans chaque pays de la région du CILSS des organismes de vulgarisation sont crées soit dans le cadre des structures traditionnelles de l'agriculture, soit dans le cadre plus opérationnel des organismes de développement. Ce sont, par exemple :

- La Société de Développement et Vulgarisation Agricole (SODEVA) dans le bassin arachidier du Sénégal.
- Les Organismes Régionaux de Développement (ORD), Haute-Volta.
- Les Opérations de Développement (Opération Mil-Mopti par ex, au Mali).
- Projet à l'échelle d'une zone d'un pays comme le projet 3M au Niger.

Dans la majorité des cas le transfert se fait selon la technique de la diffusion en tache d'huile utilisant principalement l'effet de démonstration. En effet dans la zone d'intervention sont choisis un certain nombre de paysans "modèles" auxquels sont enseignées les techniques à transférer. Ces paysans servent soit d'instructeurs aux autres paysans, soit d'incitateurs pour leurs voisins tentés d'utiliser les mêmes techniques pour obtenir les mêmes rendements que le paysan modèle.

On utilise souvent pour une information de masse les techniques audio-visuelles qui sans doute ont leur importance mais ne peuvent pas remplacer l'expérience directe que les paysans peuvent tirer de la visite du champ des fermiers modèles. C'est plutôt après cette expérience du terrain qu'ils tirent meilleur profit d'un film relatif aux techniques à vulgariser.

Dans la définition des paquets technologiques à transférer, il y a un facteur important qu'il faut toujours avoir à l'esprit : les conditions socio-économiques du paysan. En effet toute technique s'intégrant difficilement à la culture du monde rural-cible ou dépassant les capacités financières de ce dernier a très peu de chance de succès.

Il en est de même d'un paquet technologique comportant des thèmes complexes et d'une technicité assez élaborée.

Cette remarque n'est cependant pas une panacée car on a souvent rencontré des paysans ayant une extraordinaire capacité d'adaptation. C'est ainsi qu'au démarrage de programme de l'O.M.V.S., il avait été dit que les paysans du Fleuve Sénégal n'arriveraient jamais à maitriser la technique de la riziculture avec contrôle total de l'eau. Celle-ci est en effet très complexe, comme chacun sait. Cette appréhension a été démentie par les faits. Bien que les paysans du Bassin du Sénégal ne soient pas riziculteurs traditionnels ils se sont avérés aussi compétents que les asiatiques grâce à un don d'adaptation qui a étonné tout le monde.

Le transfert et l'adaptation des technologies est un domaine pour lequel il y a encore beaucoup à faire dans la région sahélienne. Il est bien connu que les recherches nationales comme internationales ont obtenu dans la région des résultats satisfaisants mais qui n'ont pas toujours eu les applications voulues faute, non seulement de moyens financiers suffisants, mais aussi de méthodes réellement adéquates pour l'application des résultats. C'est ainsi que dans le projet récent étudié par l'Institut du Sahel sur l'amélioration des mils, sorgho et niébé, l'accent a été mis en priorité en dehors de la formation et des échanges d'expérience entre chercheurs, sur le transfert, par les essais multilocaux, des variétés sélectionnées et éprouvées dans certains Etats.

L'Institut du Sahel œuvrera dans le cadre de ces essais à trouver des méthodes adéquates en vue de la maitrise des différentes techniques liées à la diffusion de ces variétés en milieu paysan.

Nous avons parlé du transfert de technologie comme si le paysan n'était appelé qu'à recevoir et qu'en retour il n'était pas créateur de techniques. C'est là sans doute mal apprécier la capacité des paysans sahéliens. Dans le milieu traditionnel des techniques nombreuses existent relatives aux méthodes culturales adaptées aux différents types de sol, à la sélection des semences et leurs conservations ainsi qu'à la lutte contre les parasites et les déprédateurs. Ces techniques traditionnelles bien que n'ayant qu'un caractère local sont très adaptées aux conditions economiques et sociales du paysan.

Les autorités de recherches et de développement devraient se pencher davantage sur ces techniques, les améliorer en vue de leur diffusion qui sera sans doute plus rapide et moins onéreuse parce que produites par le génie même de ces populations.

Avant de terminer mon intervention, j'aimerais remercier l'ICRISAT pour l'invitation faite à l'Institut du Sahel à participer à ce colloque et remercie tout le personnel pour l'excellent accueil qui nous a été réservé.

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