A METHODOLOGY FOR ON-FARM CROPPING SYSTEMS RESEARCH

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J. A. LITSINGER, and R. A. MORRIS

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FOREWORD

The Asian Cropping Systems Working Group brings together scientists from national agricultural research institutions. The group has met under the auspices of the International Rice Research Institute (IRRI) nine times since 1975 to formulate a framework for cropping systems research and develop the needed specific research methods.

The group represents the following countries and institutions:

Bangladesh	Bangladesh Rice Research Institute
Burma	Agricultural Research Institute
India	Indian Council for Agricultural Research
Indonesia	Central Research Institute for Agriculture
Nepal	His Majesty's Department of Agriculture
Malaysia	Malaysian Agricultural Research and Development Institute
Philippines	University of the Philippines
South Korea	Office of Rural Development
Sri Lanka	Department of Agriculture
Thailand	His Majesty's Department of Agriculture
International Rice Research Institute	

The research methodology resulted from the effort of a large number of people. The research station-oriented work on crop intensification, initiated in 1968 by Richard R. Bradfield, gave rise to on-farm research in the early 1970s by Richard R. Harwood and Gordon Banta. Strong support by the International Rice Research Institute and by the International Development Research Centre of Canada led to the initiation of on-farm cropping systems research at several sites in South Asia in 1974 and the formation of the Cropping Systems Working Group in 1975. Since then, under the guidance of Virgilio R. Carangal, cropping systems network coordinator at IRRI, the number of on-farm cropping systems research sites has grown to more than 50 in 9 countries in South and Southeast Asia.

The Working Group at each of its meetings discussed research methods for the different components of the cropping systems research framework developed in 1975. In response to its requests, IRRI formulated and tested several approaches to agronomic experimentation on small farms, baseline surveys, site description, evaluation of farmers' cropping systems, design of intensive cropping patterns, and use of yield-loss trials for pest control. From among the many contributors to this book, those who — through the network or their own institutions — have made outstanding inputs are:

- Suryatna Effendi, Central Research Institute for Agriculture, Indonesia;
- Arturo Gomez, University of the Philippines at Los Baños;

- Zahidul Hoque, Bangladesh Rice Research Institute, Bangladesh;
- Richard R. Harwood, now at the Organic Gardening and Farming Systems Research Center, Rodale Press, Inc., Pennsylvania, U.S.;
- Jerry McIntosh, Central Research Institute for Agriculture-IRRI, Indonesia;
- David N. Norman, Kansas State University, U.S.; and
- Mervyn Sikurajapathy, Department of Agriculture, Sri Lanka.

The final documentation, refinement, and compilation of research methods were done by the staff of IRRI's Cropping Systems Program:

- H. G. Zandstra (program leader) compiled the manual and guided the development of the overall research framework, the methods for design and testing of cropping patterns and component technology;
- E. C. Price (economist) prepared most of the economic components of the environmental description, design, and testing chapters. He also contributed greatly to the general structure of the methodology and to the definitions used in this book;
- J. A. Litsinger (entomologist) developed the on-farm research methods for insect pest control and contributed to the component technology section in the design and testing chapters and in the appendix;
- R. A. Morns (agronomist) contributed to the structure and content of each chapter. He helped develop the methods related to land-type description and the design and management of cropping pattern trials. He contributed the appendix on determining fertilizer rates for crops in cropping systems;
- V. R. Carangal (network coordinator) was responsible for the sections and appendix on varietal testing;
- Keith Moody (weed scientist) developed the weed research component and the accompanying appendix;
- S. K. Jayasuriya (network economist) contributed to the economic evaluation of cropping patterns and prepared the appendix on cost and returns.

Valuable comments on earlier drafts of this book were received from Gordon Banta, Richard Bernsten, Marlin van der Veen, David Norman, Arturo Gomez, and John Pendleton.

Walter G. Rockwood, assisted by Corazon V. Mendoza, edited the manuscript.

NYLE C. BRADY
Director general

Chapter 1
DEVELOPMENT OF A CROPPING SYSTEMS METHODOLOGY

Annual production from a given area of land can be increased by improving the yield of a crop, or by growing an extra crop during the year. Cropping systems research seeks the technology that will increase production by both methods.

Long growing seasons, small land holdings, and high labor-land ratios make complex multicrop production systems possible in most tropical regions. The availability of new crop varieties, crop establishment techniques, and fertility and pest management methods allows the formulation of new crop sequences or crop combinations that are managed differently from the existing ones. The new sequences have the potential to greatly increase food production and the benefits farmers derive from their land.

Research to develop these improved crop production methods must recognize existing trade-offs between the different farm enterprises or parts of these. The simple replacement of one management component of a crop with another is seldom acceptable to farmers because it causes major disturbances elsewhere in the management of that crop, a succeeding crop, or even a crop growing in another field.

The limited adoption by farmers of new production techniques (Brady 1977) reflects weaknesses in the ability of researchers to formulate production methods that compete favorably with the ones farmers already use. Finding alternative cropping systems and comparing their performance with existing ones in detail, therefore, require careful study of the factors that determine crop production at the farm level.

In the past decade, a methodology has evolved for analyzing the crop production environment, selecting sites where potential for introducing an extra crop or increasing crop yields exists, and establishing techniques for increasing crop production or cropping intensity. Furthermore, by working in farmers' fields, and by

analyzing the social and economic as well as the biophysical constraints that may inhibit the introduction of the extra crop, methods of realizing the extra potential are rapidly assessed. As a component of national agricultural research activities, on-farm cropping systems research is designed to provide important feedback to commodity and disciplinary research programs about the farm condition, performance of new materials and management practices in the farm setting, and agricultural research priorities that reflect the farmers' needs.

This methodology for on-farm cropping systems research is for use by professionals engaged in actual research and for those active in the management, structuring, and funding of agricultural production research and in the training of research and extension staff. This book provides background information, where needed, and defines concepts and research objectives and can help a reader justify a choice of methods. Examples are used where possible, but no attempt to provide a fixed set of treatment designs, questionnaires, or even survey techniques has been made, because experience in the cropping systems network has indicated that the most appropriate choice of these should be made site by site.

This manual starts with an introduction of general concepts—the definition of cropping systems and cropping systems research and the reasons for the choice of on-farm research as a way to find improved cropping systems that are acceptable to farmers. The remainder of the manual describes methods for site selection, site description, design of cropping patterns, and on-farm testing of such patterns. Details of several research or analytical techniques are provided in the appendices.

The final chapter covers ways in which research results can be extended to a greater area and to farmers through production programs. Although the last chapter is less detailed than those describing the on-farm research process, it is included to emphasize the need for researchers to consider the consequences of their results in production programs and to stress that on-farm research has no payoff until farmers adopt recommended practices.

The research methods were developed for the study of rice-based cropping systems, which include dryland systems where rice is grown in combination with crops such as maize, cassava, and grain legumes, and wetland systems where crop sequences such as maize-rice-grain legumes, rice-wheat, or mungbean-rice-sorghum are common. The methods are, however, already used in nonrice-growing areas and can be readily adapted to include perennial crops. They are still evolving, and will undoubtedly be further modified and improved as more experience is gained.

Chapter 2

CROPPING SYSTEMS AND CROPPING SYSTEMS RESEARCH

Most farms, particularly the small ones in developing countries, combine several production activities. Generally the farm-household unit is a combination of production and consumption activities (Fig. 1).

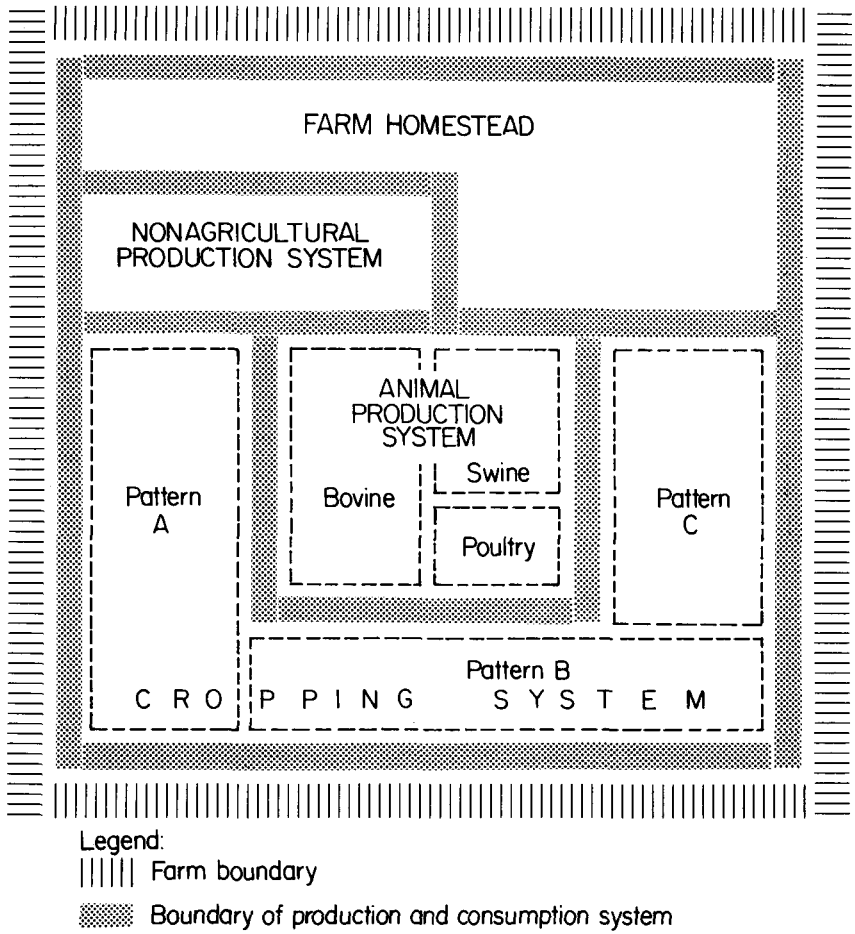
The crop production activities of the farm provide its cropping system. A system may be composed of a number of cropping patterns and involve the production of several crops. All components required for the production of a particular crop and their relationships with the environment are considered within a crop system. Those components include all needed physical and biological inputs, including technology, capital, labor, and management.

A cropping pattern comprises all the components required for the production of a set of crops on one plot during a year. Hence, a single cropping pattern can be identified for every plot, a contiguous land area to which resources are uniformly applied. A cropping system, therefore, includes all components required for the production of a farm's set of crops.

The productive base of a cropping system is plant growth, which is influenced by management and environment. Plant growth and crop yield *(Y)* can then be considered to be the result of the environment *(E)* and the management *(M)* (Zandstra 1979), so that

$$Y = f(M, E) \tag{1}$$

Management *(M)* for the cropping systems research includes the arrangement of crops in time and space and their associated cultural techniques (the cropping pattern). The cultural techniques of the cropping pattern cover the choice of crop variety, times and methods of its establishment, fertilization, field-level water management, crop protection, and harvest. These are collectively called component technology.



1. Schematic presentation of small-family farm household system with 4 production-consumption systems.

Environment *(E)* is composed of such land- and climate-related variables as rainfall availability or irrigation, the soil's textural profile, groundwater level, and toxicities; topographic position of the field and use or nonuse of bunding; day length, solar radiation, and temperature; and cost and availability of such resources as power, labor, cash, and markets, as well as the customs associated with their use (Beek and Bennema 1972, Harwood 1974). The economic performance of the cropping systems depends on the economic environment—costs of inputs and prices for crops.

The environmental variables considered by a cropping systems researcher is a result of a decision about the extent to which management is to control environment. For example, rainfall and solar radiation cannot normally be controlled by management, but it may be possible to find the resources necessary to overcome soil toxicities and irrigation shortcomings.

CROPPING SYSTEMS RESEARCH

To evaluate the relation $Y=f(M,E)$, the cropping systems researcher focuses on the interaction between E and M, and seeks to determine how to vary cropping patterns to get the best returns for different production environments. The objective is to predict the best management from information about the environment.

Because $Y=f(M,E)$ covers a wide variety of crop production environments, the researcher must eventually formulate a statement about the effect of different management practices on the performance of cropping systems in a given environment. Thus

$$Y = f(M/E_i) \tag{2}$$

describes the relationship of M to Y for E_i, specificenvironment. Operationally the transfer from equation 1 to equation 2 changes E from a vector of variables to one that imposes given constraints, some of which may only be vaguely understood. Interactions that were in terms of E and M in equation 1 are in terms of M only in equation 2.

By evaluating equation 2 for selected performance criteria (Y, for example, may represent yearly returns per hectare to land and family labor, or yearly protein yield per millimeter of rain), the researcher can identify management factors that result in high performance and recommend them for farmers' use.

To be acceptable in a cropping system, new technological components must be identified and carefully combined to fit the prevailing production environment. This requires a holistic approach to agricultural research that is oriented toward a combination of crop enterprises encountered in or suitable for a specific environment (Harwood and Price 1976). Whereas the objective of conventional agronomic research is to increase the efficiency with which a resource is used by a given crop, the objective of cropping systems research is to increase the efficiency of a cropping pattern or cropping system.

Farming systems research addresses itself to each of the farm's enterprises, and to the interrelationships among them and between the farm and its environment. The research uses information about the farm's various production and consumption systems—the animal production system, the cropping system, the secondary production activities such as mat weaving, processed food, etc., that add value to primary products—and about the farm's environment—biophysical, institutional, social, economic—to identify ways to increase the efficiency with which the farm uses its resources.

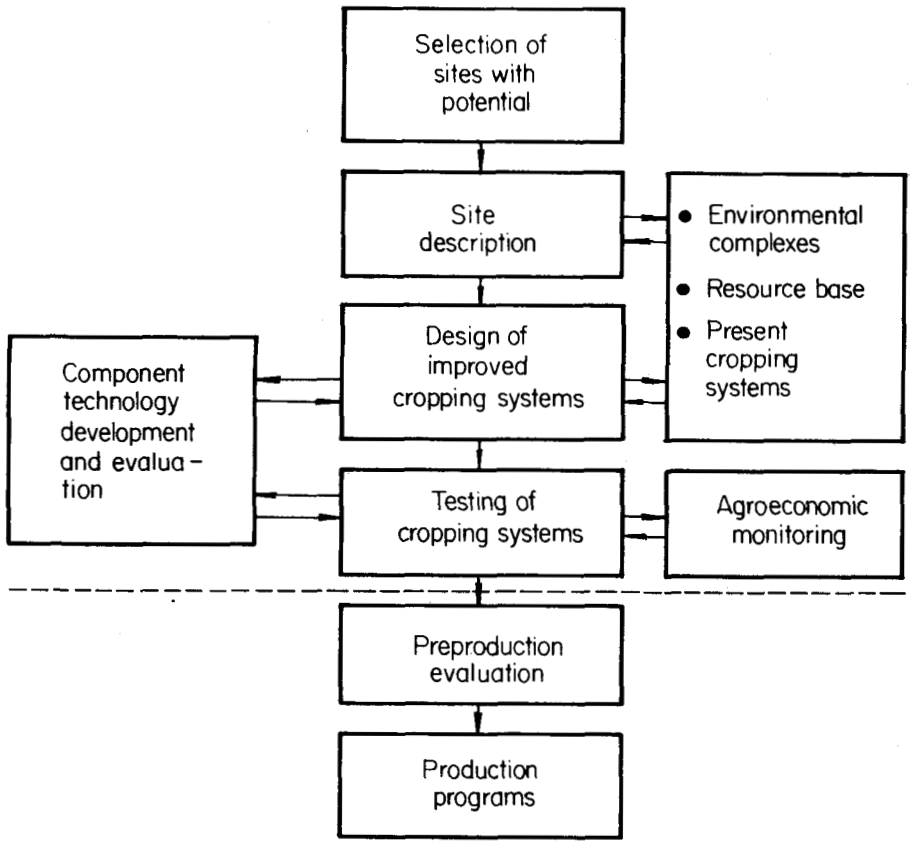
Cropping systems research, on the other hand, is a subset of farming systems research that is confined to the farm's crop-production enterprise. The various crop-production activities are considered modifiable, taking into account the relationships between the crop production enterprise and other production-consumption activities and the physical, biological, and socioeconomic environment. The objective is to increase the benefits derived by crop production with available physical, biological, and socioeconomic resources.

In addition to the development of an improved crop production technology that is acceptable to farmers, cropping systems research can help specify problems for other researchers. By studying existing cropping systems and documenting the

behavior of alternative technologies in the farm setting, cropping systems researchers can specify bottlenecks that require research and identify potential applications for specific management techniques developed by researchers (Zandstra and Price 1977). Some of these may be studied in research stations in support of cropping systems research. This manual confines itself, however, to a description of on-farm research for the identification of improved cropping systems.

On-farm cropping systems research. For research on rice-based cropping systems, an overall framework as well as specific on-farm research methods had to be developed. The research framework had to satisfy several requirements:

- The type of research had to be related to a specific production environment. In this way a close fit of technology to the physical and socioeconomic limitations and opportunities could be achieved. Understanding of the environment aids in the extrapolation of research results (see Panabokke 1976).
- Farmers had to participate in the design and testing of new multiple cropping technologies. This ensured early feedback from farmers about input, management, equipment, and market-related constraints to the adoption of promising



2. Components of the on-farm cropping systems research methodology.

production alternatives.

- The researcher had to cover several commodities and crop-to-crop interaction and be multidisciplinary in nature. A research team that combined abilities in soil and crop sciences, crop protection, and agricultural economics was required to study several crops within a cropping system.
- The methodology had to provide a clear identification of different tasks and the responsibility of the different team members for each task.
- The research had to emphasize the formulation of cropping patterns that increased cropping intensity and that were acceptable to farmers.

There is active on-farm cropping systems research at more than 50 sites in Asia. All researchers follow the Asian Cropping Systems Working Group methodology.

The research methodology described here aims for a manageable research process that is particularly suited for small farms and that treats agricultural research as site dependent (Harwood [1975], Zandstra 1977, Zandstra and Carangal 1977). The research activities therefore focus on the description and classification of the environment, on the design of improved cropping systems and their testing on individual farms, and on methods for the formulation of production programs (Fig. 2).

The research is conducted by a small team of BS- or MS-level researchers supported by village-level assistants. Team composition can vary to accommodate the research demands of a site, but generally includes one or two agronomists, a plant protection specialist, and an economist. One team member is assigned as coordinator and provides the logistic support for the team. The team, which is normally supervised by experienced senior researchers from a higher-level research body, conducts all phases of the site research.

Chapter 3
CROPPING SYSTEMS RESEARCH SITES

A cropping systems research site is the area in which a research team designs and tests cropping systems. It is often selected to represent land types or production environments that occur in extensive target areas. A site may therefore cover a contiguous area or comprise several small selected areas. This chapter covers site-selection and site-description phases of the on-farm research methodology. It provides methods to describe the environmental characteristics of the site and the existing cropping patterns. It also shows how the area can be broken into fairly homogeneous components that require different research activities.

SELECTION OF SITES

The research sites must be selected to ensure the applicability of results obtained on them to other areas with the same environment. Another important criterion for site selection is the estimated potential for cropping intensification. Undoubtedly, the extent to which the potential for cropping intensification can be estimated depends on how well the relationship $Y = f(M, E)$ is understood and how well the environment is defined.

Other site-selection criteria are political or managerial. They include national development priorities, existing infrastructure, and accessibility of the site. A research team must be able to establish an office at the site and live with no undue hardship. Often, site offices are rented in a small town or are part of an existing research station in an area. The team office should be in the area covered by the research.

SITE DESCRIPTION FOR CROPPING SYSTEMS RESEARCH

The first activity of the cropping systems research team is to describe the existing cropping systems in a selected area. The initial description should be made rapidly and should include only information required for the design of alternative cropping patterns and for the definition of research priorities at the site. Data collection and

initial summarization, grouping, and cross tabulation of results normally take 2-3 months. In this way, recent observations and impressions are available at the time of the design meeting, which is held 1 month before the start of the growing season. Field work for baseline studies should, therefore, be planned 3-4 months in advance of the earliest planting dates. Environmental description continues throughout the research process at the site and, after the initial study, concentrates on specific aspects about which more information is needed.

In the initial study, the researcher identifies the different crop production methods in the region and associates them with variations in the environment. An example of classification based on environmental complexes (the production complex was dominantly rice-fallow) is that used in the IRRI-BPI (Bureau of Plant Industry, Philippines) site at Iloilo. There, soil texture and landscape position were used to classify the environment (Morris et a1 1979). Other research sites have used the length of time the land was settled, duration of irrigation, remoteness, and others (Ismail et al 1978, Saefuddin et al 1977).

A useful approach to relate environmental factors to cropping systems potentials was proposed by Zandstra (1977). Environmental factors include physical resources (related to climate and land), economic resources (availability of land, labor, cash, power equipment, and materials), and socioeconomic conditions (product prices, input costs, marketing costs, and customs reflecting preferences for certain foods or management practices).

- The cropping systems researcher specifies the factors to operate on, and those to consider as constant. The first set will relate to management (subject to optimization), and the second to the environment of equation 1 in Chapter 1.
- In environmental classification, readily modifiable physical factors such as nitrogen and phosphorus fertility, easily corrected microelement deficiencies, and the normal incidence of pests and diseases should be excluded. $Y=f(M,E)$ is thus reduced to one in which standard crop management practices in M are assumed as correct for variations in the readily modifiable factors in E. Those factors remaining in E are cropping pattern determinants and should be used for environmental classification.
- A set of sites that have similar cropping pattern determinants is defined as an environmental complex or cropping systems land type.

The sites in which cropping patterns have substantially the same relative performance are defined as a production complex (Zandstra 1977). A production complex is measured by cropping pattern performance and, as such, is an ecological unit. It may contain more than one environmental complex because there are various ways in which cropping pattern determinants can interact to produce a particular cropping pattern performance. If the performance of cropping patterns is substantially different for any subset of sites within what researchers define as an environmental complex at a site, one or more important determinants must have been overlooked in the description and specification of that complex. This requires the ability to test the adequacy of the environmental description method used.

Site description must also include an extensive analysis of water availability. Rainfall distribution—initially monthly and weekly means for up to 20 years, sssand

subsequently a study of the time and probabilities of onset of rainfall and termination of rainfall (Morris and Zandstra 1979)—is useful. Where irrigation is available, the team must acquire knowledge about irrigation schedules and source, frequency, and dependability of the irrigation. If the rainfall begins before the turnout of irrigation, which is common, or if it ends after the irrigation ceases, which is rare, a careful analysis of these periods for the cropping potential is necessary. In areas with seasonal temperature fluctuations, cropping patterns are greatly affected by temperatures and growing season analyses must consider this factor (Wong 1975).

As research progresses, the team should attempt to establish the effective growing season for each land type using a fairly high probability level (P=0.8). This will help in the design of cropping patterns that have a high probability of success. For wetland production complexes, it is particularly important that the team get a feel of the periods in which the soil will be saturated or have standing water, as opposed to the periods in which the soil will be moist enough to sustain dryland crops but not saturated.

The availability and present use of resources such as land, labor, cash, traction power, and infrastructural support services are important determinants of cropping system performance. Most of them will not vary greatly for any one site, although certain factors may cause a stratifying of the site into land types. A clear understanding of the infrastructural support (credit, inputs, markets) that will operate at the site is particularly important for the design of cropping patterns.

Site description provides the research team with an idea of the input levels commonly used by farmers and the yields they obtain from those inputs. It allows, at the time of cropping-pattern design, use of an approximate estimate of the returns to purchased inputs that should be achieved at the site. It will also help select treatment levels for studies on fertilization, insect, and weed control.

For site description, particular attention should be paid to the history of farmers' technology, particularly the extent to which farmers have tried technological alternatives. The reason they have incorporated some alternatives and rejected others should be considered in the design of cropping patterns and component technology research.

Because economic and physical conditions vary in different regions, the types of information required to develop and introduce new cropping patterns also vary. At one site, for example, rigorous and detailed studies of water-use rights may be necessary before a suitable new technology can be designed. Elsewhere an understanding of the propensity of the land to deep flooding may prove crucial. Although the minimum information necessary to efficiently develop new technology for a site can, therefore, not be completely specified in advance of research, at least the following *initial* requirements for research planning can be specified:

- identification of land types at the site,
- identification of existing crops, cropping patterns, and cropping systems,
- description of cropping systems determinants, and
- description of farm types and the farm resource base at the site.

A format of the information needed for the design of new cropping patterns is presented in the following sections. The schedule is *not* a questionnaire to be

On-farm cropping systems research requires confirmation of problems with cooperating farmers at the site-description and testing phase. Surveys and farmer interviews form an important part of daily activities.

completed through any single data-collection exercise. Several data-collection techniques may be used. Some of them may rely on secondary sources.

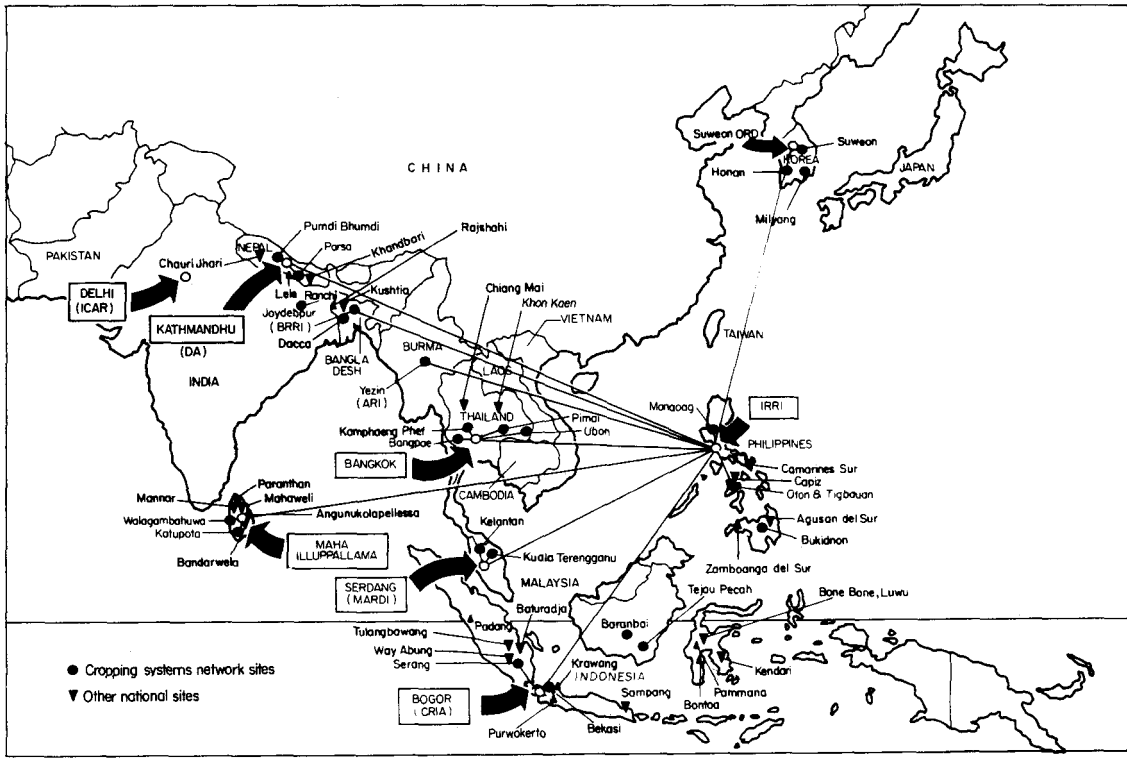
Identification of land types. Land types must be sufficiently different to merit the development of a different technology for each. Recommendations cannot be tailored to individual fields, but must be generalized to a considerable extent. That implies a loss of adjustment of the recommendation, which is unavoidable. The best division of an area into land types provides the greatest fit of the recommendations for the area with the least land types. As a rule of thumb, researchers should capture 70-80% of the area with 3-4 land types.

Recommendations, and therefore land types, may be stratified according to differences in farm types—large or small, with or without bullocks—water supply, soil characteristics, cropping history, infrastructural features, or others. It is useful to consider possible extension strategies with respect to the contemplated land-type divisions as the capacity of the extension services can influence the impact of cropping systems research results. In addition, if the site team decides to separate several land types, it may greatly overload its capability to conduct adequate research on each type.

1. Separate land types into *dryland* and *wetland.*
2. Differentiate between irrigated and rainfed land. Rainfall will normally not vary sufficiently from place to place within a site to necessitate stratifying the area on the basis of rainfall. Irrigation, however, can vary greatly. Where as little as a 30-day difference in growing-season lengths is induced by irrigation, different production strategies may need to be recommended and, therefore, a different land type recognized. With respect to irrigation, the source and the duration of irrigation can be important.
3. The next most important land quality for identifying land types is landscape or geomorphology. Although it does not intrinsically influence crop production, it is associated with many determinants, such as soil depth, depth to water table, water-enrichment potential, slope, soil texture, and fertility.
4. In wetland areas, the lowest and highest position of the water table can have great relevance to the type of cropping pattern suited for that land type. An area with a shallow water table (<1 m) during the dry season may have a vastly different production potential from one with a deep water table (>2 m). In areas subject to flooding, the water table will be above ground level for part of the year, and duration of flooding will become an important determinant. See Hobbs et al (1979) for a discussion of cropping patterns for deepwater areas in Bangladesh.
5. Because of its effect on soil-water relationships, soil texture is the next most important determinant of cropping systems. Substantial differences in clay content may justify the recognition of a different land type and the development of a different technology for it.
6. Soil fertility and soil chemical conditions can often be corrected by management. Where differences in such factors are great, or difficult to correct, an additional stratification associated with these factors may be used. This may be particularly of interest to areas subject to soil salinity, extreme acidity, or toxicities.
7. Identify major socioeconomic differences that occur within the site. Substantial differences in farm types or market conditions can often be expressed in different recommendations through analytical means and may not require stratification of experimental activities. They should, however, be reflected as different land types for extension purposes. For example, a greater distance to markets influences the suitability of sweet potatoes as a component crop in a cropping pattern. The price of sweet potato can be different in different locations as a result of transportation costs. From this analysis, decisions can be made about the distance from the market of the site to which the recommendation to include sweet potato should be extended.

A schematic sketch of the typical spatial relationships of the land types found at the sites is valuable (Fig. 2). Table 1 shows rough estimates of the land area and the dominant and possible potential uses of each type.

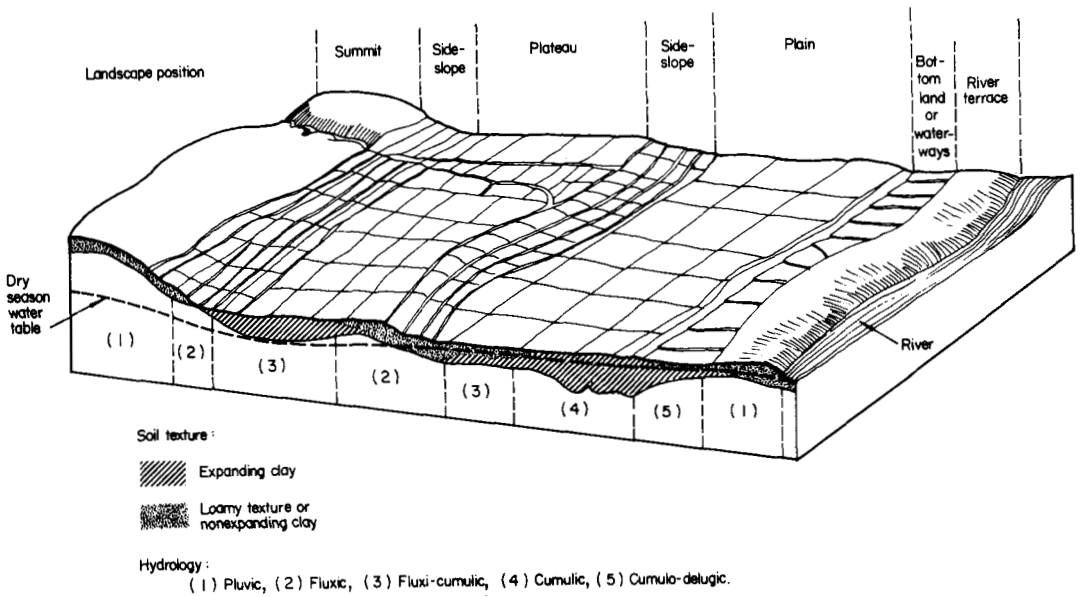
It also provides a preliminary guide to land types on which research will have the greatest payoff. Only land types that occupy a major portion of the target area of the site and that present good prospects for improved cropping patterns should be



1. The Asian Cropping Systems Network sites, 1980.

In the Asian Cropping Systems Network (ACSN) sites (Fig. 1), land types have been identified on the basis of the most important determinants — those that most strongly influence the performance of cropping patterns in the area. Careful observation and study of existing cropping systems in the area generally give important indications of what these factors may be. So far, at IRRI and in ACSN the soil's physical (profile texture, clay type) and hydrological (seepage and percolation, and the field's water-enrichment potential) variables have been most useful in the identification of land units in wetland production complexes (Morris et al 1979). In dryland production complexes, slope and soil chemical factors (pH, organic matter, or cropping history fertility) are more important (McIntosh and Effendi 1979).

Several excellent approaches to land classifications have been documented (FAO 1971, Beek 1978, Moormann and van Breemen 1978) and researchers should ascertain what soil or land evaluation surveys exist for an area. These surveys, plus aerial photographs of the sites, provide information on the most important soils (profile descriptions and laboratory analyses), their location in the landscape, and their most common use. The following steps in classifying land types for cropping systems research are only general and must be modified to suit the specific conditions of a site and the information available:



2. Schematic presentation of geomorphic and pedologic conditions at the Iloilo province net work site(Source: Raymundo 1977).

considered in the research program. Examples are wetland plateaus, plains, and, possibly, sideslopes (Table 1).

Crops, cropping patterns, and cropping systems. Cropping systems are commonly described simply by the dominant cropping patterns they include. A more complete description would indicate specific performance characteristics, the qualities and quantities of resources on which systems are based, and the technologies that transform them into crops in the patterns.

Numerical descriptors of the performance characteristics of cropping systems that have been used include the multiple cropping index, cropping intensity index, diversity index, and land equivalent ratio (Menegay [1975], Strout 1975). These are defined in the glossary. More traditional performance criteria are yield per unit area, value of product per farm or unit area, net returns above variable cost, net income to farm resources, etc. Other measures offer impressions of input-use efficiency—returns per unit labor, returns per unit cash, protein per millimeter of rain, and various other input-output coefficients. Still other criteria relate to stability of returns over time or across sites. In one way or another, all relate to the ultimate criteria of performance—productivity of the farm and acceptability to farmers.

Because interrelationships among farm activities are complex, analysis of changes in total farm productivity and of the acceptability of a given technology is difficult. In making the judgments needed in the day-to-day design and testing of experimental technology, assumptions can, however, be simplified, as follows:

- When evaluating any technology, the resources used that have no alternate employment need not be considered.

Table 1. Land types, their major characteristics, and present and potential land use.

Land type	Area (%)	Major soil type	Rainy-season water table depth (m)	Hydrology[a]	Flooding hazard	Major present use	Potential use
Summit	15	Balo loam	> 5	Pluvic	Absent	Tree crops	As is
Sideslope	10	Balo loam	> 2	Fluxic	Absent	Maize-rice	Maize-rice-mung
Plateau (wetland)	25	Albo sicl	2·3	Fluxic	Absent	Rice-fallow	Rice-(soybean, mung)
Plateau (dryland)	5	Balo loam	2·3	Cumulic	Absent	Pasture	Pasture
Plain	27	Albo sicl	1·2	Cumulic fluxic-cumulic	20%	Rice-fallow	Rice-rice Mung-rice-sorghum
Bottomland	7	Albo sicl	< 0.5	Cumulic-delugic	40%	Rice-rice	Rice-rice-rice rice-rice
River terrace	5	Olab sandy loam	> 3	Fluxic	10%	Maize-rice, pulses	Cassava+maize+ rice-pulses Maize-pulses
Home garden	5	Albo sicl	> 3	Fluxic	10%	Fruits, herbs, vegetables	As is
Bed and furrow fields	1	Loba clay	< 0.5	Cumulic-delugic	10%	Rice + vegetables	Expand area

[a]Terms in this column are defined in the glossary (see also IRRI 1978).

Table 2. Crops produced in each land type, their growing period, and yield.

Land type	Crop	Varieties	Time period	Estimated yield (t/ha)
Irrigated 1	Rice 1	RD3, Bahagia, IR8	15/4-15/9	3.5, 2.7, 3.0
Irrigated 2	Rice 3	Fastvar, IR30	1/4-15/7	3.2, 4.5
Irrigated 2	Rice 4	Fastvar, IR34	1/8-15/11	3.2, 4.3
Rainfed wetland	Rice 2	Fastvar, IR30	15/4-15/9	2.7, 3.0
Rainfed wetland	Cassava 2	Local early maturing variety	15/9-15/4	9
Dryland	Cassava 1	Local variety	15/4-30/12	13
Dryland	Maize 1 / cassava 3	Local varieties	15/4-1/8-30/12	1.8, 10
Dryland	Maize 2	DMR 2, local variety	15/4-11/8	1.9, 1.0
Dryland	Maize 3	DMR 2, local variety	15/8-1/12	2.4, 1.4
Drvland	Maize 4	DMR 2, local variety	15/1-1/14	1.6, 0.9

- When evaluating a specific technology, only there sources used and the alternative enterprises that also use them need be considered.

Cropping systems descriptions. The following format for a description of existing cropping systems captures the most important descriptors and performance characteristics of existing cropping systems.

1. First, record the major crops and varieties for each land type recognized at the site, and the time periods when they are grown. If more than one crop schedule is followed, specify and number each (see Table 2). If the same varieties and crops are grown at the same time on different land types, list the crops separately and identify them by numbers.
2. For each land type, record major cropping patterns, and include idle land, tree crops, pasture, etc. as patterns if the land where they are grown is cultivable. Denote each pattern with a capital letter and show the approximate percentage area of cultivable land planted to it (Table 3). Use the same crop definitions as those used in Table 2. Area in each crop and cropping intensity in a site will be computed from these data. To denote planting arrangements in time and space, use a hyphen (-) if crops are sequenced, use a plus (+) if crops are planted simultaneously (more than 2/3 of the growing season overlaps); use a slash (/) if crops are planted in relay (less than 1/3 of the growing season overlaps). For example, a cropping pattern of dry-seeded rice followed by a sorghum-mungbean intercrop, in which melons are interplanted into the sorghum after mungbean is harvested, would be:

   DS rice - sorghum + (mungbean - melons)

   A crop of sorghum in which mungbean is relayed would be:

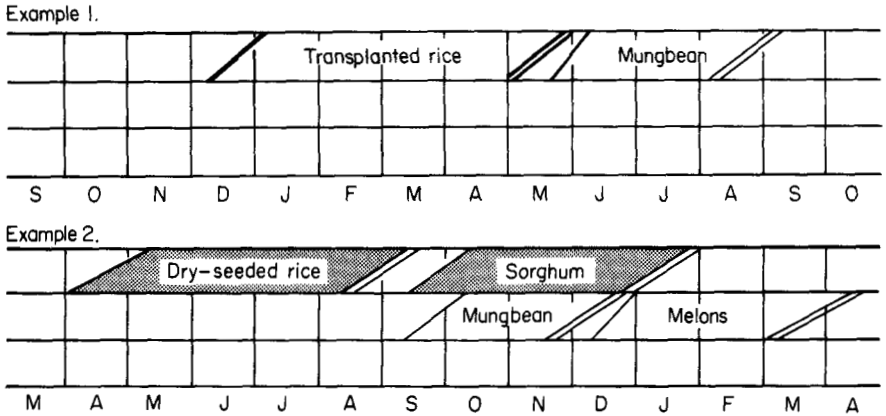
   sorghum/ mungbean

   When appropriate, the multiple cropping index (MCI) or land-use intensity is calculated for each land type. It is often useful to present cropping patterns in

Table 3. Cropping patterns, their land-use duration, land-type association, and frequency.

	Cropping pattern	Duration (months)	Land type	Cultivable land (%)	Multiple cropping index computation	Land-use intensity
A	Rice 1	5	Irrigated 1	20	100 × 0.20 = 20	5/12 × 0.20 = 0.08
B	Rice 2-cassava 2	12	Rainfed wetland	20	200 × 0.20 = 40	12/12 × 0.20 = 0.20
C	Cassava 1-maize 4	12	Dryland	15	200 × 0.15 = 30	12/12 × 0.15 = 0.15
D	Maize 1-cassava 3-maize 4	12	Dryland	10	200 × 0.10 = 20	12/12 × 0.10 = 0.10
E	Maize 2-maize 3-maize 4	12	Dryland	10	300 × 0.10 = 30	12/12 × 0.10 = 0.10
F	Rice 3-rice 4	7.5	Irrigated 2	5	200 × 0.15 = 30	7.5/12 × 0.05 = 0.03
G	Tree crops	12	Dryland	5	100 × 0.05 = 5	12/12 × 0.05 = 0.05
H	Idle land	12	Rainfed wetland	5	0 × 0 = 0	0/12 × 0.05 = 0
I	Other	6	Dryland	10	100 × 0.10 = 10	6/12 × 0.10 = 0.05
	Aggregate for the site[a]				185	0.76

[a] Weighted on the bases of %cultivable land.



3. Preparation of a cropping pattern diagram. Each crop in the pattern should be presented in a diagram. Begin by indicating the first month of the growing season below the diagram. Indicate the planting dates of each crop with a single line and the harvesting dates with two lines. Indicate the acceptable range of planting dates for each crop by a diagonal line covering the range of dates. A double line indicating the expected range of harvesting dates (not necessarily the same as range of planting dates) defines the period during which this crop is expected to occupy the plot. Write the name of the crop between the two lines. Then proceed with the next crop. In the case of a cropping sequence, use the same line of the diagram (row), indicating again the range of planting dates and harvesting dates expected for the second crop. Again indicate the type of crop between the planting and harvest lines. Continue on the same row if a third crop is planted in sequence. If any of these crops is combined with a crop planted in sequence or in relay, use the remaining rows in the diagram. Again indicate the range of planting and harvesting dates for each crop. The first example shows a transplanted-rice-followed-by-mungbean pattern in a region where the growing season starts toward the end of October. In this case, the period of transplanting (not seeding) is indicated, because that is when the cropping pattern starts to occupy the plot.

The second example shows a cropping patern of dryseeded rice followed by a sorghum-mungbean intercrop, in which melons are relayed into sorghum after mungbeans are harvested. The growing season in this example starts in April.

diagrammatic form, indicating the planting and harvesting times of each crop (Fig. 3).

3. Enumerate the principal cropping systems (combinations of cropping patterns on a farm) and percentage of all farms at the site that follow each system. Identify each system by Arabic numerals and make sure that all patterns included are identified as in Table 3. For ease of reference, the system may be named according to an important feature, as shown in Table 4.

Measurement of physical cropping pattern determinants. Climatic factors normally do not vary across the research site and their description can therefore apply to the whole site. Careful thought should be given to the best ways of describing the factors that limit production of crops during parts of the year. Land-related factors, however, vary from land type to land type and must be described for each land type. The following is an example of the initial information required for the design of cropping patterns:

Table 4. Description of cropping systems at a site.

Cropping system	Systems name[a]	Cropping pattern	Farms (%) on which observed
1	Irrigated rice	A, F	30
2	Wetland rice-cassava	A, B	20
3	Mixed wetland-dryland	B, C, D	20
4	Mixed dryland	C, D, E, G, I	10
Other			20

[a]This is any name convenient to label the system.

For the research site, compile the information on the physical qualities of the site. Long-term rain and temperature records should be obtained from the nearest meteorological stations.

1. *Rainfall.* Initially, monthly rainfall averages will suffice. Subsequent studies require weekly averages over as long a period as possible. Twenty years' data provide a good base for the evaluation of variability of rainfall events. Ten years' data will give reasonable estimates in the humid tropics, but may be insufficient in more and zones.
2. *Average monthly temperature.* Indicate the number of years averaged and identify cropping periods that may be affected by limitations of low or high temperature for crops grown at the site.

For each land type identified previously, evaluate the occurrence of drought and flooding from secondary data and by interviews with farmers.

1. *Occurrence of drought within growing season.* Refer to the major cropping patterns of the types listed in Table 3. For each crop in that pattern, estimate from local responses the number of years out of 10 when drought reduces yield more than 25%. A sample record is in Table 5.
2. *Occurrence of flooding within growing season.* Where applicable, for each crop in the major patterns of the types listed in Table 3, indicate the number of years in 10 when yield is reduced more than 25% by flooding. Also describe relevant features of the problem, such as time, duration, and extent. A sample record is in Table 6.

Farm type and farm resource base. The resources that go into the cropping systems in an area can be divided into on-farm and off-farm. Off-farm resources—the agricultural infrastructure—are institutional and often reflect public or private investment in goods and services required by a farm business. The benefit of these goods or services do not accrue to a single farm, but is shared by several farms. Private investment in public goods and services occurs when investors—bankers,

Table 6. Drought effects on yields of major crops at a site.

Pattern	Crop	Effect of drought
A	Rice 1	Seldom affected
B	Rice 2	Affected 3 years in 10
C	Cassava 1	Seldom affected
	Maize 4	Affected 2 years in 10

Table 6. Effects of flooding on major crops at a site.

Pattern	Crop	Effect of flooding
A	Rice 1	Yield reduced 3 years in 10
B	Rice 2	Yield reduced 1 year in 10
C	Cassava and maize	Yield never affected

NOTE: If rains are particularly heavy at the onset of the April monsoon, flash flooding sometimes occurs in the wetland land types. Only in 1 year out of 10 is the flooding duration sufficient to seriously damage Rice 2. In the 10 years, the lower irrigated areas accounting for about half of all Rice 1 were prone to severe flooding that lasted 3 weeks.

fertilizer suppliers, and commodity processors — can capture some of the benefit. It is more difficult for private investment to obtain benefits from building a highway, educating farmers, or constructing irrigation and off-farm storage facilities. Therefore, in such cases, public investment provides the goods and services.

In cropping systems research, off-farm resources are considered fixed and not subject to change through the direct efforts of researchers or farmers. Projections of their future characteristics are made, however, and new technology is designed to fit the projected infrastructure. The infrastructural support expected to operate in a target area greatly influences the type of technology the research team will generate. Careful analysis of previous cases of institutional support for agricultural production that can be expected at the site is therefore needed to determine the level of production that farmers, and, therefore, researchers should aim for if their cropping patterns are to be economically viable. A realistic understanding of the kind of credit, inputs, price, and market support that can accompany production programs will improve the goal-setting for on-farm research (see Chapter 6).

The following general types of off-farm resources should be identified and evaluated as part of the site-description process:

1. location and capacity of market centers for major crop commodities and product prices,
2. location and availability of major production inputs and input prices,
3. transportation facilities for products and inputs and costs of transportation,
4. location and capacity of processing facilities for farm products and costs of services,
5. communication facilities and their effectiveness in providing information to farmers about current product and input prices, and current volume of commodity trade and input supplies,
6. presence and activity of extension services,
7. locations and operational characteristics of farm cooperatives,
8. land tenure arrangements, land prices, and rental costs,
9. capacity, operational characteristics, and costs for irrigation services,
10. structure of the farm labor force, and seasonal wage rates,
11. structure and capacity of commercial farm power supply facilities and rates for hiring services, and
12. location and capacity of farm credit facilities and knowledge of their interest rates.

Table 7. Information suggested for the description of farm type by major farm characteristc and their approximate discribution.

Trait	Average of[a]		
	Lower 25%	All farms	Upper 25%
Farm size (ha)			
Parcels (no.)			
Land owned (%)			
Family size			
Value of crops:			
- produced per year			
- sold per year			
Value of livestock			
- produced per year			
- sold per year			
Value of nonfarm income per year			
Labor use (%)			
- for farmers' crops			
- for farmers' livestock			
- other[b/]			

[a] Av values refer to each trait, to provide independent information on the distribution of each traits. [b] May include nonagricultural enterprises and sale od labor.

If this off-farm resource information cannot be acquired before the field research activities are started at the research sites, it should be gathered as the research progresses. A good example of the use of key informants for this purpose is the work by Mathema and van der Veen (1978) in Nepal.

On-farm resources are crop production factors that can be modified and allocated by farmers and can be identified and measured within farm boundaries. Modifications of certain physical characteristics of a farm, such as the soil or water supply, are considered land modifications. Where substantial, they should be reflected in the land types defined for a site. For example, where farmers modify land by developing the bed and furrow system, the land so managed belongs to a different land type. Important on-farm resources are:

1. farm type — size, tenure agreement, and fragmentation; importance of animal production enterprise and other enterprises;
2. seasonal labor and cash availability;
3. family labor availability and skills;
4. farm fixed capital and power availability; and
5. farmers' technical knowledge, experience, and education.

The information indicated in this section of the baseline study can be collected in various ways. In most sites, a survey of a sample of farms plus data from existing sources have been used. In other sites, farmers' groups, village teachers, bankers, store owners, traders, and market operators have been used as sources for information (Mathema and van der Veen 1978).

Table 7 shows the information on the type of farms, farm family, and farm resources that a research site will need as background information for the design of cropping patterns and research.

Farm type. A research team should describe a typical farm at the site according to the features listed in Table 7, thereby providing insight into the type of farming system the research must deal with. The averages of the lower 25% and upper 25% provide information on the range and distribution of each farm characteristic.

The relative importance of each of the farm enterprises should be determined by comparing values or quantities produced and the amount of time spent on each enterprise. Researchers should also ascertain the extent to which the farm unit consumes its own production by comparing the quantities produced with those sold.

If different cropping systems (see Table 4) are associated with markedly different types of farms, a typical farm should be described for each system. Table 7 shows how a typical farm might be described for a given cropping system.

Wage rate and cash availability. A general insight into the variation over the year in wages paid at the site and in the availability and demand for family and hired labor is needed. In addition, where possible, the farmers' wealth and the cost of credit should be evaluated. Tables 8, 9, and 10 illustrate the information that will allow the research team to identify tentatively where major labor or capital constraints may occur. The information will also provide the means to calculate the approximate returns to labor and cash that prevail in the area. These are important parameters for the design of cropping patterns. Many of these measures, whether

Table 8. A form for use in presenting yearly recurring variations in wage rates and cash availability for a typical farm household.

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
What daily wage rate is usually paid during each month in the area? [highest, normal, lowest]												
In which months is there additional labor (A) or loss of labor (L) in the area?[a]												
When are farm labor requirements highest (H) and lowest (L)?												
How many adult family members are available for work?												
In what months is it most difficult to meet expenses?												

[a]From migrating labor; school holidays, religious, or cultural reasons.

Table 9. Example form for presenting crop production capital of a typical farm

	Farmers (%)		Rental cost[a] (M)
	Who own	Who rent	
Water buffalo			
Oxen			
Sprayer			
Tractor			
Tiller			
Irrigation pump			
Thresher			
Rice blower			
Drier			
Other			

[a]per hectare or per day, as appropriate. M = monetary unit.

Table 10. Example of information needed on sources of credit for agricultural production in the area

	Size of credit[a]	Farm households[b] (%)	Cost[c] (%/year)
Official bank			
Family			
Friends			
Commercial lenders			
Others _____			

[a]Av amount per loan transaction. bIdentifies how many farmers use each source (can add to more or less than 100). calculated as:

$$\frac{\text{Interested + other costs (M)}}{\text{Value of credit (M)}} \times \frac{12}{\text{Duration (months)}} \times 100.$$

Table 11. Example of methods and costs of production of major crops in a site area.

Activity	Material, item	Units	Quantity	cost (M/ha)[a]
Land preparation				
Animal days	Water buffalo	Days	20	200
Labor	–	Days	24	360
Planting				
Seeds	IR30	Kg	1 00	160
Seed treatment	None	Kg a.i.	–	–
Labor	–	Days	4	40
Fertilizer				
Nitrogen	Urea	Kg N	70	280
Insecticides	Lindane	Kg a.i.	1	40
	Furadan	Kg a.i.	1	180
	Azodrin	Kg a.i.	0.2	60
Irrigation				
Materials	Fuel	Liters	10	30
Labor	–	Days	2	20
Weed control				
Herbicides	None			–
Labor	–	Days	20	200
Harvest				
Labor	–	Days	40	600
Other labor	–	Days	5	50
Total costs for labor and draft power				1470
Total material costs				750
Total variable costs				2220

[a]M = monetary unit.

obtained from secondary sources, key informants, or a farm survey, will be re-evaluated on the basis of records obtained during the cropping pattern testing phase of the research. For more details, see the discussions on labor wages under the section Recording of crop production operation in Chapter 5.

Methods and costs of production. Methods and costs of production for the existing crops at a site are determined in detail at the time of cropping pattern testing. For design purposes, the research team should, however, obtain general information about them for the most important crops and operations. At this stage, only crops that occupy more than 30% of the area in any season should be considered, and in general it is sufficient to consider only the three most important crops. Table 11 shows the type of information that will allow initial analyses of methods and costs of production for the area. It also provides further information on the costs of labor for different operations.

Technical knowledge of a typical farmer. The information to collect about the technical knowledge of a typical farmer depends greatly on the dominant crop and stage of agricultural development. Initially, only a general impression can be obtained but at later phases of research at a site, surveys may be needed to ascertain

Table 12. Example of information on technical experience and practices of typical cropping systems research site farmers.

	Most have heard of	Some have tried	Usually practice
Rice planting methods			
Dry broadcast			
Dry furrows			
Wet broadcast			
Transplant: Uses seeder			
or transplanter			
Upland crop planting			
Row planting			
Intercropping			
Relay cropping, zero tillage			
Weeding after planting			
Harrowing			
Interrow cultivation			
Handweeding: Uses animals			
Uses herbicide			
Fertilization			
Basal			
Broadcast			
Band or hill application			
Split application			
Special equipment			
Insect control			
Manual			
Commercial insecticides			
Locally produced insecticides			
Use of sprayer			
Chemical disease control			

farmers' familiarity with alternatives for the following management components and their associated tools and equipment:

- crop planting times and methods,
- soil fertility and fertilization,
- weed occurrence and control,
- insect pests and control,
- disease occurrence and control, and
- history of crop varieties used in the area.

Such surveys should be concluded only on major crops in the cropping system. It is often hard to judge at the initial stages of site research which components require in-depth study. In addition, the detailed information sought in these studies requires the considerable familiarity of the research team with farmers, their dialects, and social conditions; and the familiarity of farmers with project personnel and objectives. These studies, therefore, should be formulated after the first improved cropping patterns have been designed and field work has been started. Litsinger et al (1980) provides an example of forms used for an insect pest control survey.

An example of the information that can be gathered in the initial study of the technical history at a site is shown in Table 12. This table is relevant only for a certain crop production system and requires major changes for use in another system.

Chapter 4
DESIGN

The design phase of cropping systems research has two distinct but closely related activities: the design of improved cropping patterns to be tested and the formulation of the overall research program to be conducted at the site for any 1 year. The design of cropping patterns demands clear statements of site-research staff and supporting researchers about the management alternatives they consider best. It also determines the required additional crop management information, the lack of which is acutely felt when the team attempts to design improved cropping patterns for a site.

DESIGN OF THE SITE-RELATED RESEARCH PROGRAM

The design of the research program for a site coincides with the design of cropping patterns for that site and should be completed at least 1 month in advance of the first seeding date. The research program at a site includes:

- cropping pattern testing,
- evaluation of farmer's cropping patterns,
- component technology research, which includes superimposed and researcher-managed trials, and
- special problems-oriented surveys.

This research is done by the site team, and the type and number of studies depend on the conditions at the site, the previous research conducted in it, and the size of the team.

Normally the yearly research program is designed in a workshop in which all researchers at the site participate. Site researchers should be given prime responsibility to present previous research results and be encouraged to contribute their insights about the existing farming systems, the potential for increased production, and farmers' reactions to alternatives. The workshop should include advanced cropping systems researchers and subject matter specialists in economics, entomology, weed science, water management, plant pathology, soil fertility, and plant

breeding. The workshop may take about 3 days.

The workshop provides cross-disciplinary interaction, which makes sure cropping patterns are economically viable and component technology recommendations are compatible between disciplines. Also the designed cropping patterns and component technology recommendations should be written up so that all team members are aware of the cropping pattern recommendations developed for each year. The research program should be evaluated after each crop and the necessary modifications made. This chapter describes the overall research program that should be designed yearly for a site; the methods for the design of cropping patterns; and finally the methods for cropping pattern trials and component technology research and the contribution of these experimental techniques to the overall research at the site. Details of the experimental design and management for these trials are discussed in the chapter on Testing.

CROPPING PATTERN DESIGN

In terms of equation 1 (Chapter 2), cropping pattern design is the specification of the management vector *M*. It is a synthetic activity that uses the physical and socioeconomic site characteristics obtained at the descriptive stage, together with knowledge of the effect of such characteristics on the performance of cropping patterns, to identify the patterns for intensified cropping that are well adapted to the site (Cropping Systems Working Group 1976a).

As discussed earlier, the performance of a cropping system and the patterns that compose it can be represented by

$$Y=f(M,E).$$

The cropping system *(M)* chosen is therefore subject to environmental and resource base constraints of *(E)*. From the baseline study, the team can get a first approximation of *E* and a set of limits within which to define *M*. In the course of research at the site, *E* becomes better defined and with it the resource constraints to be considered.

Cropping pattern design focuses on a certain land type. Researchers choose from an array of practices that represent the available component technology. This array includes the possible cultivars, tillage operations, planting and fertilization methods, plant populations, spatial relations between crops; intercropping alternatives; water management method; and pest control methods (manual, chemical, host-plant resistance, or cultural). Cropping pattern design depends on what is known about the performance of cultivars and the listed management practices, under the conditions that prevail in the target land types.

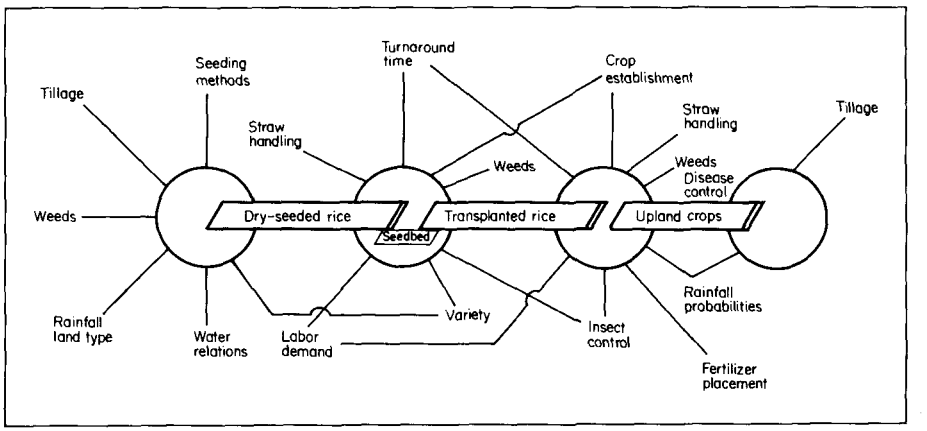
In the design of cropping patterns, three levels of suitability are considered — the biologically feasible, the technically feasible, and the economically viable alternatives. These degrees of suitability are associated with different components of the environment (Fig. 1).

For biological feasibility, the environmental factors are physical, climatological, and biotic, such as amount and distribution of rainfall and irrigation, landscape hydrology, drought, saturated soil, high precipitation, and humidity during the crop establishment and harvest periods, temperature and day length variations, extreme soil conditions, predictable flooding, and hard-to-control pests as identified for each

Table 1. An example of a guide for designing economical cropping patterns.

Resource	Present use	Present limit	Projected limits
Power	Human only	Human + 2-wheel tractor, 0.1 ha	Human, 2-wheel tractor, 0.2 ha
Labor[a]			
Class 1	0.4 day/ha per day	0.5 day/ha per day	0.4 day/ha
Class 2	1.1 day/ha per day	1.4 day/ha per day	1.4 days/ha
Chemicals			
Fertilizers	Urea, 10-30-10 Lime, ZnO_2	Urea, 10-30-10, KCl Lime, ZnO_2, $ZnSO_4$	Expanded list Expanded list
Insecticides	List[b]	Expanded list	Further expanded list
Herbicides	None	None	List
Farmers' cash for inputs	₱200/ha per year	₱300/ha per year	₱500/ha
Credit (value/ha)	₱500/ha per year	₱500/ha per year	₱600/ha
Area (%)	10%	20%	50%
Equipment	Tools only	Jabber, sprayer plus tools	At present, + some rotovators, ridgers, row seeders, and threshers.

[a] Class 1 is managerial and for land preparation and harvest. Class 2 is all other labor. [b] A list of insecticides currently used.



2. Assigning component technology to a pattern requires a careful selection from many alternatives.

weed control methods, and harvest methods in addition to the timing of all operations.

During the first year, the component technology chosen for the cropping patterns will depend primarily on information from the environmental description, national recommendations, and previous research at the site or at similar sites. Over time more information on component technology will become available from research at the site and will increasingly form the basis for decision-making about the component technology levels to be used for the cropping patterns. Sample specifications for weed-control component technology for a site in the Philippines are in Table 2.

A difficulty in cropping pattern design arises in determining the on-farm resources available to the cropping pattern more precisely than is possible with Table 1.

Table 2. Recommended weed control practices for cropping patterns, Pangasinan, 1977-78.

Crop	Weed control methods	Rate (kg a.i./ha)	Time of application
Maize (before rice)	Hilling-up, 2 passes	–	3 weeks after emergence, or just after fertilizer topdressing.
Dry-seeded rice	Butachlor followed by one hand weeding	2.0	Immediately if soil is moist, or if soil is dry, after germinating rain, followed by manual weeding or spot weeding as needed.
Wet-seeded rice	Well-puddled seedbed. If there is standing water — no weeding; otherwise, spot weeding.	–	As needed
Transplanted rice	Well-puddled seedbed. If there is standing water — no weeding; otherwise, spot weeding.	–	As needed
Upland crop			
Field not plowed	Paraquat to be applied if weeds cover 50% of plot at crop establishment; otherwise, no weed control.	0.75	Before furrowing
Field plowed	Mungbean and cowpea — no weeding	–	
	Sorghum — interrow cultivation	–	4 weeks after emergence.

For a single cropping pattern, the resources are most easily determined by substitution; the farming system's less used resources are added to the resources used by the cropping pattern that is to be changed. To be feasible, a cropping pattern should not substantially increase the use of a resource during existing periods of peak requirement. A more rigorous treatment (as a resource allocation problem) requires linear programming or similar routines for optimizing the total cropping system, or, better still, the complete farming system. That demands knowledge of the performance of all the component activities of the system as a function of resource allocation and costs, which goes far beyond a rough estimate of cropping pattern performance.

Economic viability. The economic viability of a pattern can be determined by a budget analysis at the time of cropping pattern design. This analysis uses costs of the labor and purchased inputs for all operations specified as well as a conservative estimate of expected yields. Initially costs are estimated from the baseline study. In later years, they can be refined on the basis of record keeping results. The profitability and returns to resources (productivity) of the pattern can then be compared with those of the existing pattern or patterns to be replaced. The input levels for

component technology assigned to the cropping pattern should increase net returns above those obtained from existing patterns, and still provide returns to purchased inputs and labor that are above those normally obtained in the site.

These resource productivities of existing patterns can be estimated in several ways. The averages and seasonal variations of labor wages are estimates of the labor productivities that may need to be satisfied. Budget analysis of existing patterns can also provide estimates of returns to labor and cash commonly obtained at the site. In cash-poor regions, improved production derived from increases in levels of purchased inputs will substantially reduce net returns to cash. This may be unavoidable, and may not necessarily restrict adoption as long as the returns to cash are well above those obtained in other enterprises in the region, and as long as credit is made available. Where great increases in credit availability are expected, the cost of cash (interest plus other costs, Chapter 3, Table 10) that prevails in the area can help estimate returns to cash that would have to be met by new cropping patterns. These returns should be 50% or more above the cost of cash. This high return to cash is advocated because the cost of cash is generally conservatively estimated and ignores hidden costs from risk and social consequences associated with being indebted.

Our experience is that such analyses often indicate the need to reduce purchased input levels or reduce the number of operations specified in the design. The operations and input types in which such reductions finally take place depend on the returns to the investments perceived by the group that designs the cropping pattern.

The usefulness of the expected pattern performance as a design criterion depends on the accuracy with which performance can be estimated before testing in farmers' fields. The estimate is generally obtained by extrapolating from patterns or component crops from similar environments. As this estimate is improved and the knowledge of the inputs required becomes more precise, the performance criteria used in pattern design will more closely resemble those used after field testing of the cropping patterns.

CROPPING PATTERN TRIALS

A cropping pattern trial compares a number of experimental cropping patterns with one or two representative existing patterns. The existing patterns are entirely managed by farmers and the site team carefully limits its activities to monitoring their performance. The management of experimental patterns is designed by the research team. It is discussed with farmer cooperators and, where necessary, modified. The experimental cropping patterns are then grown by farmers, who use their own power and labor sources, under supervision of the site team, who monitor the performance of the cropping pattern.

Experimental cropping patterns. The following steps are suggested for the design of the cropping pattern trial at a site:

1. Decide on the land types to be studied at the site and describe each of them as precisely as possible. The team need not conduct research on all land types in its area of operation; two to four of the most important (common) land types will generally cover most of the production systems at a site.
2. Identify factors that limit crop production similarly in all land types. They may

be climatic (temperature, winds), general fertility problems, minor element deficiencies or toxicities common to all land types, and predictable occurrences of crop pests.

3. Evaluate the present knowledge about corrective actions that can reduce the limiting effects of the factors, and specify the consequences for the choice of crops and component technology.
4. Decide on the cropping patterns to be studied for each land type. A research team should limit itself to three or four experimental cropping patterns for each land type. Some patterns may be the same for different land types. In fact, it is desirable that the performance of one or more patterns be compared between land types.
5. Assign cropping pattern management technology. As the research team considers different alternatives, it must attempt to evaluate the expected yield response and the cost involved for each alternative. At the time of design, the cropping pattern should be subjected to a simple cost-and-return analysis.

Farmers' cropping patterns. The farmer's cropping patterns are based on experience. Over time the farmer selected patterns suitable for the site. Those patterns reflect the way farmers employ labor and cash in crop production and the kind of returns they expect from those resources. In cropping systems research the farmers' patterns are the basis for evaluating the performance of experimental cropping patterns.

To minimize the effects of experimental patterns on the farmers' patterns used as a basis for comparison, it is important to select the farmers' patterns from separate farms. In this way, new management techniques, additional cash and access to new equipment are less likely to modify the monitored farmers' cropping patterns. Consideration should be given to locating part of the monitored farmers' patterns in peripheral areas not affected by other project activities as long as land types continue to be the same as those studied by the team.

The cropping system of a farm often combines patterns that differ greatly in the amount of cash and labor inputs. Selecting the type of patterns for comparison with experimental patterns is therefore important. It depends on the objectives of site researchers. The following are some common analytical objectives for which observations on farmers' cropping patterns are used:

- To compare the benefits of the farmers' patterns with the experimental patterns,
- To evaluate more precisely than in the baseline study the component technology that farmers use, and identify changes in component technology over time, and
- To identify changes in cropping patterns over time.

To compare experimental and farmers' cropping patterns, two levels of sophistication can be considered:

Pattern-to-pattern comparison. This comparison uses simple cost-and-returns analyses and partial budgeting techniques. In the analysis, labor, inputs, and product prices are varied over the year to reflect variations encountered at the site.

Experimental and farmers' patterns are compared on a field-to-field basis using a set of performance criteria.

This method ignores interactions that can occur in the allocation of resources between different cropping patterns on the farm. Analyses that capture these interrelationships can lead to a different ranking in performance of experimental patterns from that obtained by partial budgeting comparisons (Barlow et al 1979). The advantage of the partial budgeting approach is that it requires detailed information on only one or two types of cropping patterns that occur most frequently or cover the greatest area in each land type. If a research team does not intend to limit itself to staple food crops, a selection of the two most important patterns of each type will often provide a useful continuum of resource combinations used by farmers in a land type. This will often include cash-intensive and labor-intensive patterns as well as lower input patterns. With some care in interpretation of returns from crops that require specialization, this combination of patterns will provide an adequate base for the evaluation of resource productivities obtained by farmers in that land type.

Information on labor, input, and product prices and their seasonal variation required for the partial budgeting approach can be measured directly, by key-informant or group interviews at the site. This allows a further reduction of the data collection part of cropping patterns testing.

Whole-farm analyses. The analysis of the performance of the pattern, when included in the whole farm enterprise, evaluates, often in a linear programming framework, the area, per land type, that farmers would allocate to an assortment of introduced and existing patterns. This evaluation is done under a given set of resource limitations, while maximizing economic returns to the farm enterprise or some other index of farm productivity.

Whole-farm analysis of the performance of cropping patterns demands more complete information. It requires information on the availability of and the demand for land, labor, and capital at different times during the production process. The collection of such information requires the recording of land and labor use, and cash flows for all enterprises on the farm (including animal production, cottage industry, and off-farm employment). It is generally too time-consuming for most research teams and requires a substantial staff for data collection and processing. Where a cropping systems program contemplates whole-farm analysis, it should be based on the following two sets of information to be collected in addition to the information obtained by monitoring the representative farmers' patterns used in the partial budgeting analyses:

1. detailed farm record on a small number (five) of farms selected because they represent farms with a range of resource mixes (large vs small area, rich vs poor, different land type mixes on the farm), and
2. information on farm types and land types per farm, much of which is available from the baseline study. If not available, it can be collected in a single survey. This information suffices to construct whole-farm models that capture the most important enterprise trade-offs and can reflect the effects of different resource endowments on the suitability of experimental cropping patterns.

The second objective, a detailed evaluation of farmers' component technology, is best achieved by focusing on the representative cropping patterns. These have already been selected for each land type for the purpose of measuring costs and returns of farmers' cropping patterns. The record keeping for this objective should pay particular attention to time and methods of crop establishment, equipment used, plant populations or seeding rates, time and levels of application of fertilizers, pesticides, and manures, and harvest and processing methods.

Changes in farmers' cropping patterns over time can indicate farmers' acceptance of new technology, even in the absence of active extension efforts in the research area. Such acceptance provides the most definite indication of an experimental pattern's suitability. It also means that the base against which cropping patterns are tested is changed. The benefits of the introduced patterns may then have to be measured against unmodified patterns only. Although such changes in the selected farmers' patterns can be noticed, detailed measurement of cropping pattern shifts requires a broader sample. Where such information is desired, a repeated survey of the cropping patterns used in all plots of 40-80 farms is necessary. This survey should identify for each plot the crop types and varieties grown as well as their planting and harvesting dates. The first survey should be conducted at the start of the project and subsequent surveys can probably wait until the third or fourth year.

COMPONENT TECHNOLOGY RESEARCH

Because the major research activity at a cropping systems research site is the testing of improved cropping patterns, the site team must ensure that the management specified for each crop in the patterns is optimal.

As the team discusses cropping patterns and the component technology to be assigned to them, it will also identify information gaps and factors that need to be studied at the site. The information gap will often be about the levels and efficiencies of purchased inputs to be used. There may, however, be a need for further environmental description, such as better definition of the duration of irrigation, the time of rains, wage rates for labor during harvest, or the farmer's ability to identify insect pests and associated damage. A cropping pattern may be suitable except in one aspect of component technology such as suitable variety; insect weed, or disease control; fertilization or tillage method; or the date of crop establishment. An early definition of the predominant weed species and the crop response to major plant nutrients is also required.

Component technology research is conditioned to the cropping pattern selected. It normally addresses only one crop of the pattern sequence and one or two variables, such as variety trials, tillage methods, and subsequent levels of weed control, or method and rate of nitrogen application. Component technology trials are generally managed by the cropping systems researchers rather than by the farmers.

A research team must study only those management components that have a major impact on the economic performance of the cropping pattern. Generally the team focuses on the responses to inputs, and leaves explanation of underlying mechanisms to other researchers. Complex management problems, varietal traits required at the site, ineffectiveness or breakdown of pest control methods, and

Researchers lay out a trial in a farmer's field. Component technology trials are generally managed by cropping systems researchers rather than by a farmer.

complex soil problems should be discussed with research station scientists. Such requests for supportive research should be accompanied by an indication of present yield losses and future benefits associated with the management bottleneck.

Selection of factors and treatment levels. For the initial experiments, three general sources of information are used to identify the factors and treatment levels to be tested:

- baseline studies,
- *a priori* knowledge of crop requirements, and
- previous conventional field experiments in the site area or in similar environments elsewhere. These may have been conducted in anticipation of a subsequent cropping pattern research program or through the routine activities of organizations conducting multilocational trials.

It is also useful to identify the two management components that demand most cash and the two that require most labor. Then try to estimate the effect of changes in each of these components on yield and evaluate the potential input savings or yield increases that could be derived from research on these factors.

Superimposed trials for component technology evaluation. Most component technology research should be closely associated with the cropping pattern tests and should be designed to test current management components assigned to the pattern. To ensure close association with the cropping pattern trials, much of the research is conducted in the same fields in which the patterns are tested; hence, the term superimposed.

At IRRI's research site, superimposed trials were originally done by the addition of higher input levels to small plots at one side of a cropping pattern trial (Garrity et al 1979). The limitation of this approach was that only input levels above those used in the cropping pattern could be used. The advantage was that the interference with the cropping pattern management of the farmer was rare.

The design for the superimposed trials should:

- evaluate the return farmers derive with existing practices from purchased material inputs used for weed control, fertilization, and pest and disease control;
- evaluate the return the cropping pattern component technology obtains from these inputs;
- determine if it is possible to modify the management components assigned to the cropping pattern for weed, insect, and disease control and fertilization that lead to increased yield; and
- determine if these yield increases are sufficient to pay for the additional costs of the modified management components.

To achieve these objectives, superimposed trials must include:

- a simulation of the farmers' management level;
- the farmers' management level without any purchased material inputs;
- the level of component technology assigned to the cropping pattern; and
- a level of component technology that is expected to produce higher yields than the cropping pattern at the same or higher input levels.

Researcher-managed trials. Researcher-managed trials are entirely managed by the cropping systems research team. They evaluate, in detail, specific management components to be assigned to cropping patterns and cover a wider range of management alternatives than the superimposed trials. They result in an increased number of variables and levels included in the treatments.

Researcher-managed trials seek to understand more precisely the type of responses to input levels and to evaluate high-risk treatments about which too little information is available to be included in cropping pattern trials managed by farmers. The results of these trials are analyzed with an emphasis on treatment differences and require considerable precision. The results determine future changes in cropping pattern management levels and the management components to be studied in the superimposed trials.

The experimental designs for researcher-managed trials are not discussed in detail in this book. They follow the considerations of small-plot experimental design at research stations. Because of limited field size, treatment numbers should normally be kept between 6 and 12. There should be three or more replications except where

multilocational testing is involved, in which case within-field replications should be reduced to two, as long as the total number of replications is four or more. At times, researcher-managed trials are similar to superimposed trials in design, but are managed entirely by researchers in farmers' fields.

Researcher-managed trials should use the same tillage methods and implements and the same component technology (for fixed management) as those used for the corresponding crop in the cropping pattern trials. For factors that are varied, the treatment levels must include those used in cropping pattern trials and the high-level treatment of the superimposed trials. Limits to seeding dates that apply to a crop in the cropping pattern must be applied to the component-technology trials to allow linking of the results of the component-technology research and the cropping pattern trials. Where field X treatment interactions are considered important, the number of fields should be at least four and within-field replication can be reduced to a minimum. Examples of researcher-managed trials commonly conducted at the site are described in the next section.

Fertilizer-response trials. Fertilizer-response trials evaluate responses to nitrogen, phosphorus, and potassium and, where differences are suspected, responses to important minor elements. The type and number of trials depend on the soil-fertility conditions at the site and on what is known about yield responses to added plant nutrients. Generally, replicated and unreplicated trials are used to sample fields within a land type so that the recommendation will be based on results that include the variation that occurs within a land type. Appendix 1 provides two examples of research designs, their statistical analyses, and their economic interpretation. For additional references on experimental design and analyses, see Laird (1968), Houser (1970), Cady and Laird (1973), and Waugh et al (1973).

In cases where drought stress or flooding damage is common, an understanding of the reduction in response to fertilizer leads to the avoidance of high input levels on high-risk crops.

Yield-loss studies for insect pest control recommendations. A large array of insecticides is available and many variables such as formulation, dosage and timing, and frequency of application are involved in yield-loss studies. There is no need to evaluate a large set of possible insect control recommendations for each crop or to screen insecticides or evaluate dosages at the site. The task of the site researchers is to use knowledge about insecticide effectiveness, observed yield losses, timing, methods and dosages of insecticide application, varietal resistance, and costs of insecticides to arrive at an economically efficient control recommendation compatible with the resource level of the farmers (Litsinger 1977).

The following set of procedures will ensure the methodical development of the insect control component with the least research effort and ambiguity (Litsinger et al 1980).

1. Know the target farmers' current pest control technology:
   - insecticide-usage patterns,
   - present level of expenditure, and
   - ability to use other methods of insect control.
2. Define the problem for each crop and crop stage (see Appendix 2):

Insect control trials replicated across farms are repeated for 3-4 years for each crop in a cropping pattern before a recommendation is made. The growth stage yield loss method assures that insecticide usage is economically justified.

- determine the average monetary yield loss from insect pest damage for each growth stage, and
- using standard sampling procedures, identify the insect pests causing yield losses.

3. Choose the appropriate technology to test against the key pest problems:
   - least expensive, most effective insecticides,
   - insect-resistant varieties,
   - conservation of natural enemies, and
   - retention of effective cultural controls.

Appendix 2 provides an experimental design for determining a suitable insect control recommendation for cropping patterns. This design is particularly effective for developing the most efficient pest control strategy for crops in which substantial yield losses to insect pests are suspected.

Researcher-managed studies for weed control recommendations. Weed control research at a site must ascertain the extent of yield loss attributable to weeds, determine if the farmer controls his weeds adequately, and identify the extent of

Recording stem borer deadhearts during the vegetative stage of dry-seeded bunded rice determines if the pest is responsible for any measured yield loss.

weed control required. Efficient control methods must also be determined for crops that are introduced or differ substantially from the crops existing in the site in their interaction with weeds. Often, changes in establishment method (dry seeding of rice), time of planting, or crop position in a sequence or combination can materially change weed control requirements.

Because fields vary considerably in both intensity and type of weed flora, superimposed trials on the farmers' cropping pattern or experimental cropping patterns are often a preferred research method. They allow a somewhat larger plot size and a wider sampling of field-to-field variations. Appendix 3 discusses the uses of superimposed and researcher-managed trials for the development of weed control recommendations.

Variety trials. The performance of varieties will be fairly stable within land types and, often, across land types within a site. Varieties can, however, rank substantially differently when establishment methods and cropping seasons are changed. For example, it may be necessary to test for premonsoon mungbean as well as for postmonsoon mungbean, and the best varieties for dry seeding are not generally the

best for transplanted rice.

Varietal performance is, however, much less sensitive to field-to-field variation. For this reason, the most efficient way to test varieties for all crop types in a site is to select a field representative of a land type and conduct replicated researcher-managed trials. Appendix 4 provides detailed examples of variety trials for several crops.

Reporting of results from researcher-managed trials. Most countries operate several research sites. Comparison of research results between sites within a country or across the cropping systems network provides important insights into the effects of different environments on the performance of varieties, insect control practices, and other component technology aspects that are commonly evaluated at each site. Sufficient site description must accompany the research results to provide clues to the reasons associated with the differences obtained. Appendix 4 provides an example of the background information (Plot and management record for varietal testing) proposed by the Cropping Systems Working Group for researcher-managed trials.

BALANCE BETWEEN ACTIVITIES AT THE SITE

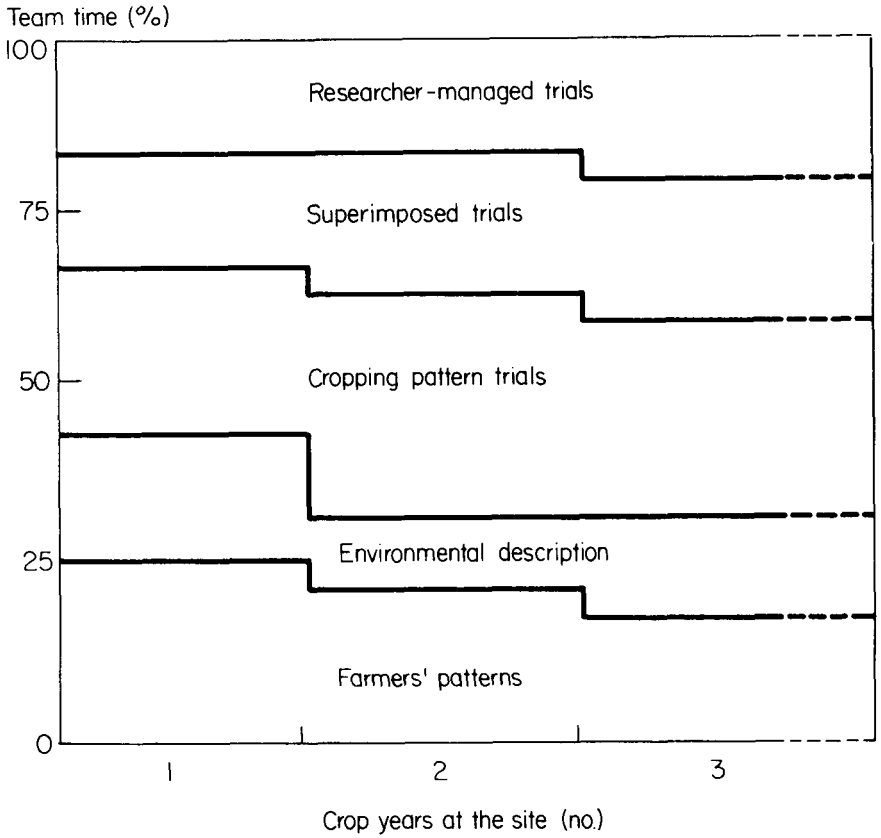
The research team at the site is the instrument of cropping systems research. It is the contact between the agricultural research structure and on-farm reality. This reality must be recognized by the site team in terms of different environmental complexes based on land topography, textural differences, irrigation and drainage characteristics, and slope of the land.

The team members must also be trained in the conduct of farm surveys to determine the farm resource base and identify existing management practices and their relation to important environmental factors at the site. They must relate to the farmers and be adept in interpreting farmers' comments. In addition, the site team executes analyses and interprets experiments.

The team must be encouraged to become a strong interdisciplinary unit that formulates hypotheses about the type of production technology required for the land types in the sites; the hypotheses must be continuously tested against daily observations from farmers' fields, cropping-pattern-test fields, superimposed trials, and researcher-managed trials.

Communication between the team members at a site is extremely important. Development of strong interdisciplinary ties can also be assisted by the whole team's engagement in field operations normally under the responsibility of a single team member. For example, the entire team should participate in initial survey activities or plot selection for pattern trials or design of specific component-technology trials. Also, members should visit each other's trials and discuss the implications jointly. For example, the establishment of grain legumes after rice is an area where several disciplines overlap. Standing rice stubble helps suppress early-season legume pests. It also reduces water losses right after rice harvest, which, together with minimum-tillage planting, can save residual soil moisture.

Omission of tillage requires the development of special planting techniques and the evaluation of weed control requirements. Where planting techniques require substantial labor or specialized equipment, the opinion of economists about



3. A suggested percentage time allocation for the site-related research team to each of the 5 research components at a site.

farmers' acceptance or limits to expenditures must be considered.

As a result of studying farmers' cropping patterns and experimentation at the site, the team becomes a dependable source of information about the behavior of the alternative production techniques in that environment. It, therefore, can greatly contribute to decisions about future research at the site. The team, therefore, should participate in the definition of research priorities for the site and in the planning of experiments and surveys, usually done at a national or regional meeting. Such meetings also provide important opportunities to discuss identified management bottlenecks with national commodity and disciplinary researchers.

It is particularly important that the site team consult with local extension and irrigation personnel. Local administrators of organizations responsible for these sectors must, therefore, participate in the decision-making about the establishment of the research site. Staff members from such organizations can provide valuable guidance in the selection of farmer cooperators, give details about the technological history of the site, and ensure that the research needed is valuable to cropping systems researchers.

The relative effort the research team should expend on environmental description cropping pattern trials, superimposed trials, research-managed trials, and monitor-

ing of farmers' fields depends on what is initially known about the site, the number of years the team has been active at the site, and the type of production problems that are encountered. The research teams should not overload itself with too many trials.

Normally cropping pattern trials should dominate the research activities at the site (Fig. 3). During the first year, the team must conduct, besides cropping pattern trials, researcher-managed trials on insect control (yield-loss method), varieties, weed control, and response to important fertilizer inputs. Superimposed trials evaluate the need for changes in component technology assigned to the cropping patterns.

In subsequent years, researcher-managed trials normally should not increase above the original level. Research should focus on cropping pattern trials and superimposed trials. Where complex problems are identified, site researchers should seek advice from research-station scientists and involve them in the solution.

Evaluation of farmers' patterns continues throughout the research activity at the site but care should be taken to avoid spending too much time on this. The data-collection load for monitoring cropping patterns can often be reduced after the first years because the labor required for standards can be adapted for most common operations. Environmental description peaks during the first year because of baseline studies. As discussed under site description, field work for baseline studies demands most of the team's time for 2-3 months before the cropping pattern design meeting. After that it continues at a lower intensity during the first year and in the following years because of special studies designed to provide additional information required for cropping pattern design and performance evaluation.

Table 1. Examples of objectivesand resources commonly used in the formulation of performance criteria for cropping patterns.

Objective	Resource
Calories	Arduous labor (h, day)
Disposable net returns	August + September labor (h, day)
Gross returns	Cash (unit)
Labor generated	Cost of inputs
Labor saved	Energy (cal)
Net returns	Family labor (h, day)
Protein	Farm owned labor (h, day)
Rice production	Fossil energy (cal)
Risk	Harvest labor (h, day)
Yield	Hired labor (h, day)
	Irrigation water (ha/m)
	Land (ha)
	Light labor (h, day)
	Manager's time (h, day)
	Nitrogen, phosphorus, insecticide (kg a.i.)
	Rainfall (mm)
	Total labor (h, day)
	Water buffalo (h)
	Weeding labor (h, day)

- those relating to resource productivities or product costs (productivity criteria).

The criteria in the first group are expressed in a simple amount; for example, the rice that has to be produced to meet the needs of a farm family, or the limits on land, labor, and cash available for the production of a crop. Some commonly used availability criteria are:

- minimal amounts of rice or other staples required for family consumption;
- maximum cash inputs for a cropping pattern, a crop, or component technology (e.g. insect pest control);
- maximum labor inputs allowed during critical periods or for specific activities (e.g. weeding or harvesting);
- maximum amount of credit that should be required for a crop or cropping pattern; and
- limits to risk that cannot be exceeded for a crop or cropping pattern.

The performance criteria in the second group are productivity criteria, expressed in the form of a ratio between a measure of the objectives of the cropping pattern and a measure of the resource required to achieve these objectives:

$$\text{Productivity criteria} = \frac{\text{objective}}{\text{resource used}}$$

The objectives and resources specified in the ratio may be either aggregate measures applying to the whole cropping pattern or partial measures applying to a crop component or a single resource used in the production process (Table 1). That can lead to ratios, such as grain produced per millimeter of rainwater or net returns per hour of farmer's time (Table 2).

The performance criteria should be so formulated that they highlight the productivity of resources considered critical in the region. An important performance

Table 2. Grain yields and net returns per millimeter of rainwater of 11 cropping patterns in a rainfed, bunded rice-growing area, Iloilo, 1975.[a]

Cropping pattern	No. tested	Total yield (kg grain/mm)	Return[b] (US$/mm)
Rice	10	1.7	0.12
Rice - maize	8	3.3	0.15
Rice - sorghum	3	3.2	0.16
Rice - maize/peanut	2	2.7	0.50
Rice - maize/mungbean	2	2.1	0.09
Rice - mungbean	9	2.2	0.12
Rice - cowpea	10	2.2	0.10
Rice - soybean	6	2.0	0.07
Rice - peanut	6	2.1	0.34
Rice - rice	31	4.5	0.32
Rice - rice - pulses	13	4.7	0.29

[a] Rainfall during crop season ranged from 1,882 to 2,114 mm among locations. [b] Return over variable costs, including family and exchange labor, but excluding cost of land.

criterion may, for example, be the return to hired labor during periods of peak labor requirements.

Some of the more commonly used productivity criteria are:

- yield per hectare for each crop;
- returns over variable costs per hectare;
- returns to material inputs and labor per hectare for the cropping pattern; and
- returns to the farm enterprise.

The returns to the farm enterprise provide a useful first estimate of the overall benefit the farm family derives from a cropping system. It evaluates the net returns the farm unit obtains from the resources under its control — use of owned land, farmer's time, family labor including exchange labor, water, daylight, and farm implements.

Performance evaluation follows the calculation of performance criteria (bottom of Fig. 1). The criteria calculated from experimental patterns are compared with those obtained from farmers' patterns or against more general indices of availability or productivity prevailing at the site. In this way, rice production of the pattern can be evaluated against family requirements. Cash requirements can be compared with cash availability, the credit requirement with the farmers' willingness to be indebted, and labor requirements during turnaround time with those of existing patterns or with indices of general labor availability during that period.

The performance evaluation of productivity criteria follows the same principle (Fig. 1). Returns to material inputs or labor can be compared with those obtained in existing patterns or with the general indices of cash and labor productivity that prevail in the region. Similarly yield per millimeter of rainwater can be evaluated against yields obtained with other crops during the same period, and yield response to inputs can be compared with those obtained by farmers or by researchers elsewhere.

Further examples and the calculation of selected performance criteria are provided in the section on analyses of cropping pattern trials and in Appendix 6.

Management of cropping pattern trials. An important aspect of the testing methodology is the nature of on-farm cropping pattern testing — on-farm testing of patterns whose management is designed by the project, discussed with farmers, and executed by farmers (Harwood [1975]).

- On-farm testing allows identification of many management problems that do not manifest themselves in small plots, where the researcher has complete control over timing of operations and often makes subtle management modifications to avoid problems. The site of a researcher-managed trial is rarely selected at random within a defined environmental complex; it is often determined with the experiment in mind.
- Resource conflicts between the proposed cropping system and the existing systems are difficult to measure in a researcher-managed trial because labor and power inputs are supplied by the researcher.
- Farmers' modification of cropping patterns and their management, particularly the timing of operation, are telltale indications of resource conflicts. Farmers' observations, although not easily interpreted, provide valuable insights into the potential and the limitations of cropping systems tested under their management.
- Through use of superimposed treatments that do not interfere with the farmers' crop production operations, alternatives to the component technology specified for a pattern can be more realistically evaluated than in researcher-managed trials.

The farmer-participant research undoubtedly requires a careful structuring of the test situation to which the farmer is exposed. Experience has shown that the relationship between the research team and the farmers needs to be structured in response to the characteristics of the community. Generally the farmers should be strongly encouraged to participate in the research. In most cropping systems research sites, farmers receive inputs such as fertilizers and other agricultural chemicals from the project. On the other hand, farmers should be encouraged to critically evaluate the proposed cropping patterns, and to comment frankly on the performance of these patterns and the difficulties they may foresee. In this process farmers' observations must be interpreted with caution. A useful way to avoid misinterpretation is to have the research team present the farmer with what it considers the farmers' reaction to the cropping patterns for verification.

A site research team must be aware of potential problems that may arise with some of the cropping patterns such as a case of unusual rainfall or rat and bird damage. The team should consider alternatives for such situations. The research team must also consider delays in certain operations and evaluate with the farmers if such delays merit modification of the cropping pattern on any one field. In this case, the original pattern is considered modified and the reasons for its modification should be documented. Where certain crops in a pattern fail, the research team must decide in advance if it will protect farmers against any losses he may have incurred. In cropping pattern trials, farmers are normally not compensated, but the returns to them are nearly always well above those they would have outside the pattern trials, particularly, where he is provided with the material inputs.

Experimental design. Cropping pattern trials compare patterns that differ in type and number of crops, establishment method, and time and management. That makes it impossible to test patterns using replicated small-plot experimental designs. Because the objective is to evaluate cropping patterns on the basis of their performance in the land types for which they were designed, the land types become the experimental area and fields within the land types become the plots. In the completely randomized design used, the replicates are assumed to sample the variation of field conditions within the land type.

These trials often involve new crops and a change in time of operation from that used in the existing patterns in the area. For this reason, the trials should be managed by farmers to evaluate their capability to manage the cropping pattern. That offers opportunities for the identification of conflicts between the operations required for the pattern and the farmers' resource base or the climate or land qualities. Cropping patterns are tested in large plots (1,000 m^2, if possible) to allow measurement of the labor and time required for the operations used in executing the patterns. Such testing allows precise cost-and-return analysis for the patterns.

For the design of cropping pattern trials, the following general guidelines are suggested:

- The research team should select two to three land types on which to focus its research.
- For each land type, the team should select about three experimental cropping patterns and two predominant farmers' cropping patterns to be evaluated. On some land types, some of the patterns may be the same.
- Each cropping pattern should be replicated in a total of at least five fields and in at least four fields per land type.

This design should be modified as the team acquires more experience in the site. During the first year, more than three patterns per land type may be studied. During the second year the number of patterns may be reduced and the number of replications may be increased to a total of at least five and at least four per land type. During the third year, the team should focus on the most promising cropping patterns. That will allow them to increase the number of replications per pattern to a total of at least six and at least four per land type (Table 3). It is recommended that the research team manage from 40 to 50 experimental cropping pattern trial fields and monitor from 15 to 30 farmers' cropping pattern fields for a total of about 70 fields.

Farmers' cropping pattern. The selection of farmers' cropping patterns should be such that adequate representation is achieved of predominant use for land types studied at the site. The two major existing pattern types, generally those that researchers seek to replace with more productive alternatives, should be selected. The number of replications for each pattern per land type is the same as that for experimental patterns. Table 4 shows how predominant farmers' cropping patterns of each land type are included in the cropping pattern trial described in Table 3. A more comprehensive approach (used at some Asian network sites) is to monitor all cropping patterns on 12-48 farms. The sample farms may be stratified to represent different farm size groups, different land types, or other factors that appear to

Table 3. Example of the year-to-year variation in the design of cropping pattern trials reflecting a trend toward a reduction in experimental patterns and an increase in replications.

Land type	Replications (no.) of cropping pattern												Total
	1	2	3	4	5	6	7	8	9[a]	10[a]	11[a]	12[a]	
Year 1													
1			4	5	4	5	4		4	5			31
2	4	5	4						4		4		21
3	4		4		4		4				4	5	25
Total	8	5	12	5	8	5	8		8	5	8	5	77
Year 2													
1			4	6				5	4	5			24
2	6	5	4						4		4		23
3		5	4					5			4	5	23
Total	6	10	12	6				10	8	5	8	5	70
Year 3													
1			4	6				4	4	5			23
2		6	4						4		4		18
3		6	4					4			4	5	23
Total		12	12	6				8	8	5	8	5	64

[a]Predominant farmers' patterns.

differentiate management. The latter approach is much more demanding in terms of data collection and is often associated with studies on testing methods that employ linear programming or other whole-farm budgeting techniques.

Selection of cooperating farmers. Farmers not representative of the site or its exploration region should be excluded. From baseline study information (see Chap. 3, Tables 7-9) the commonly occurring range of farm characteristics can be identified by excluding the lower and upper 25%. This is particularly important for farm size, ownership, dominant cropping system, family labor, and animal or other sources of traction. Farmers cooperating in cropping pattern trials are normally not considered for monitoring of selected farmers' cropping patterns or for whole-farm recordkeeping. There is an advantage in choosing farmers at the periphery of the site for monitoring of selected farmers' patterns (while keeping land-type considerations in mind). These farmers are generally less encumbered by the activities of the site

Table 4. Example of the number of fields to monitor in 3 land types for the evaluation of predominant farmers' patterns as part of cropping pattern testing.[a]

Land type covered	Predominant patterns	Fields (no.)			
		TPR	ME-TPR	M-TPR	TPR-TPR
Light-textured plateau	TPR, MB-TPR	4	5		
Light-textured plain	TPR, M-TPR	4		4	
Heavy-textured plain, partially irrigated	M-TPR, TPR-TPR			4	5
Total		8	5	A	5

[a]TPR = transplanted rice, MB = mungbean, M = maize.

team and will provide a reliable estimate of the original production system for a longer time.

Data collection from cropping patterns. This section describes data collection methods developed for use in the performance evaluation of experimental cropping patterns and farmers' existing patterns.

Data needed for cropping pattern evaluation were extensively discussed at the fourth and fifth meetings of the Cropping Systems Working Group (1976b, 1977). The cropping pattern monitoring procedure developed at those meetings has been applied for 3 years at the IRRI-managed network sites. The following description of data-collection requirements for cropping pattern testing includes modifications based on our recent experiences. The data collection is separated into four data sets concerned with climate, field characteristics, crop performance, and field operations. These are described in detail in Appendix 5.

Climate. Daily rainfall data must be collected at the site. Where the research sites cover several villages, several rain gauges must be located as centrally as posssible in the cluster of cropping pattern fields. The field numbers that belong to each rain gauge should be recorded to assure appropriate daily rainfall records.

Additional weather data can be collected from the nearest meteorological station. Where possible this should include maximum and minimum temperature, pan evaporation and total solar radiation or, alternatively, sunshine hours.

Land. A plot record is used to identify the characteristics of the plot and the cropping patterns to be planted in that plot. The plot record applies to the area of the field used for the cropping pattern trial. The area may occupy a whole farm plot, or only part of it. Ideally, the whole plot receives the same management as the cropping pattern that is tested.

Plot characteristics necessary for on-site analyses of results are plot size (area), previous cropping pattern that was grown on the field, highest and lowest ground water depth, soil texture of the top soil, and source and availability of irrigation.

More details on the characteristics of the plot are required for cross-site comparison and use of results for extrapolation studies or land-use capability evaluation. These are the texture of the soil profile, the position of the field in the landscape, the official classification of the soil type, soil fertility data such as pH, organic matter content, nitrogen, phosphorus, potassium fertility of the topsoil, and minor element deficiencies or toxicities; and the swelling-shrinking behavior of the topsoil. Appendix 5 provides an example of the plot record and explanatory notes on the methods for recording plot characteristics. This form should be completed before the start of the crop year and should be reviewed at its end to check original statements with respect to groundwater, supplementary irrigation, drainage, etc. and to add new information on the other aspects if necessary.

Crop record. For each crop in the cropping pattern, a set of data needs to be collected to clearly identify crop type, variety, establishment methods, seeding rates or plant spacing or both, crop management, and crop performance. For intercrops, records must be kept for each crop in the mixture.

For crop performance, the stand obtained; the occurrence of yield losses due to weed, disease, and insect pests; the harvest date; and yield should be recorded. An example of crop record developed as part of complete cropping pattern monitoring is provided in Appendix 5. It is accompanied by further exploratory remarks.

Recording of crop production operations. In this section, the collection of data for each operation, material inputs, power source, and the crop produced is discussed. An example format for the recording of plot operations is provided in Appendix 5. It allows entry of the type of operations and the labor and material inputs associated with land, crop establishment, crop care, and harvesting. Because labor is a major input that is highly variable among plots, it is discussed first.

Labor hours. Many methods are used to record labor use. The simplest method is to add the hours of work and multiply the sum by the number of persons working. Three persons working 2 hours each work a total of 6 hours. An implicit assumption in this approach is that all individuals working at that particular job do the same amount of work. If this assumption is not acceptable, man-equivalents can be used but must be used in the whole study.

In collecting labor hours there is a question of what hours to collect. A man leaves his house at 0600 and arrives in the field at 0630 hours. He plows until 0930, rests for 30 minutes, continues plowing until 1130, and arrives home at noon. How many hours has he plowed? The answer can range from 4.5 to 6 hours, but the normal procedure is to record starting and finishing time of the operation in the field, including normal breaks and rest periods. Travel to and from the field should not be excluded and 5 hours should be recorded.

A labor day is accepted as 8 hours of labor. There is little to be gained by choosing another standard and a great deal of confusion could result. Man-equivalents are based on a person's ability to do hard physical work. Many operations in the production of a crop do not require great physical strength. The use of man-equivalents can lead to a serious underestimation of labor requirements. Many 14-year-old girls can transplant and harvest as much rice as a man in a normal working day. Except for special studies, man-equivalents are not recommended as the unit for measuring labor.

Aside from costs, each operation on the cropping pattern plot can be defined by four types of information:

- the date the operation is conducted,
- the labor time required for it,
- the type and amount of material used, and
- the power source.

For certain operations, standard times can be used:

1. *Clearing residues.* Record hours required to clear the field and charge it to the next crop.
2. *Plowing, harrowing, and seedbed preparation.* If possible, record the actual hours, including normal rest periods. The recording of the number of plowing or harrowings is subjective, but a simple approach is to assume that one

plowing includes any number of passes as long as there is no time break of 2 or more days. In the analysis, the total number of hours will be used unless detailed management is being considered.

3. *Planting and transplanting.* These operations vary less in time requirement and standard times because the particular type of planting can be established and used.
4. *Replanting and thinning.* Actual time is needed.
5. *Fertilization.* Hours spent fertilizing make up such a small percentage of the total hours that three standards are sufficient — basal, early topdressing, and late topdressing. Where special placement methods are used, record the actual time used.
6. *Application of chemicals for pest control.* When the crop is short (rice), use one standard labor requirement and, when the crop is tall (maize, cassava, etc.), use a second. The time required for herbicide application is probably the same, irrespective of plant height. All other pest control operations (particularly hand weeding) should have actual labor hours recorded.
7. *Harvesting time.* Include cutting or picking, bundling, and carrying product from the field. Exclude threshing, winnowing, sorting, or any subsequent operation.

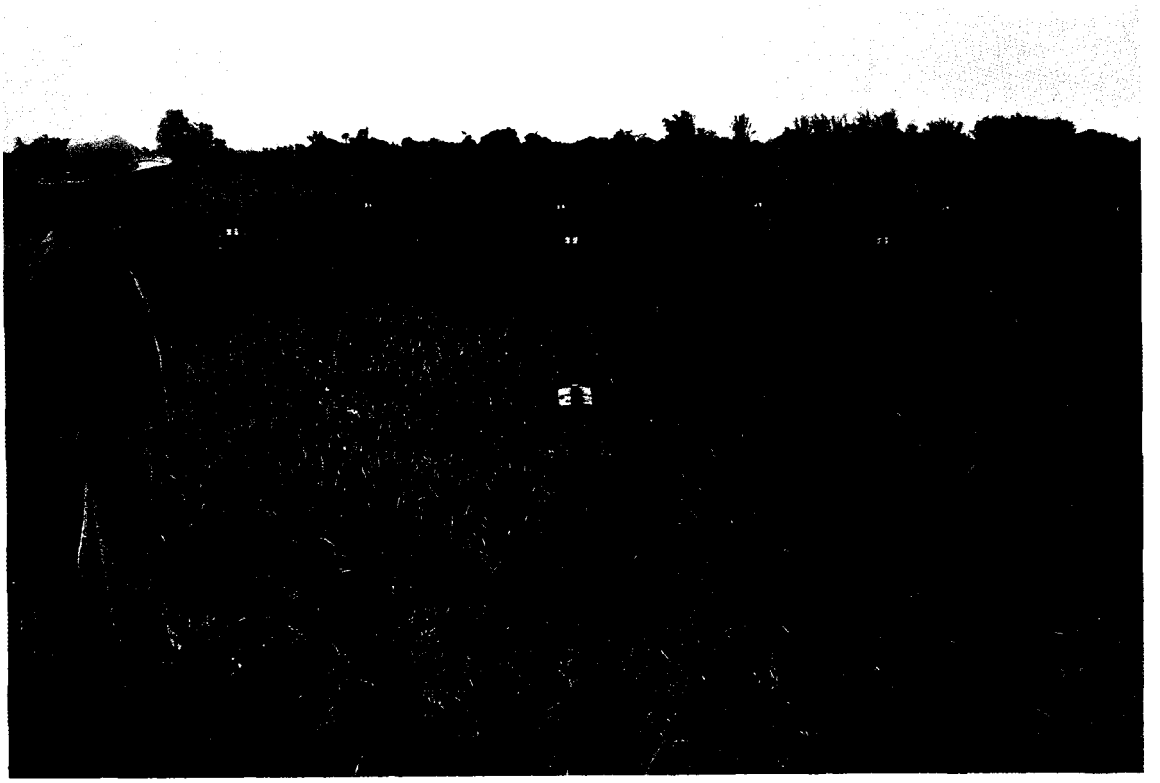
Materials. The type and the unit of measurement of materials should be clearly specified or their costs cannot be correctly computed. For example, it is necessary to specify fertilizer type (urea, ammonium sulfate, etc.), the unit of measurement (kg, bags, etc.), and the percentage of active ingredient. The price (and hence cost) is related to the type of material and the unit of measurement.

Power. The number of power hours used should include rest time of animals but not the traveling time to and from the field. It should be noted whether the power source is animal or a two- or four-wheel tractor.

Output. Production per plot can be obtained by either use of a sample area or a measure of yield from a whole plot, or both. Usually estimates based on the sample area (or crop cut) are 10-20% higher than the total plot yield. Whichever method is chosen, all plots must be handled the same way. Record all products that have value because they should be considered as part of the gross returns.

Prices. Normally prices are not recorded as part of cropping pattern monitoring activities. Prices used in analysis should be farm-gate prices. For inputs such as fertilizer, the cost of transportation (from the dealer to the farm) must be added to the price paid the dealer. If dealers are nearby, transport can be ignored. Prices of material inputs can usually be assumed as constant across months within crop years.

Similarly, the price of products should be what the farmer can obtain if he sells it at the farm at harvest time; if products are usually sold at a market and if transportation costs are substantial, they should be explicitly considered and deducted from the market price to obtain the farm-gate price. The simplest method of obtaining realistic product prices is to survey prices weekly at nearby market centers during the harvest period of the crops in experimental and farmers' patterns. The farm-gate price by period can then be estimated by subtracting the cost of transportation to market.



A researcher-managed trial is used to evaluate differential nitrogen response in a dry-seeded rice crop planted after sorghum and cowpea.

Labor wages. Different crops and different management techniques of given crops imply different rates of labor requirements for various operations. For example, direct seeding of rice is often associated with greater labor requirements for weeding and with less for planting compared with transplanting. If the wage rate for weeding is different from that for transplanting, the variable costs for these establishment methods are affected. For simplicity in analysis, the value of traction power, whether animal or machine, is included with the labor of the operator in land preparation. Obviously the cost per hour for land preparation with mechanical or animal power often differs from the rate for a person working with the hand implement, and the difference should be reflected in different prices. Also, land preparation by man plus machine costs more than that by man plus animal.

A simple initial step toward variable pricing should be to incorporate different wage rates by operation. Appropriate wage rates by operation for the prevalent crops at the site can be identified through simple survey techniques, for example through interviews with about 10 farmers or interviews with key informants such as village leaders. Table 5 shows how the information from 10 farmers might be summarized for a particular crop.

Often farmers at a site follow similar crop schedules and they prepare the land, weed, and harvest about the same time in present cropping systems. Seasonally

Table 5. A sample computation of wages for crop operations from a survey of 10 farmers.[a]

Interview no.	Wage (M) paid for 1 day's (8 h) work												
	Land preparation (person plus animal)			Transplanting			Weeding			Harvesting			
	Cash paid	Value of food	Total value[b]	Cash paid	Value of food	Total value	Cash paid	Value of food	Total value	Cash paid	Value of food	Value of crop share	Total value
1	15	5	20	5	5	10	7	0	7	0	5	16	21
2	12	5	17	5	3	8	5	0	5	0	3	8	11
3	20	0	20	4	3	7	8	0	8	0	6	32	38
4	18	3	21	4	5	10	4	5	9	0	8	10	18
5	12	7	19	5	3	8	6	0	6	0	3	20	23
6	17	0	17	7	0	7	5	4	9	0	6	15	21
7	12	10	22	4	2	6	7	0	7	0	4	10	14
8	25	0	25	5	4	9	5	0	5	0	7	11	18
9	10	5	15	5	6	11	7	0	7	0	7	16	23
10	12	7	19	5	2	7	5	3	8	0	6	9	15
Total			195			83			71				202
Av/day (83 ÷ 10)			19.5			8.3			7.1				20.2
Av/h (83 ÷ 8)			2.4			1.0			0.9				2.5

[a]Harvesters are paid a share of the amount they harvest. Information about the usual share of an adult worker for 1 day was obtained from the interviewees. [b]This value represents compensation to person + animal. A person's wage alone for plowing with an animal is assumed to be half the total value.

variable rates of labor compensation are largely reflected in variation in labor costs associated with operations. The form of compensation may differ by operation. Harvesters, for example, are often paid with a share of the produce. Weeding labor is often paid in cash, with or without the provision of food or a share of the crop.

The wage rates obtained for each operation can be used directly in cost-and-return analyses of prevalent farmers' patterns. These wages are used for operations associated with crops in experimental cropping patterns that are of the same type and that occur roughly at the same time as those in farmers' patterns. Where the type of operation is vastly different from any operation in existing patterns, a wage rate should be chosen to reflect the type of operation and the labor demand at that time.

Analyses of cropping pattern tests. Analysis of cropping pattern tests covers the agronomic and economic performance of the patterns within land types and should be conducted yearly. Because of year-to-year differences in the weather, input costs, and product prices, several years' results may be needed for a reliable evaluation of test results. By carefully considering weather and price changes, researchers can weight their evaluation of test results to obtain a better estimate of the performance of cropping patterns under the more common conditions of the site.

To compare performance among types of patterns, simple T-tests for significance of difference may be used. By combining patterns in different groups within and across land types, several comparisons can be made, giving the researcher a feel of the statistical significance of the differences found. Important criteria for evaluation of pattern performance are the size of the variation in yield and economic measures of each component crop and of the total pattern. The performance of component crops and the patterns should be compared within and across the land types studied at the site. A close study of means and standard deviations for these alternative ways of grouping the results of pattern trials provides much insight.

Agronomic performance. The first step in the analysis of a cropping pattern test is a comparison of the number and type of patterns executed with those actually designed. Farmers may have changed certain component crops or establishment techniques from those in the original design. Crop failure (failure to plant is a pattern shift) should be evaluated for all patterns. Table 6 compares designed and executed patterns for each land type and points to problems of adaptation.

Table 6. An example of the comparison of proposed and executed patterns in cropping pattern testing, Manaoag, Pangasinan, Philippines, 1977-78.

Cropping pattern	Patterns (no.)			
	Shallow water table		Deep water table	
	Proposed	Executed	Proposed	Executed
Rice-rice-upland crop	31	14	21	3
Maize-rice-upland crop	0	—	17	12
Rice-rice-rice	9	8	0	—
Rice-rice-fallow	0	5	0	9
Rice-upland crop	0	13	0	13
Rice-fallow		—		1
Total	40	40	38	38

Table 7. Time of pattern establishment in relation to the feasibility of a proposed 3-crop pattern.[a]

Time of seeding	Implemented patterns (no.)		
	DSR-TPR-UC	DSR-TPR	DSR-UC
Before 31 May	13	6	5
After 31 May	3	10	11

[a] DSR =dry-seeded rice, TPR =transplanted rice, UC = upland crop.

Comparison of proposed and actually executed patterns showed the rice-rice-rice pattern in the shallow water table land type and the maize-riceupland crop pattern in the deep water table land type to be the best adapted. The rice-rice-upland crop succeeded more frequently in the shallow than in the deep-water-table land type.

In a study of each cropping pattern shift or crop failure to identify its cause, it should be kept in mind that extremely unusual years may cause failure of a normally acceptable pattern.

Pattern failure may be associated with land type. When it is suspected, the designed and actually executed patterns should be compared within land types. Causes of pattern failure can be divided into those related to climate and land type suitability and those related to management problems. Lack of early rains may delay first-crop establishment so much that farmers decide against planting a second crop. As seen in Table 7, early established fields have a much greater chance of completing the proposed 3-crop pattern than late-established fields. Furthermore, long-term rainfall records of the research site showed that the first rice crop had to be seeded before 1 May to ensure the good performance of a dry-seeded rice-transplanted rice-upland crop pattern.

Additional analyses of individual crop yields or cropping operations can often point to relationships that are important for future cropping pattern design. These relationships may be obtained from comparisons of:

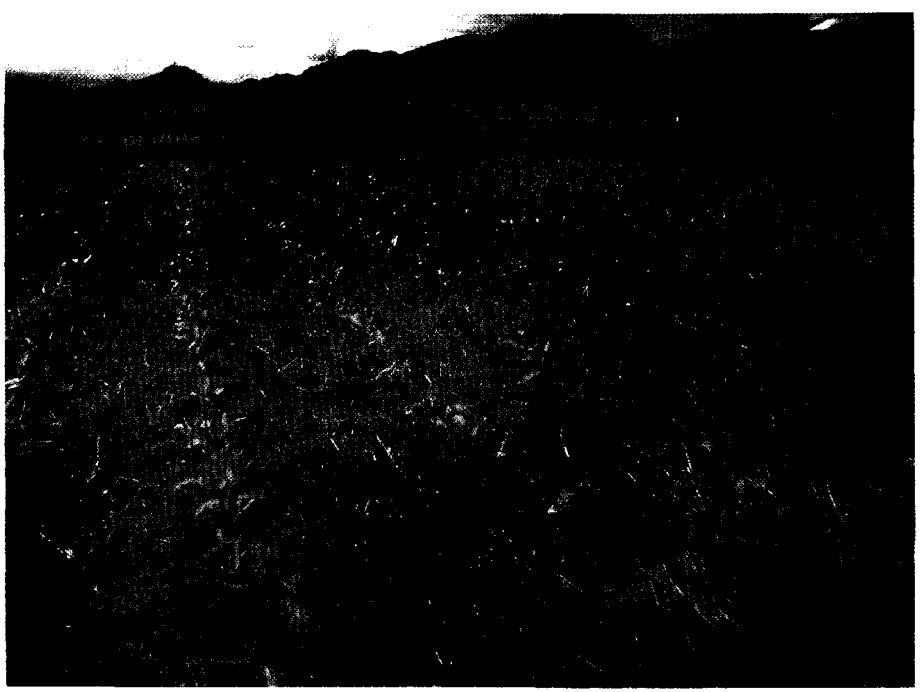
- yields and planting dates,
- yields and rainfall during the growing period or parts of it,
- accumulated rainfall and time of planting or land preparation, or
- lengths of turnaround time between crops.

Researchers may also be interested in comparing the potential productivity of the land types they have selected. This can be done by comparing the productivity and variance in productivity of the best-performing patterns for each land type as a measure of the cropping pattern potential of that land type.

Another important analysis of cropping patterns is a comparison of the performance of the same crop in different patterns. The same crop in this context means one that is established in the same way and about the same time in the cropping season, but it can be preceded or followed by a different crop and thus be part of different cropping patterns. It is useful to pull together the results for each of the crops and compare them. That will allow a more valid comparison of the effects of land types (Table 8) and previous crops on the performance of the crop being evaluated.

In addition to measuring the performance of several alternative cropping patterns, the testing phase indicates the research team's ability to design improved

Intercropping techniques allow more intensive land use in dryland fields. This is the cassava/rice bean phase of a rice + maize + (cassava/ rice bean) pattern.



Zero tillage planting of dryland crops after wetland rice saves soil moisture and growing-season time.

Table 8. An example of rice-yield partitioning by land-type determinants. Mean yields, as affected by determinants used in the land-type classification, show that the first rice crop yields were high and similar across land types, whereas yields of the second rice crop were low, but better in heavy-textured and shallow water table fields than in the light-textured and deep-water-table fields.

Crop	Mean yield (t/ha)			
	Shallow water table	Deep water table	Heavy textured[a] (c, sic, cl)	Light textured[b] (sicl, sil, sl, l)
1st rice crop	4.6	5.6	4.8	4.9
2d rice crop	2.6	1.3	2.2	1.3

[a]c = clay, sic = silty clay, cl = clay loam. [b]sicl = silty clay loam, sil = silty loam, sl = sandy loam, l = loam.

cropping patterns for each of the land types studied at the site. It also allows an evaluation of the extent to which the cropping pattern determinants, used as stratifying variables for the different land types, explain differences in pattern adaptation and will be used for future recommendations. In this manner the test results may lead to modifications in the site description through a change in land-type definition. Testing cropping patterns in the farm setting provides important clues to technological constraints to increased production such as lengthy turnaround times between crops (Table 9); a lack of techniques for upland crop establishment in previously puddled wet rice fields; plant pathological and allelopathic effects of crop sequencing; weed control in dry-seeded rice; fertilization of zero tillage planted dryland crops growing on residual soil moisture; and ratooning of rice varieties. In Table 9 comparison of the turnaround period between wet-seeded rice and transplanted rice as methods of second-crop establishment in rice-rice patterns shows that the period from harvest of the first rice crop to planting of the second rice crop is longer for fields that are transplanted than for fields that are wet seeded.

Economic evaluation of pattern performance. This section describes methods for comparing experimental cropping patterns with existing ones to judge the acceptability of research results to farmers. The comparisons, however, are no substitute for farmers' carefully recorded comments about experimental patterns. Researchers should develop, through frequent interaction with farmers, a clear understanding of the attractive and unattractive aspects of the cropping patterns they test. Quantitative analyses and evaluation of analytical results are, however, a necessary complement to feedback obtained from farmers' responses. They permit documentation and provide an objective base for comparison over different crop years and site.

The section on performance criteria showed that many availability and productivity criteria can be formulated from the data on cropping patterns. The most

Table 9. A comparison of turnaround periods for 2 systems of rice culture.

Method of establishment	Fields (no.)	Turnaround periods (days)
Wet-seeded rice	60	16.0
Transplanted rice	23	26.0
Difference		10.0**

**Significant at 1% level of probability.

appropriate evaluations to make will depend on the socioeconomic conditions at the site. Consider, for example, a site that has limited market access and in which farmers produce primarily for their own consumption and cannot sell much of their produce. For farmers in this site, increasing food production per unit cash and labor invested may be a more important objective than increasing returns above variable costs. Another site, in which land is only partly cultivated because of a lack of power and labor, may require evaluation of pattern performance on the basis of returns to labor and power cost. Most cropping systems research sites, however, are sufficiently market-oriented to allow the use of monetary performance criteria. At the risk of oversimplification, this section provides a procedure for evaluating the acceptability to farmers of new cropping patterns based on two relatively simple tests.

Cost of calculation and return analyses are the first step in performance evaluation. Appendix 6 provides a detailed example of cost-and-return analyses and the use of these partial budgets in calculating some common performance criteria, such as returns above variable costs (RAVC) and returns to selected production factors. Simply put, RAVC is the difference between the value of all the crops produced in a cropping pattern and the value of all the variable inputs — including those not purchased in the market place — used to grow those crops. Table 10 shows a simplified illustration of a cost-and-returns account. An experimental cropping pattern is first tested by comparing the RAVC of the experimental pattern with that of the prevalent farmers' patterns in the same land type. Prevalent cropping patterns are those that farmers use in 30% or more of the area of a land type or the two most common patterns, if these do not add up to 60% of the area of the land type. Minor patterns are those to which farmers allocate land portions smaller than 30%. Table 11 shows possible land allocation situations.

Farmers are likely to be attracted by a new technology that is substantially more profitable than the technology they currently use. Experimental technology whose RAVC is less than 30% greater than that of the prevalent farmers' pattern has doubtful promise for farmer adoption. Thirty percent is a rule of thumb based on the experience of cropping systems researchers.

An experimental pattern that during 2 or 3 years of trials offers 30% greater RAVC than the farmers' prevalent cropping pattern may be recommended for introduction to farmers. That is the first criterion for testing experimental patterns. The test's reliability rests on the assumption that farmers wish to increase their returns above variable costs. The simple 30% rule, however, can give erroneous conclusions regarding the likelihood of farmers' adoption, as in the following cases:

- if a new experimental pattern, while offering 30% higher net returns, offers a lower rate of return on additional costs than a prevalent farmers' pattern that can yet be expanded on the same land type, or
- if a minor pattern ignored in the analysis is actually a superior-performing recent introduction in an early expansion phase in the land type considered, or
- if the experimental pattern rapidly exhausts a limited resource such as well water or cash for inputs or labor in a critical period.

In the last case, adoption will be confined to a small area. Other resources that may

Table 10. An example of a simplified account of variable costs, gross returns, and returns above variable costs.

	First crop: maize			Second crop: rice			All
	Amt	Price	Cost	Amt	Price	Cost	crops
				Input			
Labor and power	(h)	(₦/h)	(₦)	(h)	(₦/h)	(₦)	(₦)
Land preparation	80	2.00	160	100	2.00	200	360
Planting	30	1.00	30	80	1.00	80	110
Weeding	30	2.00	60	20	1.00	20	80
Harvesting	20	2.50	50	160	2.50	400	450
Subtotal			300			700	1000
Materials	(kg)	(₦/kg)	(₦)	(kg)	(₦/kg)	(₦)	(₦)
Seed	50	2.00	100	50	2.00	100	200
Fertilizer	80	2.50	200	200	2.50	500	700
Insecticide	0	0.00	0	20	5.00	100	100
Subtotal			300			700	1000
Total			600			1400	2000
				Product			
	Amt (kg)	Price (₦/kg)	Value (₦)	Amt (kg)	Price (₦/kg)	Value (₦)	Value (₦)
Gross return	1500	1.00	1500	3000	1.00	3000	4500
Return above variable costs			900			1600	2500

limit expansion of the area planted to certain cropping patterns are traction power (bullocks or water buffalo), availability of credit, availability of specialized inputs (particularly seed), priority given to the land for subsistence crops, and lack of markets for the product.

At times areas of a land type are planted to one or more minor cropping patterns that show much higher RAVC than other patterns. A research team should determine if the minor patterns were recently introduced or if they are a type of pattern that cannot occupy much land because of a limited resource. If the pattern is recently introduced and there is no obvious reason limiting its expansion, it and farmers' prevalent patterns should be compared in a further test of the experimental patterns.

To correct for the first possible source of error indicated above, an additional test may be used based upon the marginal benefit-cost ratio (MBCR). The MBCR of the prevalent pattern (F) and any potential replacement (E) for it may be computed as:

$$\text{MBCR} = \frac{\text{gross returns } (E) - \text{gross returns } (F)}{\text{total variable costs } (E) - \text{total variable costs } (F)} = \frac{\text{MVP}}{\text{MVC}}$$

where MVP is the marginal value product and MVC is the marginal value cost. Marginal benefit-cost analysis is usually applied to crop responses to single input factors, but here it is applied across different cropping patterns, with inputs and products standardized in value terms.

Table 11. Land use on 4 land types.[a]

Pattern	Area on av farm (%)	Pattern	Area on av farm (%)
Land type 1		*Land type 3*	
Rice-rice	50*	Rice + cassava	30*
Rice-fallow	40*	Maize-rice	25*
Maize-rice-mungbean	10	Maize-maize	20
		Rice-mungbean	15
Land type 2		*Land type 4*	
Rice-rice	70*	Rice-rice	40*
Rice-mungbean	20	Rice-fallow	40*
Rice-fallow	10	Rice-ratoon	20

[a]Figures marked with an asterisk are those for prevalent patterns and the returns above variable costs should be compared with those for experimental alternatives.

According to economic theory, when a farmer is making maximum profit from all the resources and technologies (cropping patterns) available to him, the MBCR implied by all possible shifts between two cropping patterns should be equal. Actually, new cropping patterns are introduced to the farmer, or his resources change. The farmer then has several alternatives to choose from for the additional investment he is prepared to make. In such cases, the MBCR evaluates which pattern of a series of alternatives is most likely to replace an existing pattern. This will be the alternative that offers the highest MBCR for switching from the pattern in question to the alternative pattern.

This test is based upon several observations that appear applicable to most cropping systems research sites:

- Experimental patterns require higher investments of labor and cash per hectare than farmers' patterns.
- Cropping patterns that show higher RAVC generally have higher costs per hectare, and equal or lower marginal rates of return per unit of cost; that is, constant or decreasing returns to resources is generally evident among farmers and experimental cropping patterns.
- All land is so allocated to cropping activities that adoption or spread of any given cropping pattern implies the reallocation of land from some other cropping pattern.
- Adoption or expansion of area in a cropping pattern generally takes place when a farmer is willing to invest on a land type more labor and materials per hectare than previously.

The purpose of the second test is to suggest caution if a new technology offering 30% higher net returns also implies an additional cash outlay on which the rate of return is low.

The second test is easy to apply. For each existing pattern considered for replacement, one constructs a simple table in which cost and returns for the experimental patterns, the farmers' prevalent pattern, and all alternative patterns are arranged in order of increasing net RAVC per hectare (Table 12). Comparison

Table 12. Example of a test of pattern acceptability of alternatives for rice-fallow in land type 1.

Cropping pattern	Area on typical farm (%)	Total variable cost (A) (₱/ha)	Total return (B) (₱/ha)	Returns above variable cost (B-A) (₱/ha)	Marginal cost (C) (₱/ha)	Marginal returns (D) (₱/ha)	MBCR[a] for replacing rice fallow (C ÷ D) (₱/₱)
Rice - fallow (base)	50	800 (A1)	2000 (B1)	1200			
Rice - mungbean	30	1100 (A2)	2500 (B2)	1400	300 (A2-A1)	500 (B2-B1)	1.7
Rice - ratoon (exp)		1000 (A3)	2700 (B3)	1700	200 (A3-A1)	700 (B3-B1)	3.5
Rice - rice (exp)		2200 (A4)	4100 (B4)	1900	1400 (A4-A1)	2100 (B4-B1)	1.5

[a]Marginal benefit-cost ratio.

of net returns (30% rule) and MBCRs then allows determination of the alternative or experimental patterns that will expand into the area planted to the farmers' patterns. A prospective shift to a new cropping pattern should offer a higher MBCR than any shift among farmers' present patterns on similar land types.

Table 12 shows the situation where a typical farmer allocates 50% of his land to a single crop of rice and 30% to rice followed by mungbean. The remaining 20% of land is presumably allocated to several minor patterns. In determining if a new pattern might have substantial impact on an area, the possible reallocation of land from such minor patterns is ignored.

Consider first a farmer's alternative among present technologies. If a farmer wished to earn more by investing more in farm inputs — his only choice is to shift land from rice-fallow to the higher paying pattern, rice-mung. However, since the rice-mungbean pattern is only 17% more profitable than the rice-fallow pattern, it is not a particularly attractive shift. On the other hand, since it is a traditional technology, presumably there is much more certainty about how to grow it and what the outcome would be than about an entirely new technology. In this case, a farmer is likely to be willing to accept a profit incentive lower than 30% for shifting land to a different cropping pattern.

In summary, without any new technology, farmers are expected to gradually shift to the rice-mungbean pattern as additional resources to pay for variable costs become available. Note that for each additional ₱1.0 the farmer spends on inputs as he shifts from rice-fallow to rice-mungbean, he receives ₱1.7 gross return, or ₱0.7 return above variable costs.

Now consider the possible introduction of a new technology, the rice-rice cropping pattern, into the system. Will farmers adopt it; that is, is it likely to replace either the rice-fallow pattern or the rice-mungbean pattern? The rice-rice pattern offers a return above variable costs of ₱1,900, 58% greater than that offered by the rice-fallow pattern, thus it passes the 30% rule. However, as is often the case with an improved technology, the total variable costs are 2.75 times the outlay on the rice-fallow pattern, a marginal investment of ₱1,400/ha, on which the farmer can expect to receive ₱1.5 for each ₱1.0 worth of additional labor and materials. The relatively large additional cost of the new technology alone suggests caution, regardless of its profitability. But, furthermore, the farmer has the alternative of investing any additional resources he has in the relatively less costly rice-mungbean pattern, for a higher rate of return – ₱1.7 vs ₱1.5/m. It is likely that this shift will run its course until most land is planted to rice-mungbean before farmers will consider the rice-rice pattern.

The rice-rice pattern is also not likely to replace the rice-mungbean pattern as long as a significant area of land is planted to rice-fallow. Although the rice-rice pattern offers 36% higher returns above variable costs than the rice-mungbean pattern, increased planting of mungbean after rice is nevertheless a higher paying marginal investment.

Now consider the experimental technology, rice followed by a ratoon rice crop. Is it likely to replace the rice-fallow pattern, or the rice-mungbean pattern? The rice-ratoon pattern offers 41% higher RAVC than the rice-fallow pattern, and it

requires a relatively small ₱200 additional investment. However, more importantly, the farmer can earn a ₱3.5 for every additional ₱1.0 invested. This is the highest MBCR offered by any technology. Therefore, unlike the rice-rice pattern, where farmers' own technology, rice-mungbean, offers a higher MBCR, the rice-ratoon pattern is clearly a promising alternative to rice-fallow. Farmers wishing to earn more income through additional investments in crop enterprises are expected to adopt rice-ratoon or expand the area planted to it.

Is the rice-mungbean area also likely to be converted to rice-ratoon? Rice-ratoon RAVC is only 21% higher than rice-mungbean RAVC. Since rice-ratoon is new to farmers and has its associated risks, the 30% rule is probably a good guide. That is, until farmers become highly familiar with the rice-ratoon technology —by trying it in place of rice-fallow—it is unlikely that they will withdraw their investments in the rice-mungbean pattern in favor of the rice-ratoon pattern.

The new cropping pattern, therefore, should:

- offer 30% higher returns than a present cropping pattern grown by farmers on a relatively large area of land of similar quality, and
- offer a higher MBCR than the shift between any two present cropping patterns grown on proportionately large land areas of similar quality.

As a final note, the amounts of any additional investment in a new cropping pattern should be scrutinized. The more costly a new technology per unit area is, compared with the present technology, the more cautious farmers will be in adopting it despite a quite favorable RAVC or MBCR. However, high cost per unit area is not a deterrent if the MBCR is high, for clearly a farmer may simply make a marginal investment over a smaller land area. Indeed small plots of high cost-high return crops (tobacco, garlic, tomatoes, and other vegetables) are often observed on otherwise low-input farms.

Yearly summary report of cropping pattern testing results. To facilitate an overview of the results of cropping pattern testing, a committee of the Ninth Cropping Systems Working Group (Hobbs et al 1980) prepared a set of summary forms. These allow an orderly reporting of the weather, the management specifications of the patterns, the testing results, and their economic analyses.

The yearly cropping pattern summary report consists of a weather summary, a land type description, a cropping pattern management summary, an individual cropping pattern performance summary, and a summary of cropping pattern performance of all patterns tested in a land type.

The weather summary (Table 13) is limited to a record of the weekly total rainfall for the crop, starting 2 weeks before the planting of the first crop in any of the cropping patterns studied or practiced by farmers at the site. To identify the rainfall with the calendar year, it is important that the first day of the first week in the rainfall record be filled out in the form. In addition to weekly rainfall, monthly averages for maximum and minimum temperatures, solar radiation, and pan evaporation are recorded. Where this information is not available at the site, it can be collected from a nearby meteorological or research station. It is important to report the type of evaporation pan used, which allows conversion to a standard where necessary.

Table 13. Yearly weather summary used by the Asian Cropping Systems Network in reporting the results of cropping pattern testing.

Weather Summary

Country: _____ Site: _____ Year: ____

Weekly rainfall this crop year. Start 2 weeks before planting first crop.

1st ____	14th ____	27th ____	40th ____
2nd ____	15th ____	28th ____	41st ____
3rd ____	16th ____	29th ____	42nd ____
4th ____	17th ____	30th ____	43rd ____
5th ____	18th ____	31st ____	44th ____
6th ____	19th ____	32nd ____	45th ____
7th ____	20th ____	33rd ____	46th ____
8th ____	21st ____	34th ____	47th ____
9th ____	22nd ____	35th ____	48th ____
10th ____	23rd ____	36th ____	49th ____
11th ____	24th ____	37th ____	50th ____
12th ____	25th ____	38th ____	51st ____
13th ____	26th ____	39th ____	52nd ____

Date of 1st day of 1st week in rainfall record _____

Monthly temperature. Solar radiation and evaporation

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Max (°C)												
Min (°C)												
Solar rad. (cal/cm^2)												
Evaporation per day												

Type of evaporation pan: _____

Table 14. Land-type description used for reporting cropping pattern testing result

Land-Type Description[a]

Country: _____ Site: _____ Year: _____

Longitude: _____ Latitude: _____ Elevation (m): _____

Cropping pattern: _____

Land type: _____ Soil textural range _____ (0-15 cm)

Soil series (local name): _____ _____ (15-30 cm)

Soil pH: _____ Wetland ☐ or dryland ☐

Lowest groundwater (m): _____ Highest groundwater (m): _____

Slope range: _____

Flooding frequency (years out of 10) _____ in which months _____

[a]Normally cropping systems sites consider 2-4 land types. complete this form for each lang type.

The land-type description form (Table 14) describes, in general terms, the land type on which these cropping patterns are tested. The summary is completed for each land type studied at the sites. Normally cropping systems research-site researchers consider two to four land types.

The pattern management summary (Table 15) describes the land preparation, planting method, fertilization, and pest control management used for each crop tested in the specified pattern. The summary should be completed for each pattern tested at the site. The form also requests identification of the land type in which the pattern was tested.

The individual cropping pattern performance summary (Table 16) records yield, gross returns, cost of production, and returns over costs for each crop in an individual cropping pattern. This summary accommodates a single cropping pattern type designed for one of the land types studied. The averages of the three to seven replications that are normally used in testing a particular cropping pattern in a land type and the number of fields in which each crop in the pattern was replicated are entered in the form. For a site that tests three types of cropping patterns in land type A, and four types of cropping patterns in land type B, there will be seven individual cropping pattern performance summaries.

The final summary is the land-type summary (Table 17) of cropping pattern performance. It is designed to record the gross returns, costs, and returns over costs

Table 15. Pattern management summary used for reporting results of cropping pattern testing.[a]

Pattern Management Summary

Country: _____ Site: _____ Year: _____

Cropping pattern: _____

Land type: _____

	Cropping pattern				
	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5
Crop name					
Variety					
Date of 1st plowing					
Plowings(no.)					
Harrowings (no.)					
Planting date (day,mo,yr)					
Planting method(DS,WS,TP)					
Seeding rate (kg/ha)					
Row spacing (cm)					
Hill spacing (cm)					
Seeds or seedlings(no./hill)					
Age of seedlings (days)					
Basal fertilizer Source	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
N					
P (oxide)					
K (oxide)					
Others					
Sidedress Source	Time (DAP) / Rate (kg ai /ha)	Time (DAP) / Rate (kg ai /ha)	Time (DAP) / Rate (kg ai /ha)	Time (DAP) / Rate (kg ai /ha)	Time (DAP) / Rate (kg ai /ha)
N					
Others					
Pesticides Type					
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
Nonchemical weeding	Time DAP	Time DAP	Time DAP	Time DAP	Time DAP
1st					
2nd					
Date of harvest					

[a]This summary uses the following abbreviations: DS = dry seeded, for planting upland crops or rice in unpuddled soil; WS = wet seeded for seeding rice on saturated puddled soil; TP = transplanting; DAP = days after planting, where planting can be seeding or transplanting; ai = active ingredient.

Table 16. Individual cropping pattern performance summary for the yearly reporting of testing results.

Individual Cropping Pattern Performance Summary[a]

Country: _____ Site: _____ Year: _____

Cropping pattern: _____ Experimental ☐ or Farmer's ☐

Land type: _____

Observation	Cropping pattern					Total
	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	
Replications (no. of fields)						
Yield (t/ha) -standard deviation -failures (no.)						
Gross returns						
Labor costs						
Power costs						
Material costs						
costs[b]						
costs						
Total variable costs						
Return over variable costs						
Return to labor costs						
Return to power costs						
Return to material costs						
Return to _____ _____ costs[c]						
Return to _____ _____ costs						

[a]To be completed for each pattern per land type. Normally this form enters averages of 3-7 replications. [b]Labor costs include the value of all labor whether supplied by researchers, family, exchabnge, or hired sources. [c]Costs and returns to other factors considered important, e.g. costs of family labor, harvest labor, insecticides, etc.

Table. 1 Summary of cropping pattern testing result obtained during 1 year on a given land type.

Land Type Summary of Cropping Pattern Performance

Country: _____ Site: _____ Land type: _____ Year: _____

Observations	Pattern 1[a]	Pattern 2[a]	Pattern 3	Pattern 4	Pattern 5	Pattern 6
Fields tested (no.)						
Failures (no.)						
Gross returns						
Labor costs[b]						
Power costs						
Material costs						
costs[c]						
costs						
Total variable costs						
Returns over variable costs						
Returns to labor costs						
Returns to material costs						
Returns to costs[c]						
Returns to costs						

[a] first or first 2 pattern should be prevent farmers' pattern. [b] Labor cost should include the value of all labor used, whether supplied by reseachers, family, exchange labor, or hired sources. [c] costs and returns to other factors considered important, e.g. total cash requirment, cost of famly labor, harvest labor, insecticides. etc.

of all patterns tested in a land type. It should include at least one prevalent farmers' pattern. The information for the farmers' pattern or patterns comes from the direct monitoring of selected farmers' fields occupied by the types of patterns most prevalent in that land type. For the cropping pattern research site, a land-type summary of cropping pattern performance should be completed for each land type studied.

COMPONENT TECHNOLOGY RESEARCH

In this section, the relationship between on-farm trials that study technological components and the cropping pattern trials that are managed by farmers is emphasized. The difficulty of simulating farmers' practices and the upward bias normally associated with yield measurements from small-plot experiments has led to the formulation of two types of component technology trials.

Superimposed trials are located in the cropping pattern test fields, have a small number of treatments, are at least partially managed by farmers, and evaluate several components such as fertilization, and weed, insect, and disease control. The extent of farmer's management depends on the treatments included in the trial, but generally includes critical factors such as land preparation and planting. The trials suggested in the sections that follow are particularly suitable to encourage interdisciplinary evaluation of alternative management levels for the cropping patterns studied.

Researcher-managed trials are generally small-plot trials replicated within a field and entirely managed by researchers. Their discussion focuses on interpretation in relation to results obtained in superimposed and cropping pattern trials.

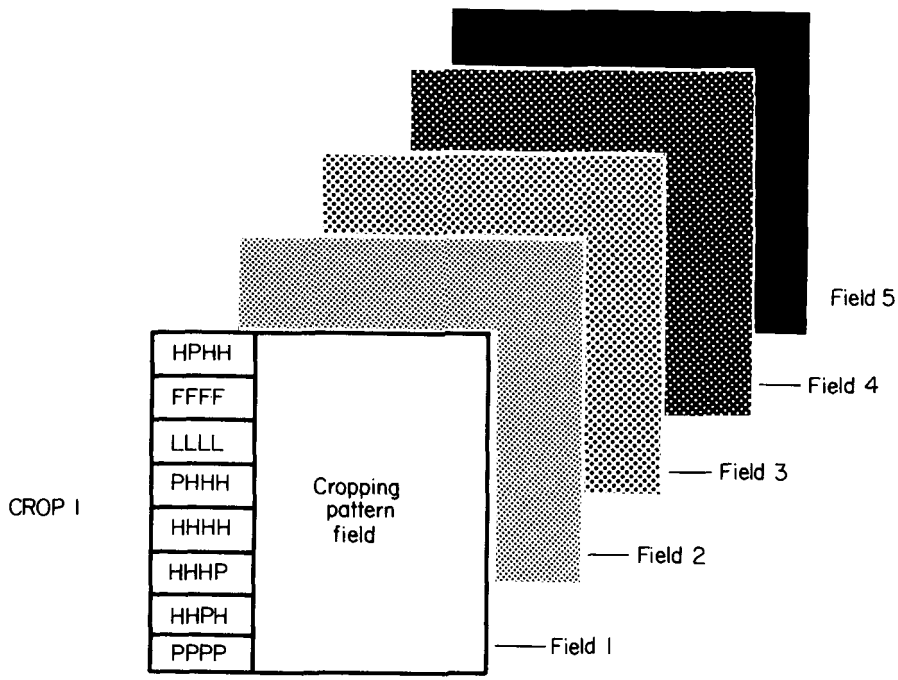
Superimposed trials. *Experimental design,* Superimposed trials are used to evaluate the performance of the component technology assigned to the experimental cropping pattern against that of alternative formulations. At times several alternatives (levels of sources, methods, etc.) may be compared.

The number of superimposed trials and treatments is limited by the number of cropping patterns tested. Because the main objective of the superimposed trials is to evaluate the adequacy of component technology used in the pattern trial, the trials should follow a standard format that allows an evaluation of the major management components that involve cash or sizable labor inputs. For the design of superimposed trials, the following guidelines are suggested:

1. Select two to four component technology factors that strongly influence the performance of the cropping pattern. In their selection, thought should be given to the cost of each component. Of particular interest are components that carry a high cash or labor cost. The factors to be studied can compare a combination of inputs, such as no insect control vs insect control (consisting of several activities during the crop season). They may also compare single-action inputs, such as the insect control recommended for the pattern vs the insect control recommended for the pattern + an additional prophylactic control (of stem borers, for example) during the reproductive stage of rice. The factors of most interest will depend on the crop and pattern involved and on the land qualities considered. Some teams may want to superimpose two levels of a

single factor, for example, nitrogen fertilizer rates, because other factors appear less important when results of previous research at the site are considered.

2. Identify the farmers' management level of each of these factors in terms of type and amounts of materials and labor used. Particularly, weed control simulation of a farmer's treatment requires knowledge of the time or times farmers weed, and the intensity of weeding. (Do they leave certain types of weeds, or weeds below a certain size, etc?) The farmers' management package to be used in the superimposed trial (treatment level F) can now be specified in terms of operations, time of operation, and amount and kind of varieties to be used.
3. To evaluate the returns farmers derive from their purchased material inputs, a treatment that does not use the most costly of these is needed for the management factors selected for the trial (Treatment level L). The treatment is essentially that described in (2) above without selected material inputs. Note that farmers' inputs for management components not included in the superimposed trial should continue to be used.
4. Recall the level of each selected factor used in the cropping pattern (Treatment level P). This level will be the team's best estimate of the input level that



2. Design of superimposed trials for use in evaluating component technology. The example is a 4-factor trial replicated in 5 fields. Treatment levels F, L, P, and H are defined in Table 18.

Table 18. Treatment designs for the superimposed trials.[a]

Treatment no.	2-factor	3-factor	4-factor
1	LL	LLL	LLLL
2	FF	FFF	FFFF
3	PP	PPP	PPPP
4	HH	HHH	HHHH
5	PH	HPP	HPPP
6	HP	PHP	PHPP
7		PPH	PPHP
8			PPPH

[a]L = low input treatment. F = farmers' level. P = level used in cropping pattern. H = high input level.

Analysis of variance of above superimposed trials, assuming 5 replications (fields) of the cropping pattern trial.

Source	Degrees of freedom			Mean
	2-factor	3-factor	4-factor	square
Total	30	35	40	
Mean	1	1	1	
Fields	4	4	4	F
Treatments (T)	5	6	7	T
Residual T × F	20	24	28	TF

Table 19. Examples of treatment levels for inclusion in superimposed trials on a dry-seeded rice crop.[a]

Factor	Selected treatment levels	
Insect control (rice bug) DSR	1. None	9. Spray Sevin 85 WP at 5 DAF (0.75 kg a.i./ha)
Insect control (DSR)	2. 0.5 kg a.i./ha Furadan 3G basal in furrows	10. P2 + Sevin at 5 DAF
Fertility (DSR)	3. 0-30-0 basal 30-0-0 PI	11. 30-30-0 basal 60-0-0 PI
Fertility (DSR)	4. 30-30-0 basal 60-0-0 PI	12. 30-30-0 basal 90-0-0 PI
Fertility (DSR)	5. None	13. 30-30-30 basal 60-0-0 PI
Fertility (DSR)	6. 40-0-0PI	14. 30-30-30 basal 30-0-0 PI
Weed control (DSR)	7. 1 hand weeding	15. Butachlor 2 kg a.i./ha + 1 hand weeding
Weed control (DSR)	8. Butachlor 2 kg a.i./ha	16. Butachlor + 1 hand weeding + 1 spot weeding

[a]DSR = seeded in dry or moist soil or *dry-seeded rice*. DAF = days after flooding. PI = panicle initiation.

provides the highest net returns and gives to purchased inputs and labor returns that are acceptable to farmers at the site. The cropping pattern level will change from year to year if the results from superimposed and researcher-managed trials indicate the need to change input levels.

5. Identify the high level for the management component selected to be included in the test (treatment level H). Superimposed trials should include treatments comparing the pattern treatment with treatments of a higher level of each of the important components—weed control, insect control, and fertilization (where applicable or possible) that would approach maximum net returns. This level should be 30% or more above the cropping pattern level. In this way, additional returns obtained by increasing the input level for each of the factors beyond that used in the pattern can be used as a criterion for considering a future increase in the level of the management component.

Superimposed trials are normally not replicated within the cropping pattern field, but should be repeated in at least five fields in which the pattern is tested. Figure 2 shows the field plan for a superimposed trial of a cropping pattern; Table 18, the treatments and analysis of variance for the two-, three-, and four-factor designs.

Examples of the type of pattern treatments and alternative treatments are in Table 19. These treatments have been combined in a sample treatment design for a three-factor superimposed trial (Table 20). These treatments, when ordered in the three-factor treatment design of Table 18, give the following set for the superimposed trial:

Treatment		Combination of levels		
No.	Code	Insect control	Weed control	Nitrogen rate
1	LLL	1	7	5
2	FFF	1	7	6
3	PPP	9	8	3
4	HHH	10	15	4
5	HPP	10	8	3
6	PHP	9	15	3
7	PPH	9	8	4

This three-factor superimposed trial can be modified to accommodate more than one level of a factor. Assume that a researcher also wants to evaluate 90 kg N/ ha at panicle initiation, with the remaining treatments at the pattern level. To do this he can include one additional treatment, PPA, which would use levels 10-8-12 in Table 19. For analyses and interpretation, this treatment can be considered as an alternative to the PPH treatment.

Plot size of on-farm research trials should be larger than that of research station trials. The following plot sizes are suggested:

- Rice (DSR, WSR, or TPR) 4 × 6 m
- Maize 6 × 8 m

Table 20. Examples of a superimposed treatment design for a dry-seeded rice crop using treatment levels listed in Table 19. This is a simple *3-factor* trial that evaluates increased inputs in insecticides, nitrogen (additional 30 kg N/ha at panicle initiation), and weed control (an extra hand weeding).

Factor	Variable	Treatment no. in Table 19			
		Low	Farmer's	Pattern	High
1	Insect control	1	1	9	10
2	Weed control	7	7	8	15
3	Nitrogen (1)	5	6	3	4

- Sorghum 5 × 8 m
- Mungbean, cowpea, and soybean 4 × 6 m

These are minimum plot sizes. Plot sizes may be increased depending on the size of the field in which the pattern trial is conducted and the special requirements for superimposed treatments (see Litsinger 1977). To study the effect of insect control treatments, the plot size for rice crops should be 5 × 6 m. To avoid surrounding plots in which insect control is absent or at a low level with plots from high-dosage insect control, the insect control check plots (HHP, where P is insect control; and LLL) should be at the extreme ends of the trial.

For a given research site, field sizes tend to be in a defined range and the research team can select the plot size and the factors to be included in the superimposed trials.

Analyses and interpretation. Analysis of variance can be used on the superimposed trial data with fields as blocks, but block × treatment interactions will often arise and inflate the error estimate. Large F-ratios for blocks should be viewed with suspicion and, when they occur, a detailed examination of the treatment-response data is needed. Insect and weed pressure scores, and soil and land form information from the cropping-pattern monitoring forms may be used to stratify fields by high and low pest levels or nutrient response categories. An alternative method of superimposed experiment analysis uses partitioning of the original Error SS, which is computed as a block × treatment interaction SS, into a block-linear × treatment interaction SS and a block-deviation × treatment SS. The former is found by regressing yields of individual treatments on the means of the block from which they came, and the latter is found by difference from the original error SS.

The use of stochastic dominance by simple plotting of results can provide very operational insight into the meaningfulness of treatment differences encountered in superimposed trials. Flinn (1979) provides a ready-to-follow description of this method. Interpretation of the yield response obtained is based on a number of comparisons between treatment means. These comparisons can be statistically evaluated using the appropriate error term.

1. Yield response to farmers' level of material inputs:

$$FFF - LLL = RF$$

Together with cost estimates of the material inputs, this yield response allows estimation of returns to material inputs obtained by farmers.

2. Additional yield response from cropping pattern management levels:

$$PPP - FFF = RP$$

Cost-and-returns analyses give returns to inputs derived from increasing input levels above that used by farmers. Results can be compared with those obtained by farmers to check if returns are rapidly diminishing.

3. Additional yield response from high-input package:

$$HHH - PPP = RH$$

Cost-and-returns analysis allows a similar analysis to that for PPP - FFF, but at still higher input levels.

4. Yield response from the high-input level associated with each factor in the presence of the other factors at the cropping pattern level:

Factor 1. HPP - PPP = R1
Factor 2. PHP - PPP = R2
Factor 3. PPH - PPP = R3

Cost-and-returns analyses of these individual responses evaluate the benefit of increasing each factor in the presence of all other factors at the pattern level. This is the simplest and generally most dependable indicator of any changes that may be required in the cropping pattern.

5. Joint yield response to two factors with the other factor at the high-input level:

Factor 1 and 2: HHH - PPH = R12
Factor 2 and 3: HHH - HPP = R23
Factor 1 and 3: HHH - PHP = R13

These yield responses are more difficult to interpret, but their comparison with the sum of the individual yield responses can help researchers evaluate if substantial treatment interactions are present.

6. Interactions: This treatment design does not allow a separation of the effects of interaction between two factors from that of three factors. The latter interaction is generally of minor importance, however, particularly at the relatively high sufficiency of inputs associated with the P and H levels. The following checks on nonadditivity of treatment effects are useful:

Calculation of interaction effect (A)	Interpretation if A is substantially different from zero
At = RH - (Rl + R2 + R3)	2- or 3-factor interaction(s) exist
A12 = R12 - (R1 + R2)	interaction between factor 1 and 2?[a]
A13 = R23 - (R2 + R3)	interaction between factor 2 and 3?[a]
A23 = R13 - (R1 + R3)	interaction between factor 1 and 3?[a]

[a]Probable, but 3-way interaction cannot be excluded.

In the absence of interactions, treatment effects are additive, so that the response of increasing factors 1 and 2 (R12) should equal the sum of the responses of increasing factor 1 only (R1) and factor 2 only (R2). Therefore, if

any of the As above is substantially different from zero (judged against the variability encountered among replications or statistically tested against the Residual, Table 18), the presence of an interaction is probable.

Researcher-managed trials. Analyses and interpretation of researcher-managed (RM) trials on fertilization, varietal screening, and weed, insect, and disease control components follow the usual procedures established for research stations. In the context of the site-related research method, it is important to compare results of researcher-managed trials with those of superimposed (SI) and cropping pattern (CP) trials.

The cropping pattern treatment may show differences in yield levels for a certain crop between pattern trials and RM trials. The yield responses in the RM trials may therefore have to be interpreted at the level of the CP yields, because the CP trial should be considered as the best estimate of the performance of the pattern treatment across the land type under study. It is suggested that the researcher combine the CP trial and the SI trial means of the pattern treatment level (P) to calculate an estimate of the performance of P (see Table 21). Responses to component technology alternatives can then be adjusted to this YP -yield level, and results from RM and SI trials can be combined as weighted means to arrive at an overall adjusted estimate of the yield response. This yield response can then be used for cost-and-return analyses to evaluate the benefit of the additional inputs.

Evaluation of the alternative component technology levels studied can generally be conducted by simple cost-and-return analyses. A rule of thumb is that additional component technology should provide an MBCR greater than 2 to be considered for the inclusion in the future cropping pattern recommendations (see Table 21).

Based on Table 21:

1. Performance of pattern level component technology (YP) is calculated as the average of the pattern level means obtained in pattern trials and SI trials weighted on the basis of the number of fields and the number of observations per field:

$$YP = \frac{3 \times 6 \times 2{,}900 + 1 \times 5 \times 3{,}200}{3 \times 6 + 1 \times 5} = \frac{682}{23} = 2{,}965 \text{ kg/ha}$$

2. Phosphorus response.

Adjusted phosphorus response of RM trials:

$$\frac{(3{,}600 - 3{,}400)}{3{,}400} \times 2{,}965 = 174 \text{ kg/ha (from 2 fields)}$$

Adjusted phosphorus response of SI trials:

$$\frac{(3{,}300 - 3{,}200)}{3{,}200} \times 2{,}965 = 92 \text{ kg/ha (from 5 fields)}$$

Overall adjusted phosphorus response:

$$\frac{2 \times 174 + 5 \times 92}{2 + 5} = 115 \text{ kg/ha}$$

Table 21. Comparison of treatment means from researcher-managed (RM), superimposed (SI), and cropping pattern (CP) trials — second rice crop rice on partially irrigated wetland (land type 2).

Treatments	Yield (t/ha)	Observations in mean (n)	
		Fields (f)	Observations (no./field)
Cropping pattern yield	2.9	6	3
Selected SI trial means:			
1) Pattern treatment (P)	3.2	5	1
2) P + fungicide	3.8	5	1
3) P + 30 kg P_2O_5	3.3	5	1
Selected RM trial means:			
1) Pattern treatment (P)	3.4	3	3
2) P + fungicide	4.3	1	3
3) P + 30 kg P_2O_5	3.6	2	3

3. Fungicide response.

Adjusted fungicide response from RM trials:

$$\frac{(4{,}300 - 3{,}400)}{3{,}400} \times 2{,}965 = 785 \text{ kg/ha (from 1 field)}$$

Adjusted fungicide response from SI trials:

$$\frac{(3{,}800 - 3{,}200)}{3{,}200} \times 2{,}965 = 556 \text{ kg/ha (from 5 fields)}$$

Overall adjusted fungicide response:

$$\frac{785 + 5 \times 556}{6} = 594 \text{ kg/ha}$$

4. Cost-and-return analyses:

Component	Overall adjusted yield response (kg/ha)	Value of yield response (A) (₱/ha)	Added cost of component[a] (B) (₱/ha)	Added net return (₱/ha)	MBCR[b] (A÷B)
Fungicide	594	891	210	681	4.8
Phosphorus	115	172	150	22	1.1

[a]Include value of materials plus labor for application and harvest of the additional yield. [b]Marginal benefit-cost ratio.

5. Economic evaluation.

For the added fungicide treatment, the added net returns are so much higher than the added cost that the benefit-cost ratio is greater than 2. The addition of the fungicide treatment should therefore be seriously considered in the future pattern level recommendation.

Chapter 6

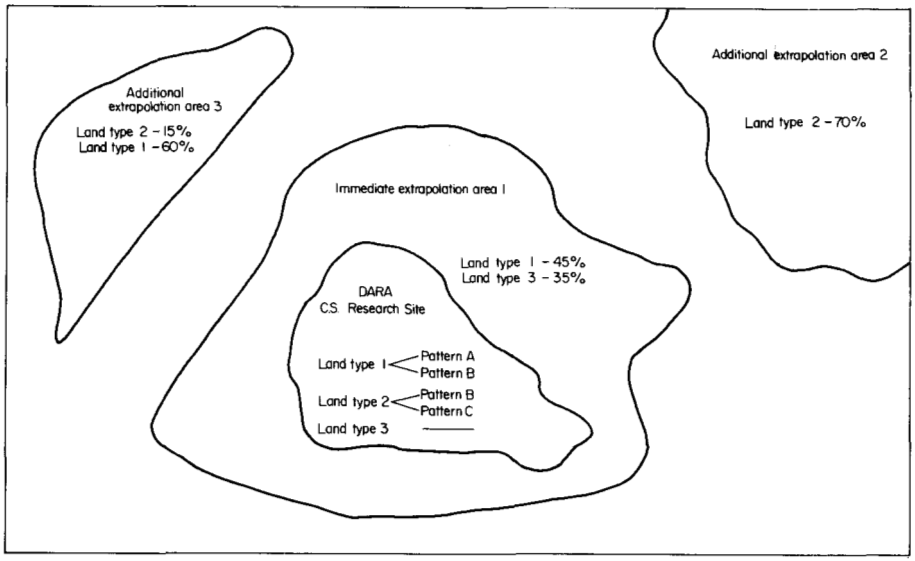
PREPRODUCTION TESTING AND PILOT PRODUCTION PROGRAMS

The preproduction phase of cropping systems research includes multilocation testing and the organization, implementation, and evaluation of a pilot production program.

MULTILOCATION TESTING

In multilocation testing, successful cropping patterns from the testing phase are evaluated at many sites representative of the land type for which the patterns were designed. The specification of the land type is an important aspect of multilocation testing, because it allows researchers to provide extension or production agencies with a clear delineation of the domain of adaptation of the recommended cropping patterns. The following procedures are suggested for multilocation testing.

1. Identify an extrapolation area by using rainfall classifications or rainfall records and soil, irrigation, or land-use classification maps where they exist. The extrapolation area is generally sufficiently large to merit future production programs. Where extrapolation appears possible over large areas, it is wise to break the area up into regions (preferably coinciding with existing governmental divisions) not greater than 5,000 ha and to treat these regions as separate expansion areas for extrapolation of research results. For an example of identification of extrapolation areas, see Moms and Rumbaoa (1980).
2. Within the selected extrapolation area, identify the location and approximate frequency of occurrence of the land types that were identified at the research site.
3. Locate cropping pattern trials in a clustered distribution throughout the desired land type or types in the extrapolation areas (Fig. 1). Because the extrapolation areas are composed of several land types, it is important to ensure an experimental design for the multilocation tests that allows comparison of the patterns' performance between extrapolation areas, even if



1. An example of identification of extrapolation areas and their land types for the assignment of multilocation test plots. Cropping patterns were developed at the DARA site for land types 1-3. Only for land type I and 2 were experimental patterns A, B, and C sufficiently attractive to be recommended for wider evaluation. Multilocation testing was designed to evaluate these 3 patterns in the area immediately surrounding the site in 2 areas elsewhere. It is important to limit the size of an extrapolation area.

researchers are convinced of the similarity of the land types in different extrapolation areas (Table 1).

4. Establish and manage trials. The multilocation tests are usually researcher managed. Farmers should be involved in land preparation, crop maintenance, and weeding, but extension or applied research staff should ensure timely application of chemicals for fertilization, and pest and disease control. It is important to adhere strictly to the specified cropping pattern management:
   - Do not irrigate a rainfed trial, even if soil drying affects the crop.
   - Do not apply prophylactic pest or disease control unless specified.
   - Apply pest control only when the specified economic threshold has been reached.
   - Use only the land preparation equipment specified.
   - Adhere strictly to the range of seeding dates and planting method specified.
   - Do not shift fields between crops if the pattern tests a crop sequence.

   Crop-cut yield samples should be used for estimating yields and, in rainfed land types, weekly rainfall should be recorded.
5. Evaluate cropping pattern performance from yield data, assuming labor and input costs to be those obtained in the cropping pattern trials.
6. Plot the results of the trials on a map of the area and attempt to associate the poor performance of crops in the pattern with soil or land factors.
7. Describe the conditions for which the pattern is suitable and formulate them in terms of a recommendation. That means that the domain of adaptation has to be mapped or associated with existing geographical boundaries, or be described in site-differentiating terms – such as soil texture or drainage characteristics – that are easily identified by extension agents on the basis of simple field observation.

Table 1. Design of muitilocation testing of patterns A, B, and C developed at the DARA cropping systems research site in Figure 3, Chapter 4. The numbers in the table represent the number of fields of that land type in which the pattern is tested for each of the extrapolation areas described in the previous example. Notice that pattern B was not tested on land type 2, expansion area 3, because not enough land was in that class to justify the effort.

Pattern[a]	Expansion area				
	1 Land type		**2** Land type	**3** Land type	
	1	3	2	1	3
A DSR-TPR	6	–	–	6	–
B Maize-rice-mungbean	6	–	6	6	–
C DSR-rice ratoon-soybean	–		6	–	–

[a]DSR = direct-seeded rice, TPR = transplanted rice.

Multilocation testing should be done by extension or production agencies or in close collaboration with them to ensure their familiarity with the recommended pattern or patterns and encourage feedback of problems that they may foresee during the extension phase. Haws and Dilag (1980) also emphasized the use of multilocation testing results for formulating pilot production proposals and for generating the interest and support of local and regional administrators.

Multilocation tests of cropping pattern trials present a final chance for the evaluation of superimposed treatments. With them, varieties or seeding rates, plant spacing, or weed control intensities can be compared. It is important to ensure that superimposed treatments do not interfere with the timing of planting of succeeding crops, which means the varieties used in such trials should have a similar growth duration. The sections on superimposed trials in the chapters on design and testing provide details.

Cropping patterns that present attractive alternatives to existing production methods form the bases for pilot production programs. Obviously such programs are easiest to structure around low-cost recommendations that do not require the creation of markets for new products. Multilocation testing should, however, continue for 2 or 3 years after the start of a pilot production program to monitor the pattern performance and allow a comparison with yields obtained by farmers in the pilot production program.

PILOT PRODUCTION PROGRAMS

The organization of pilot production programs involves factors related to production technology, the existing institutional structure, and government policy. This manual is intended for cropping systems research methods and does not go into detail on methods of structuring, management, and monitoring of development needs in production programs.

The successful introduction of improved cropping patterns into the farmers' production system depends substantially on the way production programs are organized. Conversely, cropping systems researchers should be more aware of the consequences a change of technology has for pilot production programs. The

changes in the required institutional support — such as that for seed production, changes in credit schedules, or marketing support — often take time to implement, and early communication between researchers and extension staff is necessary. The section describes the concepts that underlie production programs and briefly discusses the methods used to provide additional credit, purchased inputs, markets, and some protection against risk.

Intervention or submission as approaches. Researchers can seldom identify cropping patterns that lead to substantial production improvements while operating entirely within the resource limitations of the small farm. Generally, the production increases that can be achieved relate to the extent to which these limitations are removed. As discussed for the design of cropping patterns (Chap. 4, Table 1), researchers can decide on which level of institutional support their technology is designed for and face the institutional consequences at the technology-transfer stage. This is the interventionist approach to technology development.

Alternatively, researchers can attempt to limit their research technology designs that fit entirely within the existing constraints of the farm — the submissive approach to technology development. This approach requires more sophisticated long-term research and generally results in much smaller short-term production gains than the interventionist approach (Zandstra et al 1979).

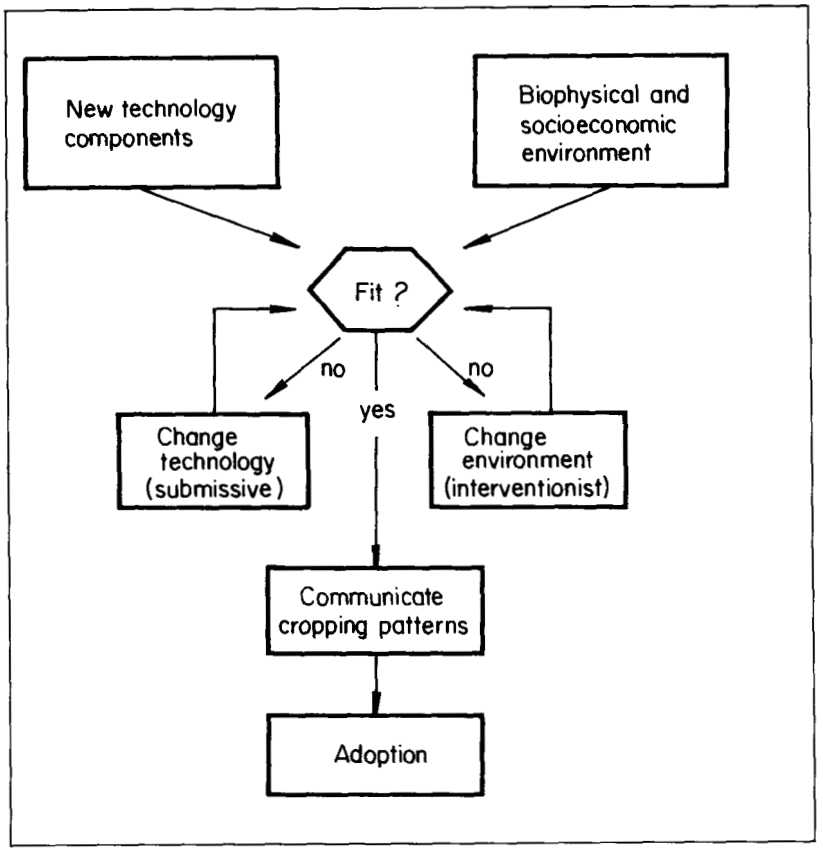
Figure 2 outlines the place of intervention or submission in the program to get farmers' adoption of new technology.

Production programs. Most recommended cropping patterns demand additional resources, generally in the form of cash, labor, seed, specific agricultural chemicals, types of equipment, added demand for produce, and farmers' capacity to assure risk. An acceptable cropping pattern — as defined in the section on economic evaluation of cropping patterns — can readily pay for the extra cost of the resources, but its adoption by farmers will still be conditioned to resource availability.

A production program provides a buffer institution that augments the existing institutional structure to the extent required for the adoption of the recommended cropping pattern (Zulberti et al 1979). The factors that demand the most attention depend on the technology to be introduced. Some common factors that require intervention by the production program are:

- understanding of the recommendations by farmers
- availability of credit
- availability of labor during critical periods of the growing season
- availability and quality of purchased inputs, such as seeds, chemicals, and specialized equipment
- demand for product in markets
- price stability for products
- farmers' capacity to assume risk

A production program should attempt to make the additional resources required by the new technology available to the farm community. This requires the structuring and careful coordination of the activities of several public service organizations.



2. Alternatives for achieving farmer's acceptance of technology: modification of technology or the environment (Zandstra et al 1979).

Pilot production programs. A pilot production program is often used to determine the support structure needed in a production program to clearly define the tasks to be completed by several institutions and the time when they should be completed. The pilot production program allows a final evaluation of the performance of the recommended cropping pattern, the cost of its extension to farmers and others, and the benefits derived from it (Nicolas et al 1980). A pilot production program should be designed to determine:

1. the intervention required by the production program to provide the needed information, credit, purchased inputs, and markets;
2. the management structure needed to ensure the timely delivery of these production factors, including a clear definition of the tasks for each institution involved;
3. the performance of the delivery system for the production factors, which requires the evaluation of the farmers' opinion about the clarity and suitability of the recommendation and the timeliness and availability of the needed production factors;

4. the extent of farmers' adoption of recommended practices and the reasons for lack of adoption, where it occurs;
5. cost of the delivery system in terms of extension and supervisory personnel; and
6. added benefits from the adoption of the recommendations compared with the existing production systems.

The results of the pilot production program should be evaluated yearly (in case of a yearly cropping cycle) and, assuming continued success, modifications should be made until the program is sufficiently stable and manageable to be extended over a larger area.

Information. Agricultural production recommendations must be as simple and as clear as possible. It is unreasonable to expect farmers to manage detailed information about varietal performance in different conditions, all insect species, symptoms of crop diseases, and mineral deficiencies. In a sense, the research structure in the country, the on-site research team, and the extension programs should provide the additional information-processing capability to the farm community.

Cropping pattern recommendations, as specified by researchers, can be complex; they include several crops and times of operations, and the times, methods, and levels of input allocations for each of the crops involved. Such recommendations contain instructions for three types of actions:

1. *Fixed actions,* the general recommendations that apply throughout the pilot project area and are independent of land type.
2. *Actions conditioned to fixed resources,* such as land type or, more specifically, soil texture, presence or absence of irrigation, or simply location. This, in effect, leads to a number of simple recommendations that differ for each land type.
3. *Actions conditioned to variable components,* such as threshold levels of insects or diseases, previous cropping history of the field, soil-water conditions at certain times during the growing season, and the presence or absence of other components of the recommendations.

A recommendation conditioned to a fixed resource:

- For heavy-textured bottomlands, plant a rice-rice cropping pattern, but for light-textured plains and light- and heavy-textured plateau soils, plant rice followed by mungbean.

Recommendation components conditioned to a variable event:

- Apply 20 kg P_2O_5/ha as a basal application, but no P fertilizer after a premonsoon maize crop that received at least 30 kg P_2O_5/ha.
- Apply 0.75 kg a.i. endosulfan/ ha to control stem borers if there are more than 5% deadhearts at the booting stage.

The communication required for recommendations that are conditioned to variable events is complex and may demand that extension services monitor the conditions with farmers and issue reminders at the appropriate time during the growing season. Communication with farmers depends more on the social structure and educational levels in the region, which influence the effectiveness of such communication channels as village billboards, village committees, farmers' group and general meetings, radio listening habits, and acceptance of printed materials.

An essential first step is the assignment of extension workers with communication skills. A next step—adequate communication between researchers and the extension workers—allows the extension staff to become thoroughly familiar with the structure of the recommendations and capable of identifying the fixed and variable events to which the recommendation is conditioned. It will require training of extension staff by the researchers who formulate the recommendations. For an example of a training schedule used to prepare extension staff for a pilot project that introduced a complete cropping pattern, see Haws and Dilag (1980).

Credit. The use of production credit is common even in most underdeveloped, small-farm areas. Credit can be extended and repaid in the form of material services or cash. It may be extended by relatives, friends, private lenders, farmers' associations, or private or government banks. The terms of credit and the conditions for eligibility vary as widely as the sources.

The credit component of pilot production programs can therefore be structured in innumerable ways. There should be careful analysis of year-round needs for credit for the completion of the recommended practices. Generally credit should cover the cost of all purchased material inputs and the services paid for in cash.

The credit-repayment schedule should take into account the considerable time lapse between harvest and sale, and the substantial price reductions that the early sale of produce can cause for the farmer. Unless these reductions have been realistically reflected in cost-and-returns calculations, an apparently profitable cropping pattern may become a losing proposition for a farmer. There are scores of aspects associated with the structuring of credit programs for small farms. The following important factors must be considered:

1. Timeliness of credit should be such that farmers have funds available for the first production operations (land preparation) well before the scheduled time. Inputs scheduled to be bought with credit, or provided in lieu of cash, should be available at the farm community level at that time. Storage and packaging should be such that spoilage during the crop season is prevented, and sufficiently small amounts can be delivered to allow for the small size of fields.
2. Field credit plans should use realistic time and production measures. The plan should be based on yield levels obtained from the farmers' management of the recommended practice because researcher-managed experiments commonly arrive at yield figures 30-60% higher than do farmer-managed experiments.

   Because of farmers' multiple cropping practices, credit should be based on the cropping pattern plan for the field and although immediate repayments may be necessary, the final repayments should not be made until well after the completion of the cropping patterns (Gomez 1977). Provisions should be made to allow rescheduling of credit repayment in the event of damage caused by force majeure.
3. Credit is often obtained from government funds and channeled through government agencies (banks). These agencies should be convinced that access to credit is best determined on the basis of the production potential of the field and the cropping pattern selected for it. Access to credit based strictly on collateral considerations often increases the disparity in welfare levels between

farms and can reduce the allocative efficiency of the credit.

4. If agricultural extension staff is responsible for or involved in encouraging the repayment of loans, it should at least be allowed to decide credit eligibility, and restructure credits in case of force majeure. There are many arguments against involving technical assistance personnel in credit collection because it emphasizes a supervisory instead of a supportive role in relation to the farmers. The staff is, however, uniquely positioned to evaluate the potential profitability of a credit to a farmer and of the farmer's capacity to apply the recommendations.

Labor availability. Labor demands of cropping patterns vary substantially over time. During the pattern-testing phase, major conflicts of demand and availability should have been identified. Little experience is gained during testing, however, in providing solutions to labor constraints, beyond the introduction of labor-saving techniques or equipment. When the adoption of recommended cropping patterns demands the use of additional or new equipment, a rapid demand for such equipment may be created as a consequence of initial partial adoption. The availability of credit for equipment purchases may determine the rate at which the equipment enters the system and the extent to which the pattern is adopted.

Markets. A wide variety of institutions influences the performance of markets. It is, therefore, difficult to identify the specific sources of probable deficiencies. Any of the functions of marketing systems – assembly, transportation, processing, distribution, and pricing – may, if inefficiently conducted, cause difficulties (Smith 1977). These functions are associated with the market for products as well as the equally important purchased-input market – improved seeds, fertilizers, machines, chemicals, etc.

The introduction of recommendations that demand the use of new inputs requires expertise in anticipating the demands and coordinating the advance ordering of these inputs. In pilot production programs, such expertise can be provided by the project. Eventually, these activities will have to be taken over by existing institutions and should include quality control for chemical inputs and seeds.

Smith (1977) emphasizes the importance of evaluating the real cost and resources used in marketing as part of a pilot production program. Specific investigations and governmental action are required to develop markets for many crops that are new to an area.

Integrated production plans. Input-supply bottlenecks can be avoided by carefully planned integrated production programs. They often use a contractual arrangement and assure availability of inputs and a well-functioning product market to the farmers. Such programs can be from government or private enterprise. The latter is often the planner for high-value commercial products such as tobacco, coffee, and cacao. There is, however, no reason why these approaches cannot be extended to food crops if a sufficiently large MBCR exists for the additional inputs required by the recommendations (Zandstra et al 1979). There are no records of such integrative production arrangements for the introduction of technology involving multiple cropping land-use during a complete growing season.

Risk. Small farmers assume risk primarily through the allocation of substantial borrowed capital to a single crop. Their capacity to assume risk may limit the

adoption of high-input technology. There is a large body of literature about measurement of risk and farmers' reaction to risk. There has, however, been little experimentation with methods to share risk among farmers or among farmers and credit agencies or integrated production plans. Where production contracts assure availability of inputs and product markets, a substantial component of the farmers' risk is already assumed by the program. To go beyond this requires complex contractual arrangements and costly estimation of yields (Zandstra et al 1979).

When cropping patterns have been tested over several years and have shown substantial stability, it is probably sufficient to make appropriate arrangement for the rescheduling of loans in the event of unforeseen natural calamities.

Coordination of institutional activities. The pilot program activities in communication, provision of credit, and assurance of input availability and markets normally involve several government and private institutions. The pilot production program strongly intervenes in the village community; it often threatens existing institutions or networks of social and political dependence relationships in the region. To be successful, pilot programs for small farmers must therefore be based on a genuine political commitment to improving the condition of small farmers. Planners and managers of pilot production programs must involve all groups that are affected by the plan. Where marketing aspects are involved, great care should be taken not to antagonize existing market services.

A useful approach to coordination of activities is to form a management committee that advises on pilot program policy (Nicolas et al 1980). It should be composed of local farmers (leaders, or representatives of farmer groups), local political leaders (governors, mayors, etc.), and regional directors of institutions for extension, credit (bank representatives), and agricultural research and marketing. The committee should define the scope of the program and the tasks for which each participant group assumes responsibility.

The overall activity of the pilot program should be presented in the form of a time schedule—if possible graphically, as a Project Evaluation and Review Techniques (PERT) diagram. By careful analyses, all actions required to be completed at certain times need to be identified. The extension group should determine the number of contact points between the program and the farmers, and classify them into four types:

1. contacts required with farmers individually at the farm field,
2. contacts required with a farmers' group in village areas (group meeting or posters),
3. contacts required with individual farmers at offices (bank or extension office), and
4. contacts with a sample of individual farmers in the field (inspection).

Note that a contact point should include any visit of project personnel (extension, credit, marketing, or political) to the farm community and any village- or town-level visit of the farmer to the project that is associated with the pilot production project.

Contacts should be minimized to those necessary to ensure a smooth transfer of information and goods. Care must be taken to avoid unnecessary travel of farmers

Table 2. Example of an activity analysis and prerequisites for the farmer and the pilot production program for a selected contact point.

Contact no. 3 Type: Each individual farmer visits offices to collect loan (cash and inputs) Time: From 1 Dec to 10 Jan

Prerequisites (program)	Actions	Prerequisites (farmer)
1. Extension staff members have and understand recommendations by field type Messages to be discussed with farmers have been scheduled Flexibility tolerated in recommendation has been specified Schedule of information to be obtained from farmer. Field type form, and credit and TA contract are ready	1. Farmer visits extension office • Bank inspects field-type form (plot, size) • Bank formulates recommendations • Bank collects inscription fee • Bank signs credit and technical assistance (TA) contract • Bank issues credit release slips for cash material inputs	1. Farmer must be an approved borrower
2. Project credit funds are available List of approved suppliers is posted	2. Farmer visits bank • Bank co-signs credit and TA contract, keeps copy • Bank endorses material input release slips • Bank releases cash component	2. Farmer has: credit and TA contract signed by Farm and Extension credit-release slips for cash and material inputs
3. Materials are available Quality (particularly of seed) has been inspected	3. Farmer visits approved suppliers • Release of material inputs	3. Bank endorses release slips for material inputs

to the offices, and several activities should be combined at each contact point. A list of actions to be completed and prerequisites at each contact point should be drawn up (Table 2). From this outline and the earlier mentioned time schedule (PERT or date-line plot) of contact points, an agenda (actions and deadline dates) can be drawn up for farmers, extension staff, the credit institution, and the group responsible for the availability of inputs at the suppliers.

Implementation of pilot production programs may require special incentives to motivate extension staff (Haws and Dilag 1980). Where possible, these incentives should be provided in forms that encourage field visits, such as provisions for staff mobility and expense coverage during field visits. Incentives in the form of extra pay can be difficult to maintain once the program extends beyond the pilot phase, when there is danger that extension staff will not get the attention, support, and financial incentives they had received during the pilot phase. This dilution effect often leads to reduced project impact at later stages.

The implementation phase must be accompanied by a monitoring and evaluation process that allows corrective action on such problems as untimely release of loans and lack of inputs and transportation. The monitoring should also allow evaluation of the performance of the recommendation, as measured by estimates of yield and of the extent of farmers' adoption or modification of recommended practices. For a comparison of farmers' adoption associated with different production programs, see Zandstra (1979, pp. 226-228).

Coordination of pilot production programs requires enthusiastic support by staff from local agencies, and such support must be generated by giving them full recognition in reports and meeting.

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Appendix 1.

DETERMINING FERTILIZER RATES FOR CROPS IN CROPPING SYSTEMS

R. A. Morris

To determine fertilizer rates for cropping patterns, ask some of the following questions:

- What is the crop and what is its nutrient requirement for high yields — and for moderate yields?
- What is known about patterns of nutrient uptake during crop growth?
- What is the soil and how much of each required nutrient can it supply?
- What are the current fertilizer recommendations for each soil mapping unit or region? Is it easy to obtain a soil analysis and are the test data for the soils reliable? (That is, has the soil test been calibrated for the soils and crops of the pattern?) Early in the project it may be important to know only if an element is deficient. Later the need may be to determine "optimum" levels for several recognized land types. Ultimately, the need may be to determine carry-over or residual effects and to compare practicable methods of improving fertilizer efficiency.
- Can the site be stratified on the basis of landscape features?

Other questions pertain to the capacity to do research:

- How diversified is the area to be studied?
- What is the size of the research staff and how familiar are they with soil fertility research, experimental designs, and methods of data analysis?
- What are the immediate and long-range objectives?

The analysis and interpretation of data — a fertilizer study is not complete until data are properly interpreted — ask the following questions.

- What are current fertilizer and product prices?
- Will farmers purchase fertilizers with the benefit of government-sponsored production loans?
- Will fertilizers be subsidized — or will a current subsidy be reduced?
- How specific must the fertilizer recommendation be? And, can a specific recommendation be justified?

The research approach will be affected by background information such as past fertilizer response experiments, soil test results, maps, and related information. The approach will also be affected by the size and experience of research staff, and the complexity of the site.

DIFFERENCES OF CROP RESPONSES TO FERTILIZERS

Keep in mind that different responses to fertilizers from field to field are expected, even where fields rather similar in soils and water regimes are selected. The differences arise partly because of differences in soil materials, past management, and crop history. In some fields, the farmer may have applied large amounts of fertilizer, which left a residual fertility. In other fields, the availability of nutrients to a following crop may be high because only small quantities of nutrients were removed by the preceding crop because of drought.

There are many reasons for not expecting reproducibility in fertilizer response. The objective should be to find a fertilizer rate that is nearly optimum for a large number of fields in an area because the rate is a component in a test of the economic viability of a cropping pattern for a large area. Therefore, sample many fields in a fertilizer research program, and if

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time allows, sample those fields over several years.

Recommendations are often specified in terms of bags of fertilizer materials or increments of 10 or 20 kg/ha. Data that permit greater precision in estimates are not necessary, and are costly.

ALTERNATIVE APPROACHES

At the start of fertilizer rate research, examine each land type selected for cropping systems research at the site (see Chapter 3, Selection of land types). Soil types, textural classes, predominant mineralogy and hydrological conditions should be recognized. Existing soil maps and previous research should be examined and soil scientists consulted to determine what mineral deficiencies can be expected. The cropping pattern design process will determine the crops and their growing periods for which fertilizer recommendations must be determined. For these crops the approximate requirements for nitrogen, phosphorus, and potassium are generally known and will provide a starting point for initial cropping pattern design and trials for fertilizer recommendation.

Two approaches are presented. These differ in complexity of design and analysis, and in their conceptual intricacy.

- Example 1. Assume, from previous studies in the area, that the crop responds to at least 50 kg N/ha. The responses to phosphorus and potassium are uncertain. Your interest is to test the response to higher nitrogen rates and for the presence of phosphorus and potassium deficiencies. You have sufficient personnel to conduct a moderately large conventional experiment plus six small superimposed N-P-K trials and you have someone on the staff who is familiar with computation of basic statistical analysis with a pocket calculator.

  This example evaluates several treatment combinations in the range in which fertilizer response may occur. Additionally, an example of a test for treatment interactions with fields in analyses of variance (AOV) of the superimposed trial is given.

  Twelve selected treatment combinations for the conventional experiments are shown in Table 1. For the superimposed trials a subset of six treatment combinations was chosen (Table 2). It will permit you to examine the response to phosphorus, potassium, and the phosphorus-potassium interaction at 70 kg N/ha, and the response to nitrogen without phosphorus or potassium fertilizer. The AOVs are also presented in Tables 1 and 2.

  In addition to the routine AOV on the superimposed trial, the Error Sum of Squares (Error *SS*), which is computationally equivalent to a Block × Treatment interaction *SS*, was partitioned into a Block (linear) × Treatment interaction *SS* ($B_L \times T$). If there is a Block × Treatment interaction, which is apt to occur when there are major field effects, the interaction will likely be most strongly expressed in the Block (linear) × Treatment component. By subtracting the $B_L \times T$ *SS* from the Error SS, the remainder (Block [deviation] × Treatment SS) is expected to be a more correct estimate of the Error *SS*. An *F*-test on $B_L \times T$ will suggest if both the $B_L \times T$ and the $B_{dev} \times T$ be considered part of the Error *SS*. When the $B_L \times T$ *SS* is large, treatment responses cannot be considered to be uniform over fields. Depending on the interaction term, responses of some treatments will increase or decrease as field means increase.

  In this analysis of superimposed trial data, the treatments did not strongly interact with block means. Therefore, the appropriate AOV is the one without error partitioned, i.e. the original AOV of superimposed trial data.

Table 1. An example of a conventional 12-treatment nitrogen-phosphorus-potassium fertilizer experiment.

Treatment no.	Treatment designation			Grain yield (t/ha) by farm				
				R_1	R_2	R_3	R_4	X
1	50	0	0	3.54	4.11	3.47	3.39	3.62
2	50	0	30	4.05	3.83	4.12	3.16	3.79
3	50	30	0	4.15	4.12	3.59	3.52	3.84
4	50	30	30	3.50	4.18	4.00	4.02	3.92
5	70	0	0	3.90	3.85	4.17	3.94	3.97
6	70	0	30	4.30	3.87	3.96	3.43	3.89
7	70	30	0	4.10	3.68	4.22	3.91	3.98
8	70	30	30	3.91	4.30	4.07	4.16	4.11
9	90	0	0	4.09	4.31	4.59	4.32	4.33
10	90	0	30	3.94	3.87	4.07	4.63	3.88
11	90	30	0	3.92	4.10	4.07	4.03	3.03
12	90	30	30	4.08	4.07	4.49	3.93	4.14

Source	DF	ANOVA		
		SS	*MS*	*F*
BLOCKS	3	0.265	0.088	
N	2	1.036	0.518	6.55
P	1	0.266	0.266	3.36
K	1	0.252	0.252	3.18
N X P	2		–	
N X K	2	0.00	–	
P X K	1	0.00	–	
N X P X K	2	0.00		
Error	33	2.611	0.0791	

		P-	P+
Yield (t/ha)	K-	3.97	3.95
	K+	3.85	4.06
		N_{50}	3.52
		N_{70}	3.86
		N_{90}	4.23

On the basis of the AOVs on both the conventional experiment and the superimposed trials, treatment differences occurred. Phosphorus and potassium did not influence yield, but nitrogen did. The results (yield levels, treatment responses, and error) are in approximate agreement between the two types of experiments, suggesting that similar behavior toward fertilizer applications would occur over many fields in the area.

Economic analysis can be applied to the nitrogen response data, but from casual inspection, it appears that response was rather linear over the range tested. Under a simple profit-maximizing assumption, the highest nitrogen rate would, therefore, be more profitable than the middle rate, provided the cost of an increment of nitrogen is less than the value of additional yield. With responses similar to that for nitrogen in this example, input availabilities, cost constraints, and risk factors should be considered jointly by agronomists and economists.

Table 2. An example of a superimposed 6-treatment nitrogen-phosphorus-potassium trial in tons per hectare × 100.

Treatment no.	Treatment	Grain yield (t/ha) by farm 1	2	3	4	5	6	×
1	50- 0- 0	336	434	451	411	402	375	401.5
2	90- 0- 0	439	416	506	459	482	431	455.5
3	70- 0- 0	443	398	457	370	454	350	412.0
4	70- 30- 0	412	419	412	398	499	386	421.O
5	70- 30- 30	416	368	482	370	397	402	405.8
6	70- 0-30	417	377	493	364	490	387	421.3
$\overline{X}$		410.5	402.0	466.8	395.3	454.0	388.5	

AOV

Source	df	*SS*	*MS*	*F*
Total	34	69,071		
Farms	5	32,178		
Treatments	5	11,212	2,242	
N	2	9,837	4,918	4.79
Remainder	3	1,375	458	<1
Error	25	25,681	1,027	

Treatment no.	*Sxx*	*Sxy*	*Syy*	Reg *SS*	Res *SS*	B
1	5,445	3,011	8,589	1,665	6.924	0.55
2	5,445	4,822	5,697	4,327	1,369	0.89
3	5,445	6,457	10,554	7,760	2,794	1.19
4	5,445	4,015	8,004	3,000	5,004	0.74
5	5,445	4,873	8,712	4,420	4,292	0.89
6	5,445	9,042	16,301	15,216	1,085	1.66
Totals:	32,672	32,220		36,389		

$$\Sigma Reg\ SS - \frac{(\Sigma S_{xy})^2}{\Sigma S_{xx}} = B_L \times T$$

$$36{,}389 - \frac{(32{,}220)^2}{32{,}672} = 4{,}615$$

AOV

Source	df	*SS*	*MS*	*F*
Farms	5	32,178	6,436	
Treatments	5	11,212	2,242	
$B_L \times T$	5	4,615	923	<1
$B_{dev} \times T$	20	21,066	1,053	

At 70 kg N/ha		−K	+K
Yield, t/ha	−P	4.1 2	4.21
	+P	4.21	4.06

At O-P and O-K		
Yield, t/ha	N_{50}	4.02
	N_{70}	4.12
	N_{90}	4.56

Terms and computations

Sxx is sum of squares of block means. The value is the same for all treatments.

$Sxx = 410.5^2 + \ldots\ldots 388.5^2 - 6(419.5)^2$
$= 5{,}445$

Sxy is sum of cross-products between block means and treatments. For Treatment 1.

$Sxy = 336 \times 410.5 + 434 \times 402.0 + \ldots\ldots + 375 \times 388.5 - 6(401.5)(419.5)$
$= 3{,}011$

Syy is sum of squares of treatments. For Treatment 1

$Syy = 336^2 + 434^2 + \ldots\ldots + 375^2 - 6(401.5)^2$
$= 8{,}589$

Reg SS is sum of squares of regression. For Treatment 1

$Reg\ SS = (Sxy)^2/Sxx = (3011)^2/5{,}445 = 1{,}665$

$B_L \times T$ is Block (linear) × Treatment interaction.

$B_{Ldev} \times T$ = Error $SS - B_L \times T = 25{,}681 - 4{,}615 = 21{,}066$

B is the simple regression coefficient of treatment yields on block yields. For Treatment 1

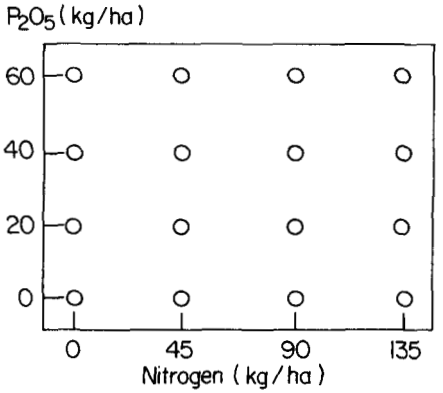
$B = Sxy/Sxx = 3{,}011 / 8{,}589$

- Example 2. This example shows a more complete definition of the yield response to fertilizer. It allows calculation of optimal rates of two nutrients for different cost-price relationships. This example also includes a complete analysis and economic interpretation. In a site where five or more crops are managed in cropping patterns, this more complete approach should be confined to the most important and most responsive crops.

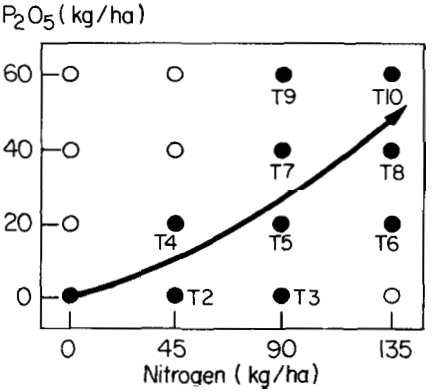
  Assume that you know the upper limits of fertilizer response for both nitrogen and phosphorus, and that potassium is not limiting in the area of the research. Furthermore, you strongly suspect that nitrogen is more limiting than phosphorus and you have ample personnel to conduct 6-10 experiments of 9-12 treatment combinations replicated twice in each field.

  To decide the rates, a five-step method shown schematically in Figure 1 can be followed.

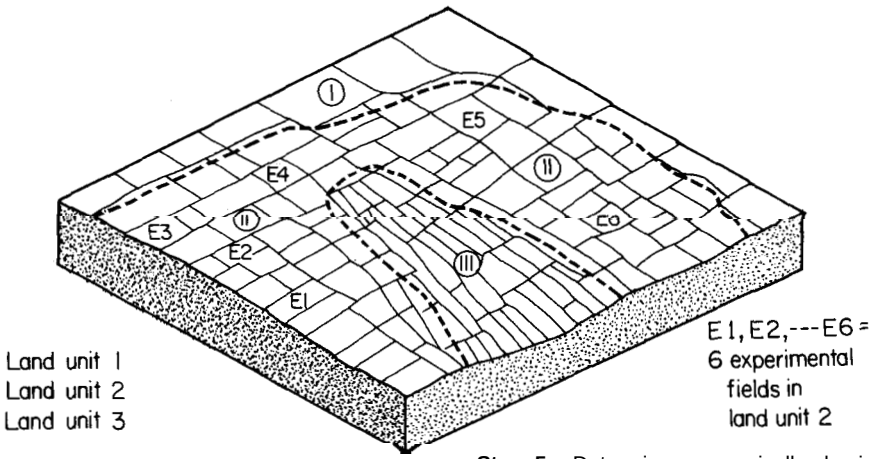
Step 1. Determine experimental fertilizer ranges and select test levels,



Step 2. Determine rational treatment combinations.



Step 3. Allocate experiments to fields within recognized land units.

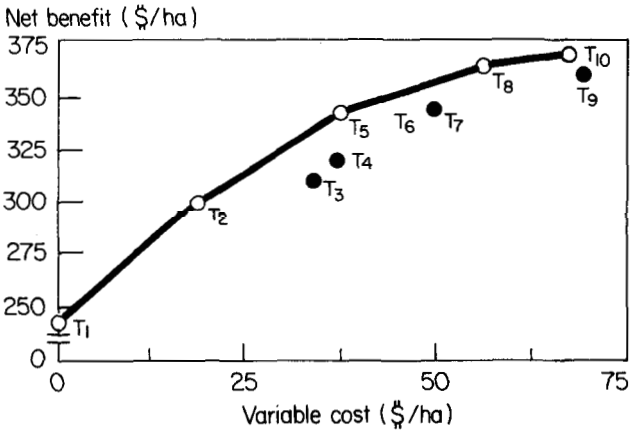


Step 4. Review data statistically.

Analysis of variance

Source	*df*	*F*
Replications	1	
Treatments	9	**
A. T2-T5		
N	1	**
P	1	**
NP	1	*
B. T5-T10		
N	1	**
P	2	*
NP	2	ns
Error	9	

Step 5. Determine economically dominant fertilizer rates.



1. Five steps to determine economical fertilizer rates by field experimentation.

1. Determine experimental fertilizer ranges and select test levels on the basis of soil tests or previous experiments, or both, on similar soils.
2. Determine rational treatment combinations on the basis of fertilizer prices and crop nutrient requirements, eliminating treatment combinations that will obviously be uneconomic.
3. Allocate experiments to fields within recognized land units, using 2 replications-/field in at least 6 fields to sample for yield variability.
4. Review the data statistically by computing ANOVAs on each experiment, and inspect treatment and error mean squares, and treatment means for extreme behavior.
5. Determine economically dominant fertilizer rates by plotting benefits against costs.

In the first step, collect information about general soil fertility in the research area. Logical sources of information are reports on fertilizer experiments and soil test results. Identify nutrient application limits that are thought to satisfy the needs of the crop being studied.

Note that to determine reasonable fertilizer rates for crops in patterns being tested in the first year, the same fertilizer response information should be available as that required to determine the limits for the fertilizer experiments. Generally the levels used in the first year fall somewhere between 50% and 75% of the limiting level used in the fertilizer-rate experiments. In the second year of the study, the cropping pattern fertilizer levels are adjusted on the basis of results of the fertilizer trials and after consultation with the site economists. It is impractical, however, to refine rates more precisely than 10-20 kg N/ha and 5-10 kg P_2O_5/ha in recommendations targeted at areas of about 3,000-5,000 ha.

In the example, fertilizer limits were set at 135 kg N/ha and 60 kg P_2O_5/ha. Nitrogen was considered as the primary limiting element, and all treatments, except the nonfertilized control, contained nitrogen at some level, thereby eliminating treatments with phosphorus alone. The nitrogen-phosphorus treatment combinations roughly bracket what is thought would be the expansion path. Note particularly that resources are not wasted by including high phosphorus rates, which would be limited by low nitrogen levels, or high nitrogen rates, which would be limited by low phosphorus levels.

Keep in mind that the objective was to determine fertilizer rates for a rice crop in one of your patterns, not to identify nitrogen-phosphorus interactions. From other studies you already know they are important.

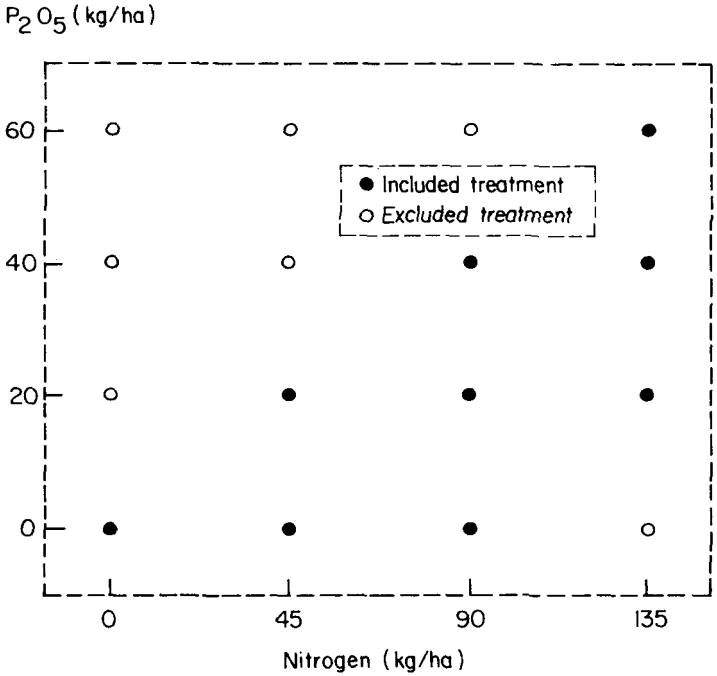
Following the procedure, treatment combinations were formed at constant intervals (i.e. 0, 45, 90, and 135 kg for nitrogen, and 0, 20, 40, and 60 kg for P_2O_5), those thought to add little useful information were eliminated.

The treatment design is shown in Figure 2. The most appropriate treatment number for these types of studies is generally 9, 10, or 12.

Following the field phase of the study, review your data for reliability. Initially data should be inspected for missing values (which may be estimated in most cases) and values that are obviously erroneous (extremely high or low). When a value is suspect, it should be recalculated from raw data to determine if computation errors were made. Staff members who frequently observe the experiment in the field should be asked their opinion of the soundness of suspect numbers. If no valid cause can be found that can explain why the value may be in error, and the value is within biological possibilities, the value should be assumed correct and part of the natural variability in the population.

Statistical partitioning of the Total *SS* into Rep *SS*, Treatment *SS*, and Error *SS* will aid the data review process by calling attention to two possible types of errors:

1. obviously erroneous data, usually from one or two plots from which very high or low values were obtained and which cause inflation of experimental error, and



2. Included and excluded treatment combination.

2. treatment behavior that is clearly different from other fields, such as no yield response to any treatment, despite a low coefficient of variation.

In the statistical analysis, the coefficient of variation (CV) should be from 10 to 12% to expect good sensitivity in the tests. CVs exceeding 25% indicate major yield differences within the same treatment, even after the effect of replications is removed. Seldom will experiments with such high CVs generate a feeling of satisfaction, even if the treatment differences are large enough to be detected.

Further partitioning of Treatment *SS* can be used to isolate the contributions of nutrients to yield increases. Where data on other attributes such as plant height, straw weight, stand, or tiller counts are recorded, statistical analysis of these attributes can be used to strengthen the convergence of evidence of the yield response to nutrients.

Convergence of evidence becomes very important when analyzing data in which sensitivity is not very high (i.e. the CVs are greater than 15%) or the yield differences between treatments are not substantial, and below a level of detectability at 1 or 5% significance level. The statistical tests of many attributes can show a pattern that is consistent with underlying basic principles (e.g. phosphorus fertilizer promotes tillering; both nitrogen and phosphorus increase plant height). In such a case, there is strong evidence that yield differences statistically significant at only the 10 or 15% level are indeed due to true responses to applied nutrients, and not to chance variability.

In this example, the 9 treatment combinations (kg N/ha and kg P_2O_5/ha) were:

T1 - 0-0	T4 - 45-20	T7 - 90-40
T2 - 45-0	T5 - 90-20	T8 - 135-40
T3 - 90-0	T6 - 135-20	T9 - 135-60

[1]The data used in this example are from Ali 1979.

Table 3. Summary of frequency of treatment significances obtained in 9 experiments.

Source	df	Frequency
First factorial set[a]		
N	1	7
P	1	4
N × P	1	0
Second factorial set[b]		
N	1	4
P	1	1
N × P	1	0

[a] N = 45 and 90 kg/ha, and P_2O_5 = 0 and 20 kg/ha. [b] N = 90 and 135 kg/ha, and P_2O_5 = 20 and 40 kg/ha.

Treatment effects were significant in each experiment analyzed separately. Two 2 × 2 factorial sets of treatment combinations, from within the full set were examined separately; the frequencies of significant effects and interactions are summarized in Table 3. Examples of AOVs are shown for four fields in Table 4. The summary table shows that nitrogen and phosphorus effects were essentially additive, both at the intermediate (first factorial set) and high fertilizer rates (second factorial set). Significant nitrogen and phosphorus effects were frequent at intermediate levels, but only nitrogen effects were common at the high levels.

To the farmer, perhaps the most important question is "Will fertilizer be profitable?" You can examine profitability more realistically by applying marginal analysis than by comparing net profits obtained from the treatments tested (see discussion on researcher-managed trials in Chapter 5). The marginal analysis involves estimations of net yields, gross field benefits and total variable costs, and calculation of the marginal benefit cost ratio (MBCR) to each increment of variable cost.[2]

Table 4. Degrees of freedom and mean squares of analysis of variance (AOV) on grain yield as affected by nitrogen and phosphorus fertilization in 4 of the 9 farm fields.

Source of variance	DF	AOV on grain yield (t/ha) in field[a]			
		1	2	3	4
Replication	1	427.49**	276.83ns	287.28*	0.53
Treatment	8	3,255.28**	3,422.50**	2,051.11**	2,423.50**
Error	9	15.49	84.07	40.44	37.22
	Planned comparisons based on 2 × 2 factorial N (45 and 90 kg/ha) and P_2O_5 (0 and 20 kg/ha)				
N	1	606.65**	521.73*	243.60*	203.52*
P	1	239.78**	472.88*	165.31ns	68.12ns
N × P	1	47.28ns	169.07ns	1.92ns	39.76ns
	Planned comparisons based on 2 × 2 factorial N (90 and 135 kg/ha) and P_2O_5 (20 and 40 kg/ha)				
N	1	414.96**	179.70ns	90.95ns	615.50**
P	1	54.45ns	59.00ns	77.82ns	105.57ns
N × P	1	17.11ns	1.17ns	5.25ns	0.33ns

[a] *significant at the 5% level. **significant at the 1% level. ns, not significant.

[2] A comprehensive discussion of the economic concepts and their application in analysis is given in Perrin et al 1976.

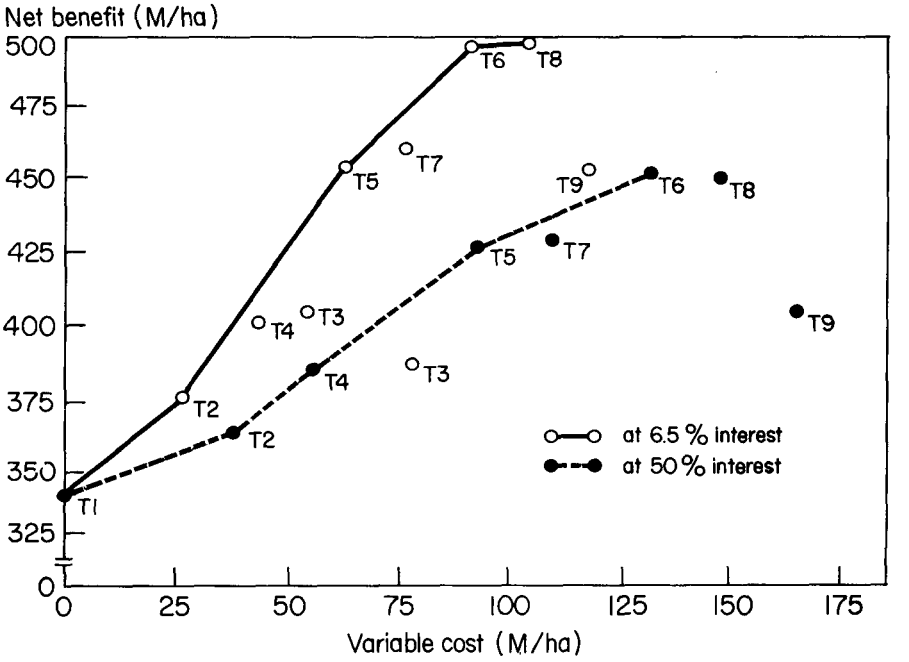
Table 5. Partial budget for grain yields, variable costs, and net benefits of 9 fertilizer treatments, at 2 interest rates.

Treatment no.	Fertilizer treatment 1	2	3	4	5	6	7	8	9
Fertilizer rates (N-P_2O_5)	0-0	45-0	90-0	45-20	90-20	135-20	90-40	135-40	135-60
Av grain yield (t/ha)	3.67	4.37	5.03	4.78	5.65	6.33	5.84	6.48	6.16
Net yield (t/ha[a])	2.91	3.46	3.98	3.78	4.47	5.01	4.47	5.13	4.87
Gross field benefit (M/ha)	339	403	463	440	520	583	538	597	568
Fertilizer cash cost[c] (M/ha)	0	25	51	36	62	87	73	98	109
Other variable cost and interest at 6.5%	0	3	4	4	4	6	5	7	8
Other variable cost and interest at 50%	0	14	26	20	32	45	37	50	56
Net benefit, 6.5% interest	339	375	408	400	454	490	460	492	451
Net benefit, 50% interest	339	364	386	384	426	451	428	449	403

[a]Assuming one-sixth share goes to harvesters, and field losses are 5% for a total reduction of 20%. [b]At M1 16/t of net yield. [c]At M0.55/kg N and M0.56/kg P_2O_5.

As applied to results in this example, net yield was taken as the measured yield per hectare in the field, minus a 5% harvest loss and a one-sixth harvester share. Gross field benefit was taken as the net yield times field price. Total variable costs were taken as the sum of the fertilizer cost, the cost of application of fertilizer topdressings, and interest on variable costs. Costs and prices assumed are given in Table 5. Two cases were examined; one with interest at 6.5% (institutional credit rate) and the other at 50% per half year (village moneylender's rate). Net benefit was computed as gross field benefit minus total variable cost. The partial budgets of the 9 treatments, using mean yields over the 10 experiments, are presented in Table 5.

The net benefit curves were constructed by plotting the variable costs of the alternative fertilizer rates against their net benefits (Fig 3). Only treatments that form the upper bound



3. Net benefits and variable costs of 10 fertilizer treatment combinations, at 2 interest rates.

(efficient frontier) of the net benefit relationship to available cost should be considered. T9 and T3 were obviously inferior to other alternatives. For the treatments that form the efficient frontier, the MBCR can be calculated from Table 5 for each cost increment:

Treatment increment	Added gross benefit (M/ha)	Added cost[a] (M/ha)	MBCR
TI - T2	64	28	2.3
T2 - T5	117	38	3.1
T5 - T6	63	26	2.4
T6 - T8	14	12	1.2

[a]At 65% interest.

The MBCRs were high where fertilizer applications were low but relieved limiting nutrient supplies. The MBCR obtained by shifting 90-20(T5) to 135-20(T6) was about 2.4 at the 6.5% interest rate and 1.7 at the 50% interest rate. Beyond 135-20, returns decreased rapidly.

Although 90-20 produced an MBCR near or greater than 2 for both interest rates, fertilizer cost of M62/ ha was required. This appeared high in relation to most farmers' expenditures on fertilizers in the research area. A rate of 70-15, determined by interpolating between rates used in the experiments, would provide a high rate of return under a restriction of M50/ha on fertilizer materials.

Appendix 2.

EXPERIMENTAL DESIGN FOR DETERMINING YIELD LOSSES AS A GUIDE TO DEVELOPING INSECT CONTROL RECOMMENDATIONS.

J. A. Litsinger

EXAMPLE FOR A TRANSPLANTED RICE CROP

The transplanted rice crop has insect damage at four growth stages:

1. seedbed (caseworm and armyworm),
2. vegetative stage (whorl maggot, caseworm, and stem borer deadhearts),
3. reproductive stage (stem borer deadhearts and leaf folder), and
4. ripening stage

Figure 1 illustrates how yield losses for a growth stage can be assessed. To quantify the yield losses for each of the four growth stages, insecticide protection is successively omitted during one stage and provided for the other three. The yield losses measured will be those for an insect-resistant variety, if one is recommended. The cost of the insecticides used in determining yield loss is not relevant in the treatments. The most effective available insecticides should be applied at adequate dosages and frequencies to ensure as near an insect-free condition as possible.

The subtractive approach allows greater interpretation than the mere application of insecticide during each stage, because yield loss occurs during more than one growth interval. The trials are performed in the same manner as cropping patterns on farmers' fields using the management practices recommended by the research team. Because of the relatively large

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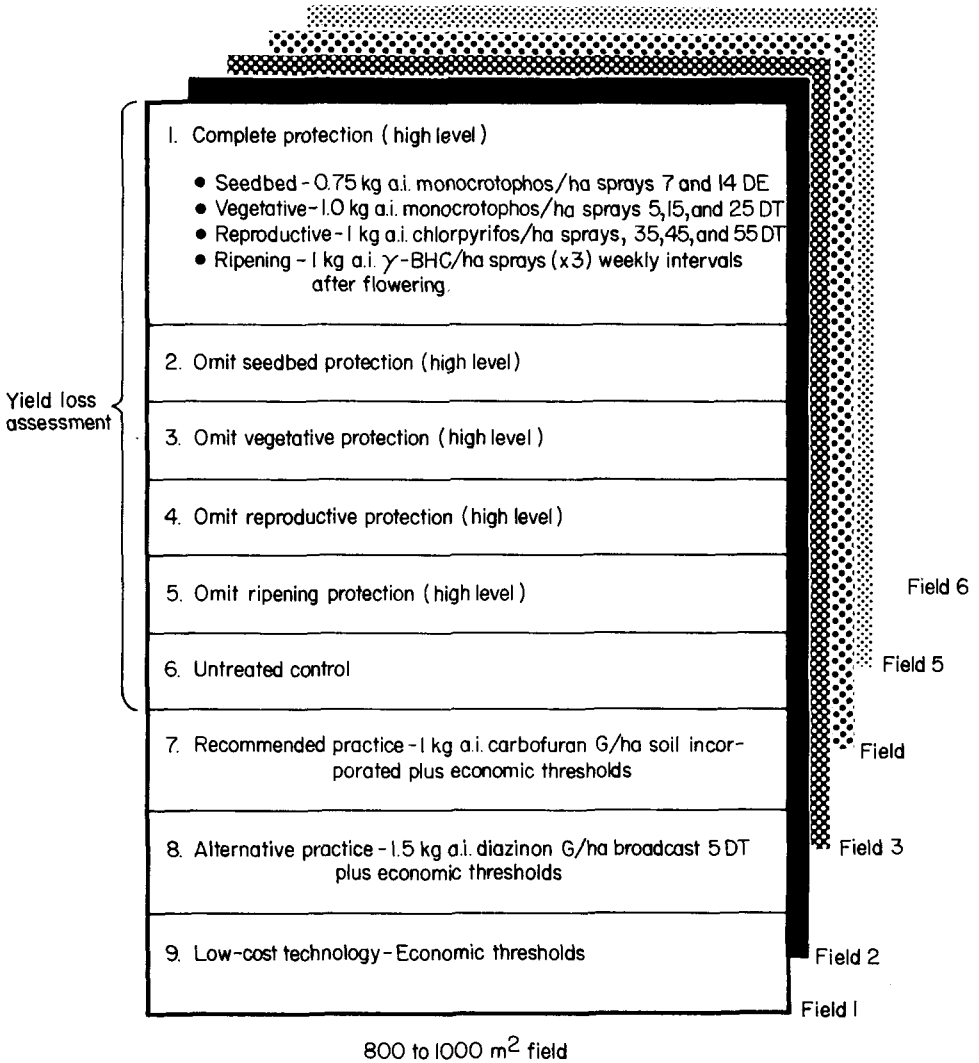
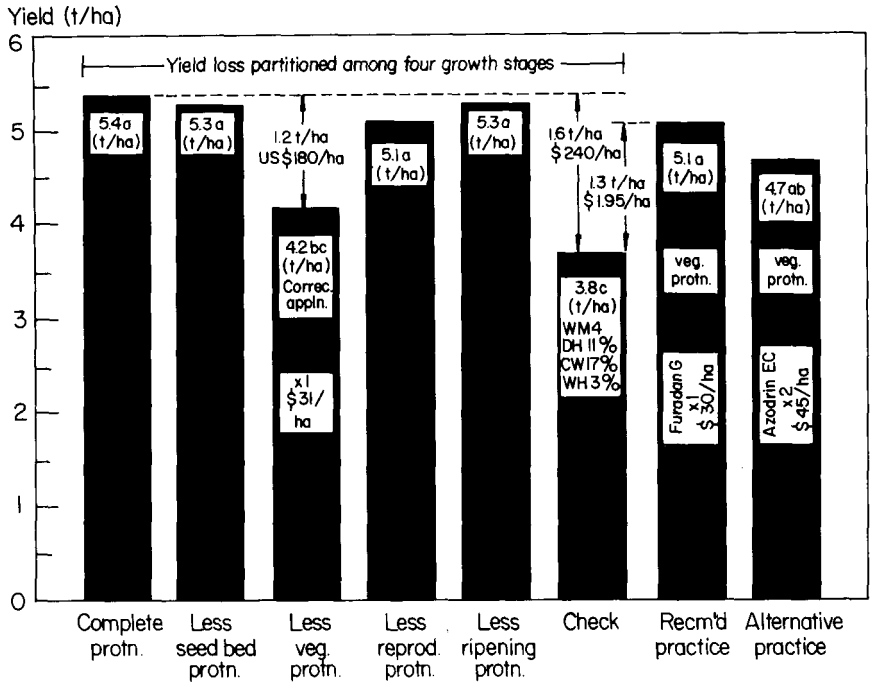


1. Experimental design for yield-loss assessment and determination of the optimal insect control recommendation for transplanted rice.

plot size necessary for insect studies (50-100 m^2), treatments are replicated across farms in a randomized complete block design. A minimum of four farms is suggested, but six to eight are best in terms of statistical precision. The treatments for the yield-loss assessment and the insect control treatments are pooled and randomly assigned to plots within each field.

Insect pest populations during the crop are monitored by recognized sampling procedures. The effort spent on monitoring depends on the manpower availability, but at least some quantitative measurements should be taken to identify the key pests responsible for any yield loss that may occur and choose the appropriate insecticides to be tested as a recommended practice. Yields are later analyzed statistically to ensure that numerical differences are real. The analysis allows for more precise interpretation.



2. Yield-loss assessment and an economic evaluation of the chemical insect control recommendation for single-crop transplanted rice (IR36), Pangasinan, 1976-77.

Results of a 1976-77 trial in Pangasinan (Fig. 2) illustrate the method. A significant yield loss (1.6 t/ ha) occurred because of whorl maggot (WM) infestation, stem borer deadhearts (DH), and caseworm (CW) defoliation. All the yield loss occurred during the vegetative stage when insecticide protection was omitted. No significant yield loss was recorded during the other 3 growth stages, even though 3% of the crop was damaged by stem borer whiteheads (WH).

The results of the yield-loss assessment provide information on the correct timing of insecticide applications. In this case only insecticide application during the vegetative state was warranted. These trials must be repeated for several years to determine the year-to-year variability of pest populations. Prophylactic insecticide applications are warranted for growth stages that register consistent yield losses; otherwise only corrective applications are warranted. The yield-loss method provides an objective standard to evaluate, in economic terms (marginal return), any insect control recommendations, including the use of corrective applications based on economic thresholds.

There is no need to evaluate a large set of possible insect control recommendations for each crop. The recommended practice plus one or two alternative practices are sufficient. It is a good idea to consult a local extension technician and evaluate his recommendation for farmers in the area.

There is no need to screen insecticides or to evaluate dosages at the site. Choose a recommendation that is compatible with the resource levels of the farmers and the production practices recommended by the other team members. Table 1 outlines the types of technologies to consider for on-farm cropping systems trials.

The results of partitioning the yield losses among crop growth stages allow the researcher to evaluate insect control recommendations. The recommended practice (Treatment 7 in Fig. 1), in the example, can be assessed objectively by comparing the results and the yield-loss

Table 1. Division of roles for entomologists in experiment stations and cropping systems sites.

Pest control method	Basic research activity (technology generation)	Applied research-production activity (technology specification)
Ecology and pest management	Taxonomy Pest bionomics Economic threshold etermination National pest control recommendations	Pest complex determination Population assessments Target farmer (behavior, resource level, and managerial capabilities) Pest control recommendations for each site
Chemical control	Screening (efficacy) Dosage Formulation Method of application Timing and frequency Residues Phytotoxicity Environmental impact assessment Toxicology	Timing and frequency Method of application Minimum dosage
Host plant resistance	Varietal screening Mode of resistance Genetics	Verification of resistance Deselection of susceptible varieties
Cultural control	Seasonal effect Spacing Fertilizer Tillage Trap crop Intercropping Crop residue management Crop rotation Crop maturity (Micro level studies)	Planting time Synchronous planting Crop residue management Tillage Removal of alternate hosts (Macro level studies)
Bicontrol	Taxonomy Natural enemy effectiveness and bionomics Introduction of exotic species Augmentation (mass release) Conservation	Natural enemy complex determination Populations of natural enemies Conservation

assessment. The single application of carbofuran granules was properly timed at the vegetative stage and gave a yield gain equal to that of the complete-protection plot (Treatment l). It yielded a 6.5 return on investment (benefit-cost ratio = US$195/ US$30). The alternative practice of monocrotophos sprays was equally effective but more costly (US$45 vs US$30/ha). If the recommended practice is not properly timed, then it should be altered accordingly on the basis of the yield-loss assessment. Future alternative recommendations to the carbofuran granules soil incorporation at transplanting should be less costly than US$30/ha.

The cropping systems researcher should know the costs of insecticides. A list of calculated per-hectare cost of the active ingredient at the recommended rate would serve as a useful guide.

Appendix 3.

YIELD-LOSS STUDIES FOR WEED CONTROL RECOMMENDATIONS

Keith Moody

FARMERS' CROPPING PATTERNS

To determine if farmers are controlling weeds adequately in their crops, superimpose plots in which a higher level of weeding than the farmers' is done at random throughout the selected farmers' fields. This higher level of weeding may consist of weekly hand weeding during the first 25 or 33% of the crop's life cycle when weeds are most competitive in most crops. The treatment should be replicated three or four times within a field on 20- to 30-m^2 plots. The yields from these plots can be compared with yields from the same number and size of samples taken at random from a portion of the farmers' field. The difference in yield, if any, indicates the loss in yield that the farmer suffers through inadequate weeding or weeding at the wrong time.

If yields in the portions of the field where the farmer weeded are not significantly less than those where the researcher did additional weeding, then the farmer is controlling weeds adequately. In that case it is difficult to introduce a new method of weed control unless it is more economical than the farmer's.

If the yield from the plots where additional weeding was done is significantly higher than that from the plots where the farmer weeded, the possibility of introducing a new weed control method or improving his present techniques should be investigated. However, the method introduced should be feasible and should cost the same as or less than what the farmer would pay for weed control.

EXPERIMENTAL CROPPING PATTERNS

The weed control method recommended for use in the cropping pattern should be based on experiments at the research site. If trials have not been conducted, the technology should be based on the method most commonly used by the farmer or that recommended by national agencies. If such information is not available, or the crop is new to the area, an *educated guess* will have to be made. The weed control recommendation for the cropping pattern will probably change each year on the basis of the results obtained from superimposed and researcher-managed trials.

The level of weed control in the plots superimposed on the cropping pattern field can be higher or lower than that used for the cropping pattern. For example, in Figure 1 the level of weed control in the cropping pattern might be a hand weeding 5 weeks after crop emergence, which is the farmers' level of weeding. In the superimposed plots, the levels of weeding might be:

A. 2 hand weeding, 2 and 5 weeks after emergence;
B. interrow cultivation, 2 weeks after emergence, followed by hand weeding 5 weeks after emergence;
C. herbicide 1 applied before emergence, followed by hand weeding 5 weeks after emergence;
D. herbicide 2 applied before emergence, followed by hand weeding 5 weeks after emergence; or

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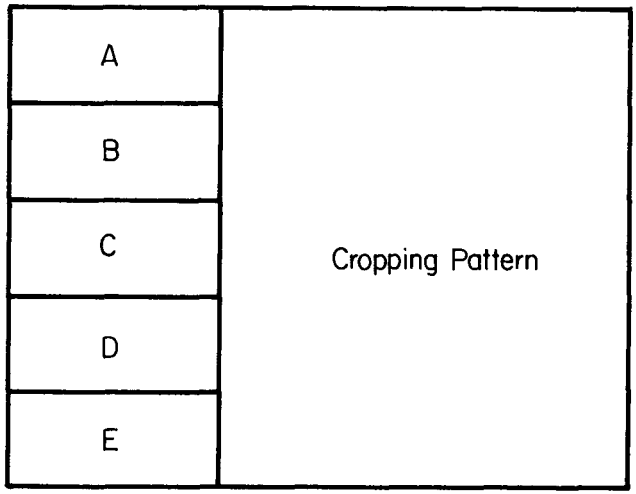


1. Suggested layout for superimposition of weed control treatments in a cropping pattern field.

E. herbicide 3 applied 10 days after emergence, followed by hand weeding 5 weeks after emergence.

Thus, all levels of weeding in the superimposed plots are higher than those in the cropping pattern plot. The advantage of this design is that when the farmer weeds, he weeds the whole field (the cropping pattern and the superimposed plots). He does not become confused about what he should or should not weed. The design's disadvantage is that the weeding practice for the cropping pattern is used in all superimposed treatments. No information can be gathered about the treatments themselves. This can be overcome by deleting the cropping pattern weeding practice from the superimposed plots.

Another example is where the level of weeding in the superimposed plots is lower than that in the cropping pattern or is a combination of treatments that are higher or lower than that in the cropping pattern. For example, if the weed control treatment for the cropping pattern is Herbicide 1 at 2 kg/ha applied before emergence, the weed control treatments in the superimposed plots could be:

A. farmers' weed control method,
B. herbicide 1 applied before emergence at 1.5 kg/ha,
C. herbicide 1 applied before emergence at 2 kg/ ha, followed by hand weeding at 5 weeks after emergence,
D. herbicide 1 applied before emergence at 2 kg/ ha, followed by herbicide 2 applied 14 days after emergence, or
E. herbicide 1 applied before emergence at 2 kg/ha, followed by interrow cultivation at 4 or 5 weeks after emergence.

Interrow cultivation treatments are sometimes difficult to include in superimposed treatments because the small plot size makes the turning of equipment at the end of the field difficult and increases the possibility of crop damage in the adjacent plots.

These trials should be conducted across five or six fields that are representative of the area.

The researcher may wish to conduct fully replicated trials across fields instead of superimposed trials. A randomized complete block design should be used and the trial replicated three times. Because of limitations in field size, the trials may be limited to five or six treatments, which should include the weed control method recommended for the cropping

pattern and the farmers' weed control level, if it is different from that recommended for the pattern. Other treatments that may be included can be at a higher or lower level of weeding than that used in the cropping pattern.

If possible, a no-weeding treatment should be avoided unless it is the farmers' level of weeding. Farmers complain about such treatments and also frequently harvest them to feed to animals.

This type of trial should be run across sufficient fields so that the different weed flora encountered in the area are well represented.

Appendix 4.

VARIETAL TESTING

V. R. Carangal

Varietal testing is best conducted in researcher-managed replicated trials in fields selected to represent the land types studied. The trials should be planted simultaneously with, and using the same establishment technique and other component technology as those used for, the same crop in the cropping pattern. In sites where the crop to be tested is not part of a cropping pattern, the variety trial should be conducted during that part of the growing season when that crop would most probably be planted in future cropping patterns. It is important to design some of these patterns on paper to arrive at the most appropriate planting time of the variety trial.

DESIGNS AND CROP DATA GATHERING

The following sections describe the designs and the crop information to be gathered from trials for sorghum, rice, maize, mungbean, cowpea, soybean, and peanuts. The choice of data to be gathered takes into account that these variety trials are conducted at an on-farm research site and should shed light on varietal performance in terms of yield, and insect and disease tolerance. Such detailed varietal characteristics as leaf angle, head type, and grain size should be determined at research stations.

Identification of diseases and insect pests is an important aspect of varietal testing. When the research-site staff is not thoroughly familiar with observed insects and diseases, arrange ments should be made for field visits by collaborating entomologists and pathologists. Such pests are commonly overlooked but may cause sizable yield reductions.

This appendix also provides the standard form developed by the cropping systems network for the description of the conditions in which a trial is conducted. Finally a set of high-input management practices is listed for use by researchers who intend to test the varieties in sites where no management recommendation is available. Note that these practices are intended to provide good plant protection and nutrition; they are not advisable as a farmer's management practice.

Agronomist and Cropping Systems Network Coordinator, IRRI.

PLOT AND MANAGEMENT RECORD FOR VARIETAL TESTING

Country: _____ Cooperator: _____

Site or station: _____

Latitude: _____ Elevation: _____

Soil texture: Light /__/ Medium /__/ Heavy /__/ Classification _____

Drainage: Good /__/ Fair /__/ Poor /__/ Wetland /__/ or dryland /__/

Crop: _____

Land preparation: _____ No. of reps _____

No. of plowings and harrowings

Spacing (cm): Between rows _____ Between hills _____

Date: Planting _____ Emergence _____

Fertilizer applied (kg/ha):

	Kind	Amount
Basal:	_____	_____
Side dress:	_____	_____

Pesticide applied:

	Kind	Amount/ha	Date of application
1st	_____	_____	_____
2nd	_____	_____	_____
3rd	_____	_____	_____
4th	_____	_____	_____

Weed control:

Herbicide applied

	Kind	Amount in kg a.i./ha	Date of application
1st	_____	_____	_____
2nd	_____	_____	_____

Nonchemical weeding: Number: _____ Date: _____

Flooding: Yes No How many times: _____

Weekly rainfall in mm and temperature in centigrade (start 2 weeks before planting)

Week	Rainfall	Temp.	Week	Rainfall	Temp.
1st	_____	_____	13th	_____	_____
2nd	_____	_____	14th	_____	_____
3rd	_____	_____	15th	_____	_____
4th	_____	_____	16th	_____	_____
5th	_____	_____	17th	_____	_____
6th	_____	_____	18th	_____	_____
7th	_____	_____	19th	_____	_____
8th	_____	_____	20th	_____	_____
9th	_____	_____	21th	_____	_____
10th	_____	_____	22th	_____	_____
11th	_____	_____	23th	_____	_____
12th	_____	_____	24th	_____	_____

Date Harvested: _____

Remarks:

Sorghumyieldtrial

Design. Randomized complete block replicated four times.

Plot size. Four 6-m rows/plot (75 cm row space, 5 cm between hills, 1 plant/hill).

Data to be gathered, Take yield and other data or observations from two inner rows.

1. Seedling vigor—10–15 days after emergence, rate on a scale of 1 to 5, in which 1 means good vigor and 5 poor vigor.
2. Days to flowering—record the date when at least 50% of the plants have shed pollen.
3. Plant height—measure the distance from the ground to the tip of the panicle 5-15 days before harvesting.
4. Disease resistance rating—rate disease resistance on a scale of 1 to 5, with 1 indicating high resistance and 5 high susceptibility.
5. Insect damage rating—use a rating of 1 to 5, with 1 indicating no damage, 3 intermediate damage, and 5 heavy damage.
6. Number of plants harvested—record the total number of plants harvested from the two middle rows.
7. Plot yield (g)—harvest the panicles of harvested rows. Dry and thresh them and weigh the threshed grains.
8. Moisture content (MC)—record immediately after weighing the threshed grains. Use a moisture tester.
9. Yield per hectare—use the formula for converting plot yield to kilograms per hectare at 15% MC

$$\text{Yield (kg/ha)} = \frac{\text{plot yield (g)}}{1{,}000\ \text{g}} \times \frac{10{,}000\ \text{m}^2}{9\ \text{m}^2\ \text{(plot area)}} \times \frac{100\text{-MC}}{85}$$

Transplantedriceyieldtrial

Design. Randomized complete block replicated four times.

Plot size. Seven 6-m rows/plot.

Growing the seedlings. Grow the seedlings following the wetbed or dapog method. Before seeding, soak the seeds in clean water for 24 hours and then incubate them for 36-48 hours in a warm place, keeping the seeds moist. Sow the pregerminated seeds uniformly in the seedbed. For 250g seeds of each selection or variety, use a 1–× 3-m wet seedbed or a 0.5-× 0.5-m dapog seedbed.

Land preparation. At least 3 weeks before transplanting, start land preparation by plowing or rototilling it wet. Flood the field to arrest further growth of weeds and minimize denitrification.

Five to seven days later, harrow the field and construct levees according to the experimental layout.

One day before transplanting, broadcast the recommended basal fertilizer uniformly in each of the four replications.

Transplanting. Transplant wetbed seedlings 21 days and dapog seedlings 14 days after sowing. Use 2-3 wetbed seedlings/hill and 4-6 dapog seedlings/hill with 25 cm between rows and 25 cm between hills in the row. Each plot will have 7 rows of 24 hills each.

Replant missing hills within a week after transplanting, You may plant left-over seedlings outside the plot.

Roguing. To maintain the purity of an entry, pull out offtype plants in the plot a week after flowering.

Harvesting. Harvest the crop when about 80% of the grains in the panicle are yellowish –28-30 days after flowering. Harvest and thresh the 5 middle rows (excluding end hills) in

each subplot separately. Clean and dry the grains in the sun for 2-3 days. Measure the yield in terms of grains harvested from each subplot.

Data to be gathered. Take yield and other data or observations from the 5 inner rows. The data should include:

1. Seedling vigor – 10-15 days after emergence, rate vigor on a scale of I to 5 with 1 indicating good vigor and 5 poor vigor.
2. Days to heading – record days from seeding until 50% of the panicles emerge.
3. Days to maturity – record days from seeding until 85% of the grains are ripe in the panicle.
4. Plant height – measure distance from the base of the plant to the tip of the tallest panicles just before harvest.
5. Tiller count – record the number of tillers per square meter just before harvest.
6. Lodging rating – rate lodging on a scale of 1 to 9 at the hard-dough stage or ripening stage. Be sure that lodging is not influenced by adjacent plots.
   1 – no lodging,
   3 – most plants (more than 50%) slightly lodged,
   5 – most plants moderately lodged,
   7 – most plants nearly flat, and
   9 – all plants flat.
7. Yield per plot – record weight (g) of sun-dried grain.
8. Moisture content (MC) – determine MC from the cleaned sample with a moisture tester.
9. Pest and disease rating – use a scale of 1-5 with 1 indicating resistant and 5 susceptible.
10. Yield per hectare – use the formula

$$\text{Yield (kg/ha)} = \frac{\text{yield/plot (g)}}{1{,}000\text{ g}} \times \frac{10{,}000\text{m}^2}{\text{plot area (m}^2)} \times \frac{100 - \text{MC}}{86}$$

Dryland or dry-seeded wetland rice yield trial

Design. Randomized complete block replicated four times.

Plot size. Seven 6-m rows/plot.

Spacing. Drill seeds at the desired seeding rate in each plot with 25 cm between rows. To determine the number of grams of seed to sow from a given seeding rate:

Seed required (g) = seeding rate (kg/ ha) × distance between rows (m) × row length (m) ÷ 10.

Example: How much rice should be sown in a 6-m-long row spaced 25 cm apart at a seeding rate of 120 kg/ ha?

$$\text{Seed required (g)} = \frac{120 \times 0.25 \times 6}{10} = 18 \text{ g/row.}$$

Data to begathered. Yield and other observations are to be taken from the inner 5 rows as specified for the transplanted rice yield trial (see above).

Maize yield trial

Design. Randomized complete block replicated four times.

Plot size. Four 6-m rows/plot.

Spacing. Space rows 75 cm apart with 25 cm between hills and 1 plant/hill. Plant 2 plants/hill and thin to 1 plant 15-20 days after emergence.

Data to be gathered. Harvest plants in 2 inner rows when ears are dry about 50 days after silking, and record yield and other observations.

1. Maturity – record days from seeding to harvest.
2. Downy mildew – count total number of plants and infected plants with downy mildew and calculate the percentage of downy mildew infection.
3. Plant height – measure the distance (cm) from the base of the plant at the soil level to the base of the tassel. Use an average of 10 random plants/plot.
4. Ear height – measure the distance (cm) from the base of the plant at the soil level to the uppermost ear-bearing node of the plant. Use an average of 10 random plants/plot.
5. Lodging – before harvest, count the root and stalk lodged plants. Include any plant with an inclination angle of 30 degrees or more from the vertical among root lodged plants; plants where the stalks are broken below the ear are stalk lodged plants.
6. Pest and disease rating – use a 1-5 rating scale in which 1 means highly resistant and 5 highlysusceptible.
7. Number of plants harvested – record the number of completely bordered plants harvested from the two inner rows.
8. Number of ears harvested – record the number of ears harvested from the two inner rows.
9. Field weight – weigh all husked ears harvested from the two center rows.
10. Moisture content (MC) – take a sample from 10 ears from the 2 center rows right after harvest and check MC with a moisture tester.
11. Grain yield per hectare – calculate the yield per hectare in kilograms at 15% MC:

$$\text{Grain yield (kg/ha)} = \frac{\text{yield/plot (g)}}{1{,}000\text{ g}} \times \frac{10{,}000\text{ m}^2}{\text{plot area (m}^2\text{)}} \times \frac{100 - \text{MC}}{85}$$

Mungbean yield trial

Design. Randomized complete block replicated four times.

Plot size. Four 6-m rows/plot.

Spacing and plant density. Space rows 50 cm apart during the dry season and 75 cm apart during the wet with 23 living plants per linear meter. Drill enough seeds to compensate for germination loss.

Data to be gathered. All data should be gathered from the two inner rows.

1. Seedling vigor – 10-15 day after emergence, rate vigor on a 1-5 scale, with 1 indicating good vigor and 5 poor vigor.
2. Date of flowering – record the number of days between emergence and the stage at which 75% of the plants have flowered.
3. Date of maturity – record the number of days between emergence and the stage at which 80% of the pods are ready for harvest.
4. Plant height – before harvest, measure the distance (cm) from ground level to the tip of the stem. Take the average of 10 random plants/plot.
5. Lodging index – rate lodging on a scale of 1-5, with 1 indicating resistant and 5 susceptible.
6. Disease and pest rating – rate pest resistance on a 1–5 scale in which 1 means highly resistant and 5 highly susceptible.
7. Number of plants harvested – record the number of plants harvested per plot.
8. Moisture content (MC) – determine MC with a moisture tester immediately after the plot yields have been weighed.

9. Plot yield — weigh all grains (g) harvested from the two center rows.
10. Yield per hectare — calculate yield at 12% MC:

$$\text{Yield (kg/ha)} = \frac{\text{plot yield (g)}}{1{,}000\ \text{g}} \times \frac{10{,}000\ \text{m}^2}{\text{plot area (m}^2\text{)}} \times \frac{100-\text{MC}}{88}$$

Note: Separate yield per priming (picking). Have at least a maximum of 3/harvest.

Cowpea yield trial

Design. Randomized complete block replicated four times.

Plot size. Four 6-m rows/plot.

Spacing. Space rows 75 cm apart during the wet season and 50 cm during the dry and 10 cm between hills with 1 living plant/hill.

Data to be gathered. Harvest pods when they are dry. Take yield and other data or observations from the two inner rows.

1. Seedling vigor — at 10–15days after emergence, rate vigor on a scale of 1 to 5, with 1 indicating good vigor and 5 poor vigor.
2. Date of flowering — record days from emergence to flowering when 50% of the plants start to flower.
3. Date of maturity — record days from emergence to maturity when all the plants show mature pods.
4. Plant height — measure 10 plants (cm) from the ground to the tip of the main stem when plants are mature.
5. Lodging index — rate lodging on a 1-5 scale, with 1 indicating resistant and 5 susceptible.
6. Disease rating — rate disease on a 1-5 scale, with 1 indicating highly resistant and 5 indicating highly susceptible.
7. Number of hills harvested — record number of plants harvested from the two inner rows.
8. Moisture content (MC) — take MC with a moisture tester after harvest.
9. Plot yield — record the weight (g) of grains harvested from the two inner rows.
10. Yield per hectare — convert plot yield to kilograms per hectare at 12% MC:

$$\text{Yield (kg/ha)} = \frac{\text{plot yield (g)}}{1{,}000\ \text{g}} \times \frac{10{,}000\ \text{m}^2}{\text{plot area (m}^2\text{)}} \times \frac{100-\text{MC}}{88}$$

Note: Separate yield per priming (picking) and its computation. Limit to 4th priming only.

Soybean yield trial

Design. Randomized complete block replicated four times.

Plot size. Four 6-m rows/plot.

Spacing. Space rows 50 cm apart during the dry season and 75 cm apart during the wet. Space hills 10 cm apart with 3 living plants/hill.

Data to be gathered. Take yield and other data or observations from the two inner rows.

1. Seedling vigor — at 10-15 days after emergence, rate vigor on a scale of 1-5, with 1 indicating good vigor and 5 poor vigor.
2. Date of flowering — record days from emergence to flowering when at least 50% of the plants have flowered.

3. Date of maturity—record days from emergence to maturity when plants have dropped their leaves and the pods have turned brown.
4. Plant height—measure (cm) 10 randomly picked plants—preferably 5 plants from each of the 2 inner rows—from the cotyledonary node to the tip of the highest stem.
5. Disease rating—rate bacterial pistule and rust incidence on a scale of 1-5, with 1 indicating high resistance and 5 high susceptibility.
6. Lodging index—rate lodging on a 1-5 scale, with 1 indicating resistance and 5 indicating susceptibility.
7. Moisture content (MC)—take MC with a moisture tester immediately after weighing the plant yield.
8. Number of hills harvested—record plants harvested from the two inner rows.
9. Yield per hectare—the formula for converting plot yield to kilogram per hectare at 12% MC:

$$\text{Yield (kg/ha)} = \frac{\text{plot yield (g)}}{1{,}000\ \text{g}} \times \frac{10{,}000\ \text{m}^2}{\text{plot area (m}^2)} \times \frac{100 - \text{MC}}{88}$$

Peanut yield trial

Design. Randomized complete block replicated 3 times.

Plot size. Two 6-m rows/plot.

Spacing. Space rows 50 cm apart during the dry season and 75 cm during the wet season with 20 cm between hills and 3 living plants/hill.

Data to be gathered. Yield and other data or observations should be taken from the two rows.

1. Seedling vigor—10-15 days after emergence, rate vigor on a scale of 1-5, with 1 indicating good vigor and 5 poor vigor.
2. Date of flowering—record the number of days from emergence to flowering when 75% of the plants have flowered.
3. Date of maturity—record the number of days from emergence to maturity when plants are ready for harvesting.
4. Plant height—measure the distance from the ground level to the tip of the highest stem for 10 representative random plants a few days after flowering.
5. Disease and pest rating—rate pest damage on a scale of 1-5, with 1 indicating high resistance and 5 high susceptibility.
6. Number of plants harvested—record number of plants harvested in each plot.
7. Plot bean yield—weigh all pods (g) per plot and multiply by the mean shelling percentage.
8. Moisture content (MC)—record MC with a moisture tester immediately after determining bean yield.
9. Yield per hectare at 12% MC is:

$$\text{Yield (kg/ha)} = \frac{\text{plot yield (g)}}{1{,}000\ \text{g}} \times \frac{10{,}000\ \text{m}^2}{\text{plot area (m}^2)} \times \frac{100 - \text{MC}}{88}$$

COMPONENT TECHNOLOGY FOR VARIETY TRIALS

High-input component technology is used only when no adequate local recommendation is available, and when the crop is not common to the region or not included in any of the

cropping patterns tested at the site. These methods and rates are not recommendations for commercial crop production.

Sorghum

Fertilizer rate. 120-50-50kg (N, P_2O_5, K_2O)/ha. Apply 40 kg N and all the P_2O_5 and K_2O at planting. Sidedress 40 kg N about 4 weeks after emergence, and 40 kg N at flowering.

Weed control. Use butachlor at 1.2 kg a.i./ha at planting plus hand weeding when necessary.

Insect control. Use carbofuran 3G at 1.0 kg a.i./ha at planting and on the whorl 30 days after planting. Use a supplemental spraying of azodrin, thiodan, or malathion at flowering.

Disease control. Apply Dithane M45 at 38 g/liter of water to control rust and Helminthosporium leaf spot. Also check the recommended chemical control in your country.

Transplanted rice

Fertilizer application. Use 80-40-40 kg (N, P_2O_5, K_2O)/ha. Apply 40 kg N and all of the P_2O_5 and K_2O at planting. Apply the remaining N (40 kg) at panicle initiation.

Water management (if irrigation is available). For best yield of irrigated rice crop, maintain about 3-5 cm water in the field from transplanting through the hard dough stage. Keep bunds around the plot firm and well lined with mud to hold water with minimum percolation.

Weed control. Control weeds as early as possible. Because the main purpose of the trial is to test the yield potential of the selections, herbicide use is not encouraged because its application may harm the seeds or the growing plants. Hand weed the field 10 to 15 days after transplanting and repeat the weeding 25 to 30 days after transplanting.

Insect control. Use carbofuran 3G at 1.0 kg a.i./ha at planting and 30 days later. Use a supplemental spray of azodrin, thiodan, and other recommended chemicals as necessary.

Disease control. Apply Dithane M45 at 38 g/liter water to control leaf spot and other diseases. Also check for other recommended chemicals.

Dryland or dry-seeded wetland rice

Fertilizer rate. Use 80-40-40 kg (N, P_2O_5, K_2O)/ha. Apply 40 kg N and all the P_2O_5 and K_2O at planting. Apply the remaining amount of N (40 kg) at panicle initiation.

Insect control. Apply carbofuran 3G at 1.0 kg a.i./ha at planting and 30 days later. Use supplemental spraying of azodrin, thiodan, or malathion as necessary.

Diseuse control. Apply Dithane M45 at 38 g/liter water to control leaf spot and other diseases. Also check other recommended chemicals.

Maize

Fertilizer rate. Use 120-50-50 kg (N, P_2O_5, K_2O)/ha. Apply 40 kg N and the whole amount of P_2O_5 and K_2O at planting, and sidedress 40 kg N 4 weeks after emergence and 40 kg N at tasseling stage.

Weed control. Apply butachlor 60 EC at 1.2 kg a.i./ha immediately after planting and hand weed when necessary.

Insect control. Apply carbofuran at 1.0 kg a.i./ha at planting and just before flowering. Supplement with foliar spray as necessary.

Disease control. Spray Dithane M45 at 38 g/liter water, followed by sprays at 15-day intervals if necessary. Pull and burn mosaic and downy mildew-infected plants.

Mungbean

Fertilizer rate. Use 30-60-60 kg (N, P_2O_5, K_2O)/ha for both seasons.

Weed control. Apply butachlor 60 EC at 1.2 kg a.i./ha before planting and hand weed when necessary.

Insect control. Apply carbofuran at 1.0 kg a.i./ha before planting and alternately spray malathion, thiodan, and azodrin.

Disease control. Spray benlate at 1.5 g/4 liters water against *Cercospora* leaf spot and powdery mildew and Dithane M45 (10g/4 liters water) against rust twice at 15-day intervals.

Cowpea

Fertilizer rate. Use 30-60-60 kg (N, P_2O_5, K_2O)/ha for both seasons.

Weed control. Apply butachlor 60 EC at 1.2 kg a.i./ha before planting and hand weed when necessary.

Insect control. Apply carbofuran at 1.0 kg a.i./ ha before planting and alternately spray malathion, thiodan, and azodrin.

Disease control. Spray benlate at 1.5 g/4 liters water against leaf spot disease and Dithane M45 (10 g/ liter water) against rust twice at 15-day intervals.

Soybean

Fertilizer rate. Use 30-60-60 kg (N, P_2O_5, K_2O)/ha for both groups and seasons.

Weed control. Apply butachlor 60 EC at 1.2 kg a.i. / ha after planting and hand weed when necessary.

Insect control. Apply carbofuran at 1.0 kg a.i./ha before planting and alternately spray malathion, thiodan, and azodrin.

Disease control. Spray benlate at 1.5 g/4 liters of water against *Cercospora* leaf spot and Dithane M45 at 10 g/4 liters water against rust twice at 15-day intervals.

Peanut

Fertilizer rate. Use 60-60-60 (N, P_2O_5, K_2O)/ha for both dry and wet seasons.

Weed control. Apply butachlor 60 EC at 1.2 kg ai./ ha before planting.

Insect control. Apply carbofuran at 1.0 kg a.i./ha before planting and alternately spray malathion, thiodan, and azodrin.

Disease control. Spray benlate at 1.5 g/4 liters water against *Cercospora* leaf spot and other leaf diseases and Dithane M45 at 10 g/4 liters water against rust twice at 15-day intervals.

Appendix 5.

CROPPING PATTERN MONITORING
(as compiled by the Asian Cropping Systems Working Group)

The set of cropping pattern monitoring forms provides a systematic way of collecting the data needed for evaluating results of cropping pattern trials and selected farmers' patterns in terms of agronomic and economic performance. Following these forms will provide the data necessary to arrive at a clear summarization of test results at the end of each year. These forms were originally designed in September 1976 by the Working Group. Since then, experiences at IRRI and in the network, and comments by Working Group members led to a modified set

of forms. The set has been tested in IRRI's outreach sites. It adds flexibility (no need for daily monitoring or soil water studies) and is substantially simplified (standard costs and labor times can be used for operations) compared with earlier forms.

DAILY CLIMATE RECORD (FORM A)

The daily climate record (form A) provides a daily record of the weather under which cropping patterns are grown. The minimum requirements of weather records are daily measurements of rainfall (mm), solar radiation (cal/cm^2), minimum and maximum temperature (°C), and open pan evaporation (mm). Form A also provides comments on measures recorded in sufficient proximity to the test plots to be applicable — for example, wind speed or floods and unusual events, such as hail, strong wind, and volcanic ash.

Rainfall should be measured at 0800 hours and the readings at that time recorded, as for the previous day. The same principle applies to solar radiation and maximum and minimum temperature and evaporation measurements.

The daily climate record can be applied to all plots that are grouped by rain gauge number, which is recorded on the plot records. Rainfall measurements should preferably be taken so that they refer to an area not more than 3 km in diameter. Rainfall should be measured at a central site a minimum distance from the research plots. Where the project area is widespread and covers several villages, it may be necessary to keep two or more rainfall records. It is important to clearly indicate the rain gauge (by plot no.) that belongs to each rainfall record.

Solar radiation, temperature, and evaporation measurements can apply to a much wider area — as much as 10–to 20-km distance. Those records can often be obtained from a nearby research station or meteorological station. It is important to ensure proper installation and maintenance of these instruments.

Further instructions for using form A are provided at the back of the form.

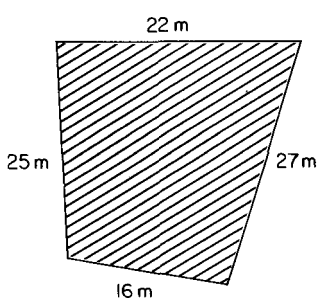
PLOT RECORD (FORM B)

The plot record (form B) should be completed before the beginning of the crop year. It should be reviewed at the end of the crop year to check original statements with respect to ground water, supplementary irrigation, drainage, etc. and to add new information on the other aspects, if necessary.

The term *plot* applies to the area used for the cropping pattern trial. It may occupy a whole field, or cover only a part of it.

For the *plot number,* use 3 digits. This number should correspond to the plots you have grouped on form A as those that belong to the rain gauge number in the climate record. Further identitication under country and site is the same as that for Form A.

1. The plot diagram gives an idea of what the plot looks like. Draw a layout of the plot in the box provided, stating its length and width (m). A plot may be an irregular field:



ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM A: DAILY CLIMATE DATA
See instructions overleaf

Record all data to the nearest whole number in the units indicated

Country _____ Site _____ Calendar year 1 9 Month

Day	Evaporation (mm)	Solar radiation (cal/cm^2/day)	Temperature (°C) Minimum	Temperature (°C) Maximum	Temperature mean	Rain gauge . . . . (mm) 1	2	3	4	5	Mean	Comments
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
Total												
Mean												
Initial of recorder												

[a]Readings from rain gauges located far from the research fields (e.g., at the site office) should not be entered on this form.

How To Use This Form

1. Below is an example of the form used for January 1976 at the Philippine site in the town of Oton.

2. Enter COUNTRY and SITE in words; they will be coded later at IRRI.

3. Enter the YEAR and MONTH in the boxes. Code months 01 for January through 12 for December. Take a new sheet for each month.

4. Enter all data as whole number (round 0.5 up). There should be no decimal points anywhere on this form.

5. EVAPORATION, SOLAR RADIATION, MINIMUM AND MAXIMUM TEMPERATURE may not all be available at the site but may be available from a nearby meteorological station. If suitable data for any of these variables are not available, leave the appropriate column(s) blank.

6. Each RAIN GAUGE at the site should be assigned an identifying number (1-10), which is retained as long as the gauge remains in use, and the data for that gauge always entered in the same column on the form from month to month, and year to year. Enter the location of each gauge in the correct box. When entering data from the different gauges, check across the gauges. Large discrepancies between gauges located nearby may indicate errors of recording and should be double checked.

7. Anyone entering data on the form should record his or her initials at the bottom.

8. COMMENTS should be written in whenever you think necessary. Always comment on:

   i) unusual events,
   ii) changes in the source of the data
   iii) whenever equipment is changed, serviced, or restandardized.
   iv) missing data (see note 9).

9. Missing data: when data are temporarily not available, enter a dash (-), and give an explanation under COMMENTS.

10. Copying data: we expect that the data on this form will be copied from other forms, for example the records of a local meteorological station for some or all of evaporation through maximum temperature, and field notebooks for rain gauges located at cropping pattern trial plots. Please double check when copying so as to preserve the accuracy of the data. If possible, keep the original data as a safeguard against loss of this form.

Country Philippines Site Iloilo - OTON Calendar year 19 7 6 Month 0 1

Day	Evaporation (mm)	Solar radiation (cal/cm²/day)	Temperature (°C) Minimum	Temperature (°C) Maximum	Mean	Rain gauge . . . . . (mm) 1 BITAS	2 BAGUM.	3 NAP	4 CORD.	5 RIZAL	6 SM	7 BURAY	Mean	Comments
1	—	285	24	29	27	0	4	0	0	8	4	6	3	
2	3	332	23	31	27	0	0	0	0	0	0	0	0	
3	4	385	24	31	28	20	30	25	28	18	7	6	19	
4	4	440	22	31	27	0	0	0	0	0	0	4	1	
5	4	500	22	31	27	0	0	0	0	0	0	3	1	
⋮														
31	5	352	21	29	25	0	0	0	0	0	0	0	0	
Total			679	973	826	0	48	42	39	31	21	27	30	
Mean			22	31	27									
Initials of recorder	JL	JL	JL	JL		JL	CRD	DOL	NCB	WH	EBM	FCA		

ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM B: PLOT RECORD

Country _____ Site _____ Calendar year at start of crop year 19 __ Plot no. ____

Use this form to describe the physical characteristics of the plot. If data is gathered from this plot for more than one crop year, retain the same plot number and enter a new form B for each crop year. Mark with dash (-) any nonapplicable, unavailable, or missing information.

1. PLOT DIAGRAM

Indicate length and width (in meters)

2. PLOT SPECIFICATIONS

Nearest Form A rain gauge Barangay _____ Number __

Area of plot (sq m) _____

If plot is bunded: Bund Height (cm) ___ Bund Width (cm) ___

Landstratum ___

Slope of land (%) ___

Surface drainage (0=to adjacent field; 1=to a man-made or man-improved ditch; 2=to natural drain (small stream or gully) ___

3. DIAGRAM OF PROPOSED PATTERN

Month before first crop planting _____

Months: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th

4. DIAGRAM OF IMPLEMENTED PATTERN

Months: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th

5. MONTHLY IRRIGATION SUPPLY EXPECTED THIS CROP YEAR:

(0=none. 1=1-7 days per month. 2=8-14 days. 3=15-21 days. 4=22+ days)

Month: 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th

6. SOIL DESCRIPTION

Soil series (local name) _____

PROFILE DESCRIPTION

Depth(cm)	Soil texture Manual	Soil texture Lab	Soil pH	Soil color	Organic* ( )	Fertility P( )	Fertility K( )

P soil test method _____
K soil test method _____
Organic method _____
Laboratory _____

Soil texture: S = sandy; LS = loamy sand; SL = sandy loam; L = loamy
SIL = silt loam; SICL = silty clay loam; CL = clay loam; SIC = silty clay; C = clay
*Indicate whether organic carbon or organic matter. Enter units, e.g. % or ppm in ( )

2. The plot specification gives further information about the plot—its position in the landscape and the hydrology of the plot. Start by indicating the rain gauge number from the climatic record that applies to the plot.

Area of the plot is based on the plot measurement provided in the plot layout. If the plot is bunded, *bund height* should be measured from the level portion of the paddy to the height at which water would flow over the bund without making openings in the bunds.

To measure the *drop off* from the highest *adjacent paddy* and that to the lowest adjacent paddy (cm), measure the distance from the level portion of the adjacent paddy to the level portion in which the cropping pattern is to be established.

Groundwater depth indicates estimates of the highest and the lowest groundwater depths during the year. Also indicate the month during which these occur. This is best obtained by referring to farmers' wells (before draw down) or to natural drainageways that occur close to the plots. Where groundwater depth is greater than 2 m, an estimate need not be exact, but it may be important to differentiate between a 5-m and a 10-m shallowest groundwater depth. Where the shallowest groundwater depth is less than 2 m, record it to the closest meter (round 0.5 m upward).

It is important not to confuse groundwater depth with a perched water table created by puddling and collection of water on a paddy field. The shallowest groundwater depth can, however, be above the soil surface in cases where low-lying areas are flooded by river water or substantial interflow from higher areas. In such cases, indicate on the measure of the shallowest groundwater depth that it refers to a measure above the soil surface — for example: *1 m above.*

To obtain the *slope of land* (%), consider the slope of the land lying from 100 m below the plot to that 100 m above the plot. For *landscape type,* select from the following definitions:

Summit—convex high areas in the landscape

Slope—areas with more than 2% slope

Plain—large level land forms, may be low or high in the landscape

Bottomlands—lowest points in landscape where runoff water converges, generally smaller units

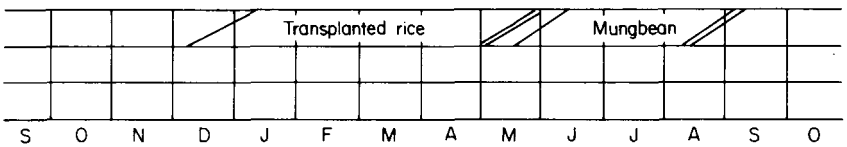
As to whether the *plot has been puddled,* indicate the entry that applies. Puddling is considered the purposeful destruction of soil aggregates by working wet soil (by repeated trampling, harrowing, beating, laddering, rototilling, etc.). Simple wet plowing is not sufficient to destroy the structure of most soils and, therefore, does not constitute puddling. For example, a field may have been puddled for the last year but not for the last crop (fill in 2). Alternatively the field that has been puddled may not have been puddled for the last 2 years (fill in 3). Some bunded fields are never puddled (fill in 0). In *drainage* by pump, tidal, ditch, other, indicate if the plot is artificially drained by such ways as making ditches or lifting water out of the field. This question does not consider natural drainage because of slope, seepage, or percolation.

3. Diagram of proposed pattern is a diagram of the cropping pattern to be planted in the plot. Although the pattern may not be executed, as proposed, this section should not be changed in later reviews. Begin by indicating the *first month* of the growing season above the diagram. The first month is the month in which the first land preparation activities of the earliest crop in any of the patterns take place. It is normally the month in which the first rains, or supplementary irrigation water, starts the growing season. This month sequence is also used for the irrigation supply section of the form.

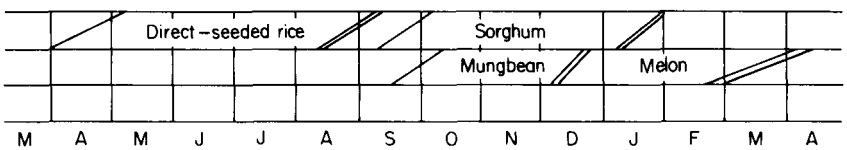
Indicate the planting dates of each crop with a single line and the harvesting dates with a double line. The acceptable range of planting dates for each crop should be indicated by a diagonal line covering the range of planting dates. A double line indicating the expected range

of harvesting dates (not necessarily the same as range of planting dates) defines the period over which the crop is expected to occupy the plot. Write the name of the crop (refer to lists of crops stated in form D instruction) between the two lines. Then proceed with the next crop in case of cropping sequence, using the same line, indicating again the range of planting dates and harvesting dates expected for this second crop. Again indicate the type of crop between the two lines. Continue this if a third crop is planted in sequence using the same line.

In case any, or more than one, of these crops is combined with a crop planted in sequence or in relay, use the remaining lines in the diagram. Again indicate the range of planting and harvesting dates for each crop. The example below shows a transplanted rice-mungbean pattern in a region where the growing season starts about mid-December. In this case the period of transplanting (not seeding) is indicated as that when the cropping pattern will occupy the plot.



The next example shows a cropping pattern of direct-seeded, rice-sorghum intercropped with mungbean, in which melon is interplanted into the sorghum-after-mungbean harvest. The growing season starts in April.



In case a part of the pattern is left as an option to be determined at seeding time, use a comma between the two crop names – /mungbean, cowpea//.

4. Monthly irrigation. Fill in what is expected for the crop year. The first month should be the same as the first month of the cropping pattern diagram. For this starting month and each of the following months, enter 0 for no water, 4 for more than 22 days of that month.

5. Soil description. The soil series using its local name must be indicated. This soil series can be found in soil maps, from soil surveys, or on the basis of local information. Where the soil has been classified, indicate official classification, preferably up to the family level.

Note that the profile description portion is optional. If available, information in this section may be supplied by the site; otherwise leave this portion blank. For soil texture, indicate if the information was obtained from laboratory analysis or manually. Use a soil auger to extract samples from the depth indicated in the table. When desirable, replace the listed sampling horizons with those that coincide more with existing profile differentiation — strike out printed depths and indicate the depth of replaced sampling horizons. Indicate the soil textural class by number, choosing from sand, loamy sand, sandy loam, loam, silt loam, silty clay loam, clay loam, silty clay, clay, and heavy clay. The textural classifications are entered on the plot form.

Measure *soil pH* with a pH kit for the three top horizons indicated in the table. If possible, measure pH of the soil before reduction due to flooding occurs. A soil may be moist, but should not be reduced. If a flooded sample must be used, a 24-hour drying period will oxidize a reduced soil sufficiently to measure pH. Take the color of moist or wet soil and indicate it by

noting the color number given on a color chart (Munsell) that is closest to it. Do this for the top three horizons.

Estimate *organic matter* as low for light-colored soils in which little or no stable decomposed humic material is found; as high for dark-colored soils in which substantial stable decomposed as well as some fibrous organic matter is encountered; and as average for any other soil. This needs to be indicated only for the 0- to 15-cm horizon or at the depth of the first horizon.

Soilfertility for nitrogen, phosphorus, and potassium is indicated as low (1), medium (2), or high (3). Nitrogen, phosphorus, or potassium fertility may be considered *high* when no or few responses to the three nutrients are obtained, and *low* if crop production is severely limited (yields less than 5% of fertilized yield) when these nutrients are not added. Indicate medium if it falls between high and low.

CROP RECORD (FORM C)

A crop record for each crop in the pattern is required and should accurately record the crop management as it happened on the plot. This requires careful inspection of calculation (pesticides and fertilizers) and application to the plots.

Identification is the same as for other forms. Fill out the 3 digits of the plot number.

Cropping pattern. If crops are sequenced, use a hyphen (-). If crops are planted simultaneously (more than 2/3 of the vegetative period overlaps), use a plus sign (+). If crops are planted in relay (less than 1/3 of the growing season overlaps), use a slash (/). For example, a cropping pattern of direct-seeded rice followed by maize intercropped with peanuts would be presented as:

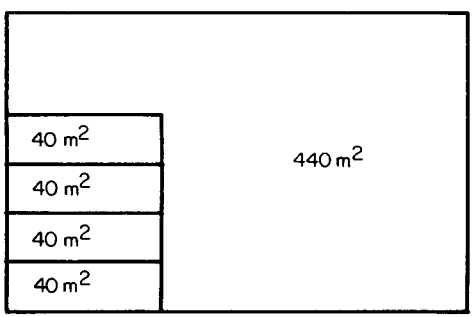
DS rice – maize + peanut

In case options for part of the pattern continue to exist, use a comma:

DS rice – mung, cowpea

Crop. Indicate the common crop name. In describing rice crops, differentiate transplanted rice (TPR), wet-seeded rice (WSR), and dry-seeded rice (DSR). Indicate the position of the crop in the cropping pattern. An example of DSR – maize + peanut (DSR circled) shows DSR as the first crop in the cropping pattern.

1. A *plot crop diagram* is required only if superimposed trials exist in a plot. Do not draw a plot-crop diagram if crop occupies the whole plot. The example below shows a plot with 4 superimposed trials. Each subplot has 40 m^2 and the total area of the whole plot is 600 m^2 with 440 m^2 as the area left for cropping pattern trials.



ASIAN CROPPING SYSTEMS NETWORK: CROPPING PATTERN MONITORING PROJECT

FORM C: CROP RECORD

Country _____ Site _____ Calendar year at start of crop year 19 ☐☐ Plot no. ☐☐☐☐

Cropping pattern (circle this crop) _____ Crop _____ Variety _____ Crop position ☐

Use this form to describe the planting and harvesting of one crop. There should be a separate form C for each crop in the cropping pattern. If more than one crop shares the plot (e.g. intercrops, relay crops, split plots, strip crops), a separate form C is required for each crop.

1. *PLOT-CROP DIAGRAM*

Draw a plot-crop diagram only with superimposed trials. Indicate area of each sub-plot. Otherwise leave it blank.

Size of whole plot (m^2) ☐☐☐☐☐ Total area of super-imposed trial (m^2) ☐☐☐☐☐

2. If this crop is not the crop in original pattern design, give reason for change

_____

_____

3. AREA PLANTED WITH THIS CROP (m^2) ☐☐☐☐☐
(Exclude any superimposed trial area)

4. PLANTING CHECKLIST

These questions refer to the establishment of the crop itself, not the establishment of seedbeds for transplanting.

Date of first planting (Year, month, day) ☐☐☐☐☐☐

Planted on: 1=clean fallow; 2=stubble ☐

Crop type: 1=sole; 2=relay; 3=intercrop; 4=ratoon ☐

Method of planting: 1=broadcast; 2=row seeded 3=transplanted ☐

Pregerminated seeds: 1=yes; 2=no ☐

Seeding rate (kg/ha) ☐☐☐

Row spacing (if not broadcast) (cm) ☐☐☐

Plant or hill spacing (if not broadcast or drilled) (cm) ☐☐☐

Age of seedlings (days) ☐☐

Seedlings/hill (no.) ☐

5. CROP DAMAGE REPORTS

	Rating		Rating
Weeds		Insect/pests	
Lodging		Other	

Weeks after planting when most lodging occurred ☐☐

RATING SCALE: Weeds, Pest, and Lodging status

0 no economic damage
1 slight economic damage
2 moderate economic damage
3 severe economic damage

6. HARVESTING

Date Year, month, day	Product type	Crop cut sample(s) Area (m^2)	Yield (kg)	% moist	Calculated yield % moist	kg/ha	Initials of recorder	Comments (especially if crop failed or when yield is low because of drought, flooding, rodents, brids, and others)

7. Stand at harvest (%) ☐☐. Reasons for low stand _____

2. State any *reasons* the crop is not the one originally designed in the proposed pattern of form B. The common reasons are: excess water for planting the second crop, prevention of land preparation by drought, farmers' abandonment of the field because of weeds, animal damage, or forced change of plans after heading of first crop.

3. *Area planted with this crop* refers to the cropping pattern area only (excludes areas designed for superimposed treatments). In example 1, above, 440 m^2 is the area. (Note: In some sites, superimposed treatments are applied to plots that occupy the whole pattern field. These sites often monitor operations not affected by the treatments (plowing, planting, harvesting, etc.) and fill in standards for the pattern-level treatment estimating input and labor requirements on the whole-plot bases. Here the plot size would be the size of the whole plot.)

4. The *planting checklist* describes the crop establishment and the plant arrangement. Any activities intended for seedbeds on other fields will not be included in this list. Fill in planting dates in any of these records in the sequence: year, month, day. (This date of planting does not apply to replanting or reseeding.) In transplanted rice, planting date refers to the date of transplanting of seedling, *not* the sowing or seeding date of seedbeds. Specify how the crop was planted. The remainder of the cropping pattern description is self-explanatory.

For crops that are planted in rows or a description of the plant arrangement for a wide variety of crops, information on row spacing as well as spacing of hills within rows is needed. If hills contain one or more plants, that should be indicated. For small-seeded crops, row spacing and seeding rates are often sufficient. Where crops are not seeded in hills (most common), the plant and hill spacing should be read as plant spacing and the number of seedlings per hill = 1. When row spacing, plant spacing, and number of seedlings per hill are specified, seeding rates are not important.

The remainder of this crop record requests information about the crop that will be completed at 15 days after emergence (stand obtained) or at crop harvest time (crop damage reports). It is important to instruct field staff in the record-keeping requirements for the crop.

To take the percentage of *stand obtained* at 15 days after emergence, consider a full stand acceptable and express the observed stand as a percentage of the full stand.

5. The *crop damage report* indicates the causes of crop damage. The incidence of weeds as a group, the occurrence of diseases or insect pests, and crop lodging, recorded at harvest time, should be reported only if they caused damage to the crop. If diseases, rats, farm animals, or other causes of damage apply, enter such causes in the box provided for *others.* To identify the extent of damage, use the following rating for lodging, weeds, diseases, and insect pests and other damage:

Rating scale: weeds, diseases, or insect pests, and lodging status

1 slight economic damage
2 moderate economic damage
3 severe economic damage

6. The information required at harvesttime are harvest date, the type of product obtained such as grain, straw, first priming, second priming, plant tops, etc.; the sampling area (m^2), the sample yield (kg), and sample moisture content (%). Definitely fill in the calculated yield per hectare (kg/ha) and the standard moisture percentage used in the yield calculation as requested (even if *air dry* applies).

Comments. This section allows explanation for low yield or any other occurrences such as

- crop stress that strongly influenced the performance of this crop such as drought, excess water, wind damage, or nutrient deficiency, or
- reasons for abnormal delays encountered in crop establishment (plowing to seeding), crop maintenance (weeding, spraying), or crop harvest.

PLOT OPERATIONS FORM (FORM D)

The plot operations form is the only form that requires frequent entries and field visits. It is designed to provide information on all operations in the field for the establishment, maintenance, and harvest of the crop. This form should be filled out at least twice a week to capture all operations. The operations form is linked to the plot. A set of operations forms that completely covers all crops over the period of the cropping pattern in the plot, including operations during fallow periods, is required for each crop. Because the plot operations form will lose substantial value in cases where the record becomes incomplete, plot monitoring at the sites should be carefully scheduled.

Note: Use a new form for each plot, and for each crop or crop position.

On the left-hand column the recorder should indicate the *date* each operation was performed in the plot.

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CODING FOR FORM D
SUMMARY OF CODING
(See manual for full details)

WHEN TO TAKE A NEW SHEET

each PLOT each CROP each CROP POSITION each YEAR

FERTILIZER/INSECTICIDE CODES

- are provided separately to coders

MANHOURS

Multiply the number of people working by the time worked. Round to the nearest whole number (round 0.5 up). Enter 0 for values 0.01 to 0.49 labor hours

QUANTITY UNITS

Record quantity to the nearest whole number. Enter units (e.g. kg, gm, cc, %)

POWER/TRACTOR CODES

1 draft animal
2 hand tiller
3 tractor

CROP CODES

High yielding rices	Native rices	Grain legumes	Coarse grains	Miscellaneous
01 Dry-seeded direct	06 Dry-seeded direct	12 Mungbeans	21 Corn (Maize)	31 Cassava
02 Wet-seeded direct	07 Wet-seeded direct	13 Cowpeas	22 Sorghum	33 Sweet potatoes
03 Transplanted	08 Transplanted	14 Peanuts		
04 Ratoon	09 Ratoon	16 Bush sitao		44 Others

UNIFORMITY SCORE

1 80% in 3 days or less
2 80% in 3-7 days
3 80% in 8 days or more

FIELD WATER STATUS CODES: 1 or greater = depth of water; S = saturated; W = wet; M = moist; D = dry

OPERATION AND CROP DEVELOPMENT CODES — Enter: date, operation, code and details in the columns indicated

(REPORT ONLY ACTIVITIES CONDUCTED ON THE PLOT .....)

h=time p=power source (tillage) m=material type q=material quantity c=comments s=score

Land preparation	Crop establishment	Crop care	Harvesting
01 Clearing residue. . h	20 Transplanting . . h	30 Fertilizing. . . . . mqh	51 Manual harvesting. . h
02 Field repairs . . .	21 Planting . . . . h	31 Pesticide application . . . mqh	53 Manual threshing . . h
03 Plowing . . . . . hp	22 Replanting . . . h	32 Herbicide application . . . mqh	54 Power threshing . . h
04 Harrowing . . . . . hp	23 Thinning . . . . h	34 Handweeding . . . . . h	55 Manual winnowing . . h
05 Levelling . . . . . hp	29 Other crop establishment . . hc	35 Mechanical weeding . . . . . hp	69 Other harvest . . . c
06 Furrowing . . . . . hp		38 Hilling-up . . . . . hp	
09 Other land prep . . hc		39 Off-barring. . . . . hp	
		49 Other crop care. . . . . hc	

Crop development

80 Initial emergence . . . . . sc
81 Initial flowering . . . . . sc
82 Crop-cut sampling . . . . . sc
83 Crop failure c

On the next column, the field staff should describe the field *operations* performed on the plot, on the date indicated. Any operation performed on the plot, foreseen or unforeseen, whether executed by project or farmer, should be included. Do not record operations not done on the plot, such as those associated with raising seedlings in another field.

If an important operation (time-consuming or of consequence to crop performance) cannot be classed among those in the operation classes provided, specify the operation and provide an explanatory note in the comments section of the form.

If the *crop failed,* indicate the date the crop was discontinued and enter a brief explanation in the comments section of the form.

For each operation entered, record one or several of the following-aspects:

Information	*Indicated by*
Material type	m
Quantity	q
Power type	h
Comment	c

A list of operations, their description, and the records required for each operation is provided at the end of this section and on the back of form D.

For specifying the *material* inputs, indicate the type of fertilizer, insecticide, pesticide, and herbicide applied to the plot. *Quantity* is the amount of product applied and its units under quantity (in kilograms, cubic meters, grams, tablespoonfuls, etc.). Specify the percentage of active ingredient (a.i.) and the formulation under the material column. Formulation may be in granules (G), wettable powder (WP), or emulsifiable concentrate (EC). The method of applying fertilizer and pesticides can be specified in the comments column. Whether labor used was family or hired can also be indicated in the same column.

The time required and quantities of materials used should relate only to the plot area to which the operation applies (m^2) indicated above the comments section, or to the plot area indicated in form C. All values for labor hours will be in whole numbers. Power used may be that of draft animal, hand tiller, or tractor.

WATER STATUS (Supplementary Sheet)

The *water status form* provides information and interpretation of the soil moisture and water conditions of the plot for specific soil-water studies. This form can accommodate daily monitoring of a plot. Begin by indicating on the form the first month (the same starting month you have identified in the diagram of proposed pattern and irrigation supply on form B).

Soil *moisture* content should be rated for the upper 2 cm for puddled plots and for 10-cm depth for unpuddled plots. (Note: Soils that have not been plowed or harrowed since puddling are considered puddled soils).

If the plot is flooded, a contiguous (connecting) layer of water is present and the soil surface is broken into islands. Record the depth of flooding (cm) for plots that have standing water. A common procedure is to place a stick with a 0-50 cm scale marked on it vertically in the plot. The 0 point on this stick should coincide with the water level of the newly flooded field described above as having a continuous layer of water and higher spots that may not be flooded yet. The depth of flooding is then read off the stick in centimeters. A water depth greater than 50 cm should be estimated to the closest 10 cm for depths up to 100 cm and to the closest 25 cm for depths greater than 100 cm. If stick reading is 17.8 cm, fill in 18 only.

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FORM D (office)

Country _____ Site _____ Calendar year this month 19 ___ Plot no. ____

Recorder _____ Number of crops sharing the plot ___ If more than 1, use separate forms for each crop Crop _____ Crop position ___

Date Month 01-12 Day 01-31	Field water status	Operation	Code 1-99	Material (Name, formulation, % A.I.) m	Code 1-9999	Quantity/plot 1-99999 q	units q	Labor hours (people x hours) 0-99 h	Power traction p	1-99 h	Non-SI	Area to which operations apply (m^2) Total Non-SI Comments c	Score s

"CROP FAILURE" should be indicated at the date the crop was discontinued.

If the plot is not flooded, the soil surface becomes contiguous and standing water is reduced to puddles or is absent. Record soil moisture rating (D, M, W, or S) using the following scale:

D = *Topsoil is dry,* almost has the color of dust;

M = *Topsoil is moist,* feels moist to touch. It does not form 1- to 2-mm threads when rolled between the fingers. There is no apparent free water if soil is very sandy.

W = *Topsoil is wet,* threads are formed when worked between fingers, except for very sandy soils. There are no isolated puddles and there is no apparent free water.

S = *Topsoil is saturated,* isolated puddles are present or free water is very obvious.

List of operations to form D of CPM record
Select your operations from the following:

		Information required
Land preparation		
01	Clearing residue—removing, piling in heaps, cutting, burning	h
02	Field repairs—fixing of bunds, ditches, fences, etc.	h
03	Plowing—initial primary tillage operation in the field to break soil surface before secondary tillage. Exclude plowing done to seedbed.	hp
04	Harrowing—process of breaking clods by passing any type of harrow (comb, tooth disk, etc.) over a field. (As in plowing, exclude harrowing done to seedbed.)	hp
05	Leveling—passing of a plain board over the harrowed field to reduce slight soil surface depressions for even water distribution. It is the final operation before transplanting.	hp
06	Furrowing—passing a plow or other tool over a finally prepared field to prepare furrows at a given (row) distance just before planting.	hp
07	Incorporating—mixing or placing fertilizer, insecticide, pesticide, herbicide into the soil.	mqh
08	Intercrop land preparation—any tillage operation to allow planting of secondary crops between major crops.	h
09	Other land preparation—an operation that cannot be classified under any of the above operations. Specify the operation with an explanation in the comments section. Examples: ridging, bedding, etc.	hc
Crop establishment		
20	Transplanting—planting of seedlings (often rice) in the pattern plot.	h
21	Planting—placing crop seeds properly in or on the soil by broadcasting, dibbling, drilling, or other methods for crop establishment.	h
22	Replanting—planting seedlings or seed in missing hills after first planting.	h
23	Thinning—removing extra plants to obtain the desired plant density.	h

24	Ratooning – the crop regrowth and yield obtained after the plant crop has been harvested.	c
	Soaking (or dipping) – immersing seeds for pregermination or treating them or seedlings with chemicals.	h
29	Other crop establishment – any operation that cannot be classified into any of the above operations (codes 20-). Provide explanation at the comments portion.	hc
Crop care		
30	Fertilizing – application of fertilizer material with particular nutrients that aid in crop growth and development.	mqh
31	Pesticide application – spraying of chemicals or broadcasting them in granular form to control destructive insects and diseases.	mqh
32	Herbicide application – spraying or broadcasting of herbicides to the plot to control weeds.	mqh
33	Nonchemical pest control – operations for control of pests, manual insect control, and control of rats, birds, etc.	hc
34	Hand weeding – removing weeds from the fields manually or by nonchemical tools such as blades, hoes, etc. (no rotating or oscillating parts).	h
35	Mechanical weeding – weed control method using hand or engine-powered mechanical equipment.	h
36	Canopy manipulation – bending, clipping, pruning, binding up or in any other way systematically changing the structure of the crop canopy, e.g. bending back of maize.	h
37	Mulching – placement of straw or similar farm residues on the ground (often to conserve soil moisture or reduce soil temperatures).	h
38	Hilling-up – plowing between rows of plants with furrow slices thrown toward the base of the plant.	h
	Off-barring – plowing between rows of plants with the furrow slice thrown back to back to the center between plant rows.	h
49	Other crop care – operations that cannot be classified into any of the above operations (code 30-). Provide explanation in comments section.	hc
Harvesting		
50	Crop-cut sampling – sample harvested in a defined area of a plot for yield determination.	q
51	Manual harvesting – cutting the crop manually using scythe or any other tool.	h
52	Power harvesting – method of cutting the crop by using mechanical harvesters.	h
53	Manual threshing – separating straw from grains without machines, e.g. by foot or by striking a bundle of panicles over slats or by having an animal trample the grains and straw.	h
54	Power threshing – separating grain from straw by using an engine-, human-, or animal-powered mechanical thresher.	h

55	Manual winnowing — separating unfilled grains from developed grains by gravity or natural air current.	h
56	Power winnowing — separating untilled grains from developed grains by a mechanical blower.	h
	Drying — removal of excess moisture in seeds by exposure to the sun or in driers or ovens to meet the desired moisture level for storage.	h
	Hauling — transporting manually or mechanically of product from the field to storage or market.	h
	Shelling — removal of the outer seed cover of a crop, like peanut, or the maize grain from the tusk.	h
69	Other harvest — operations that cannot be classified under any of the above operations (codes 50-). Provide an explanation in comments section.	hc
70	Crop failure — if crop failed, enter the date the crop was discontinued and provide explanation in comments section.	c

Appendix 6.

COSTS AND RETURNS ANALYSIS OF CROPPING PATTERNS

S. K. Jayasuriya

All the input and output data for a cropping pattern grown on a particular plot must be arranged in a suitable format before economic analysis.

The *plot summary form* (an example with hypothetical figures for a rice crop is shown in Fig. 1) is a convenient general format for arranging data from experimental and farmers' cropping patterns for economic analysis. Some of the operations listed may need to be modified, or added to, to accommodate the requirements of particular management practices and cropping patterns at a site.

Operations and input applications are specified over weekly periods. Where data are transferred from monitoring records, the operations taking place on particular dates should be allotted to the appropriate week. The methods and pitfalls associated with the recording of operations are described in the section on testing and will not be repeated in this appendix.

COMPUTATIONS

Once the operations and input applications for the plot have been recorded, they are converted into per-hectare figures by dividing them by the plot size. In the example, the plot size is 0.1 ha and all the figures are divided by 0.1 to yield the per-hectare figures, which are 10 times the per-plot figures.

These figures are then multiplied by the price (cost) of each to obtain the cost per hectare. At the wage rate of ₱1.50/h for a plowman, the first plowing (30 h/ha) costs ₱1.50 × 30 =

Network economist, Cropping Systems Program, IRRI.

Fig. 1. Cost and returns of cropping pattern trials.

Plot Summary

Country _____ Program _____ Site _____

Farmer _____ Plot _____ Plot size 0.1 ha

Cropping pattern A

ITEMS	1st crop					2nd crop				
LABOR	wk /no	1h[a] /plot	1h[a] /ha	cost /h	cost /ha	wk /no	1h[a] /plot	1h[a] /ha	cost /h	cost /ha
Plowing 1	16	3	30	1.50	45	43	2.5	25	1.50	37.50
Plowing 2	18	2	20	1.50	30					
Harrowing 1	19	3	30	1.50	45					
Harrowing 2	25	2	20	1.50	30					
Seedbed prep.	22	2	20	1.50	30					
Plowing 3	25	4	40	1.50	60					
(Other) Fixing bunds	29	2	20	1.50	30					
TOTAL LAND PREPARATION		18	180		270		2.5	25		37.50
Planting/Transplanting	26	20	200	0.50	100		0.5	5	0.75	3.75
Replanting										
Thinning										
TOTAL PLANTING		20	200		100		0.5	5		3.75
Handweeding 1	30	5	50	0.50	25					
Handweeding 2										
Cultivation 1										
Cultivation 2										
(Other)										
TOTAL WEEDING		5	50		25					
Fertilization 1	26	1	10	0.50	5	43	0.5	5	0.50	2.50
Fertilization 2	30	1	10	0.50	5					
Insecticide Ap. 1	29	0.5	5	0.50	2.5	44	0.4	4	0.50	2.00
Insecticide Ap. 2						45	0.4	4	0.50	2.00
Herbicide Ap. 1	30	0.5	5	0.50	2.5					
Herbicide Ap. 2										
Nonchemical pest control										
Mulching										
Watering										
Draining										
Canopy manipulation										
(Other) Fertilization 3	37	1	10	0.50	5					
		4	40		20					
TOTAL OTHER CARE							1.3	13		6.50
Harvesting 1	41	60	600	1.50	900	56	26	260	2.00	520
Harvesting 2										
Harvesting 3										
TOTAL HARVESTING			600		900					520
TOTAL LABOR			1070		1315		30.3	303		567.75

[a]1h = labor hours.

Fig. 1 continued

ITEM	1st crop						2nd crop				
MATERIAL	Kind	amt /plot	amt /ha	A.i. /ha	Cost /ha		Kind	amt /plot	amt /ha	A.i. /ha	Cost /ha
Seed		12 kg									
Fertilizer 1	14-14-14	20 kg	200		220		14-14-14	30	300		330
Fertilizer 2	Urea	15 kg	150		180						
Total N		14.3	143					4.2	42		
Total P		2.8	28					4.2	42		
Total K		2.8	28					4.2	42		
Insecticide 1	Carbaryl	0.2	2 kg	1.5 k/ha	20		Azodrin	0.15	1.5	0.25	110
Insecticide 2							Azodrin	0.15	1.5	0.25	110
Herbicide 1	2,4-D gran.	2.5kg	25kg	0.8 kg/ha	150						
Herbicide 1							Azodrin	0.15	1.5	0.25	110
Herbicide 2											
Fungicide 1											
(Other)Fertil-ization 3	Am. sulfate	20 kg	200		200						
TOTAL MATERIAL					670						550
POWER	Type	h /plot	h /ha	cost /h	Cost /ha		Type	h /plot	h /ha	Cost /h	Cost /ha
Plowing 1	Animal	3	30	1.50	45		Animal	2.5	25	1.50	37.50
Plowing 2	"	2	20	1.50	30						
Harrowing 1	"	3	30	1.50	45						
Harrowing 2	"	2	20	1.50	30						
(Others)	"	4	40	1.50	60						
TOTAL POWER					210			2.5	25		37.50
PRODUCTION	Grade	Amt /plot	Amt /ha	Price /unit	Value /ha		Grade	Amt /plot	Amt /ha	Price /unit	Value /ha
Harvest 1- unmilled rice		500kg	5000kg	1.10	₥5,500		Mung	80	800	5.00	₥4,000
Harvest 2											
Harvest 3											
TOTAL PRODUCTION					₥5,500						₥4,000

SUMMARY OF COSTS AND RETURNS PER HECTARE

	1st crop	2nd crop	Both crops
Yield	5000 kg	800 kg	
Gross returns	5500 kg	4000 kg	
Labor & power cost ₥	1525 kg	605.25 kg	
Material cost ₥	670 kg	550 kg	
Total variable costs ₥	2195 kg	1155.25 kg	
Returns above variable costs ₥	3305	2844.75 kg	
Returns to labor & power costs ₥/₥			
Returns to material cost ₥/₥			

₥45; 150 kg urea at ₥1.20 costs ₥1.20 × 150 = ₥180; 5,000 kg unmilled rice at ₥1.10/kg has a value of ₥1.10 × 5,000 = ₥5,500.

From these data, one can compute the summary of costs and returns per hectare shown at the bottom of Figure 1. The data can also be used to compute other measures of productivity

or performance and also serve as building blocks for more sophisticated types of analyses such as whole-farm analysis using techniques of mathematical programming such as linear programming.

Examples that use data for Crop 1, Figure 1, for computing some of the more commonly used performance criteria are:

1. Returns above variable costs = gross returns – variable costs
   = 5,500 – ₱2,195/ha
   = ₱3,305/ha

2. Returns to factors. It is helpful to look at the rate of return to a factor or a group of factors. This factor may be considered throughout the production cycle or over a limited time, usually the time at which it may be most scarce in relation to demand. The general formula for the rate of return to factor A is,

$$\text{Rate of returns} = \frac{\text{gross returns} - \text{all costs other than costs of A}}{\text{amount of A}}$$

Examples of performance criteria that evaluate returns to a group of factors are returns to farm resources, returns to labor and power costs, and returns to all variable costs. Other criteria may be returns to a subset of labor input, such as family labor or labor during certain periods:

- Returns to farm resources = gross returns - costs of all non-farm resources
  = ₱5,500 – ₱100 – ₱900 – ₱670/ha
  = ₱3,830/ha

- Rate of return to variable costs $= \dfrac{\text{gross returns}}{\text{variable costs}} =$ ₱2.5 /₱

In this case there are no variable costs other than those considered in factor A (all variable costs) and nothing is subtracted from the gross returns in the numerator.

- Returns to labor and power costs $= \dfrac{\text{gross returns} - \text{all material costs}}{\text{cost of labor and power}}$

$$= \frac{₱5{,}500 - ₱670/₱}{1{,}525}$$

$$= ₱5.9/₱$$

- Returns to material cost $= \dfrac{\text{gross returns} - \text{labor and power costs}}{\text{material costs}}$

$$= \frac{₱5.500 - ₱1.525/₱}{670}$$

$$= ₱5.9/₱$$

Table 1. Cropping patterbn summary for use on performance of each pattern in each land type.

CROPPING PATTERN: Farmer Pattern A LAND TYPE: 2

Replications	Gross returns	Cost of					Total variable costs	Returns over variable costs	Returns to costs for				
		Labor	Power	Materials	Other: _____	Other: _____			Labor	Power	Material	Other: _____	Other: _____
Plot 1													
Plot 2													
Plot 3													
Plot 4													
Plot 5													
Plot 6													
Total Σ													
Mean $(\frac{Total}{n})$													
C.V.													

CV = Coefficient of variation

$CV = \frac{Mean}{sd}$, where Sd is the standard deviation

$$Sd = \frac{\Sigma x^2 - (\Sigma x)^2}{(n-1)}$$

- If the amount of family and hired labor used in the operation is known, one can also compute:

$$\text{Returns to family labor} = \frac{\text{gross returns - all material and power costs} - \text{cost of hired labor}}{\text{amount of family labor}}$$

In the above example, if all operations other than transplanting and harvesting used family labor, then

$$\text{Returns to family labor} = \frac{₱5{,}550 - ₱670 - ₱210 - ₱100 - ₱900/\text{man-hour}}{180 + 50 + 40}$$

$$= ₱13.4/\text{man-hour}$$

- In the above example, one looks at returns to labor during the period week 25-29 (which may be a peak labor demand period), then the total labor used during this period was spent on:

Plowing =	40 hours/ ha
Harrowing 2 =	20 hours/ ha
Fixing bunds =	20 hours/ ha
Transplanting =	200 hours/ ha
Total	280 hours/ ha

The costs of all operations and inputs is = ₱1,975

$$\text{Rate of return to labor during weeks 25-30} = \frac{5{,}500 - 1{,}975}{280}$$

$$= ₱12.6/\text{hour}$$

If a number of crops are included in the pattern, data can be recorded and computations carried out for the subsequent crops in the same manner.

The performance criteria for the entire cropping pattern can then be computed using the cost and returns data for all crops. The actual figures for the categories must be added together and then used in these computations; the performance criteria figures for the pattern, in general, are not a simple average of the figures for the crops in the pattern.

Once the plot summaries are compiled and the performance criteria are computed for all plots in a given land type growing the same pattern, they can be used to find:

- the mean performance of the pattern and
- its variability across farms, in terms of inputs, yields, and the performance criteria selected (Table 1).

The results obtained from the prevalent farmers' patterns and the experimental patterns studied in a land type can then be conveniently summarized for evaluation, as described in the section on testing.

GLOSSARY

COMPONENT TECHNOLOGY — the cultural techniques used in the management of a cropping pattern. These include choice of variety, times, and methods of tillage and crop establishment, fertilization, field-level water management, pest management, and harvest.

CROPPING INTENSITY INDEX (CII) (Menegay [1975]) — a time-weighted land-use index that evaluates the fraction of the total hectare-months available to the farmer that are used for crop production.

CROPPING PATTERN — the spatial and temporal combination of crops on a plot and the management used to produce them.

CROPPING SYSTEM — the crop production activity of a farm. It comprises all components required for the production of the set of crops of a farm and the relationship between them and the environment. These components include all necessary physical and biological factors, as well as technology, labor, and management.

CUMULIC — derived from *accumulation.* Descriptive of a wetland type where 100 mm of accumulated water will stay for more than 7 days when the soil has been puddled, even without rain or irrigation.

DELUGIC — derived from *deluge.* Descriptive of a land type where the water levels stay for more than 2 weeks at a depth greater than 30 cm, which is above the normal height of bunds or dikes, during high-rainfall months.

DETERMINANTS OF CROPPING PATTERNS—environmental factors that influence the performance of cropping patterns and are not readily modifiable by changes in cultural techniques of crop production.

DRYLAND — land that, except for limited periods, does not hold moisture in the rooting zone in excess of that held at field capacity.

ENVIRONMENTAL COMPLEX—a union of sites within which the values of cropping pattern determinants are the same (see *Land type*).

EXTRAPOLATION AREA — the domain of adaptation of a cropping pattern. It is composed of the land types to which the cropping pattern is adapted.

FARMING SYSTEM (FARM SYSTEM OR WHOLE-FARM SYSTEM) — the production and consumption activities used by a person called *a farmer* to derive benefits from land and other inputs through crop growth and the use of technologies available to him under specific environmental conditions.

FLUXIC — derived from the *flux* or *passing through.* Descriptive of a wetland type where free water remains in the field when the soil has been puddled, but the depletion rate of free water, including evapotranspiration losses, is more than 10 mm/day.

HYDROMORPHIC — derived from *hydro* (water) and *morph* (form). Descriptive of soil developed in the presence of permanent or periodic excess of moisture.

INTERCROPPING — growing two or more crops simultaneously in alternating rows or sets of rows in the same plot (see also *Mixed intercropping*).

LAND EQUIVALENT RATIO(LER)—the area needed under sole cropping to produce the same amount as 1 ha of intercropping or mixed cropping.

LANDTYPE—a union of sites within which values of cropping pattern determinants are the same (see *Environmental complex).*

LAND UTILIZATION INDEX (LUI)—the number of days during which crops occupy the land during a year, divided by 365.

MIXED INTERCROPPING—growing two or more crops simultaneously intermingled in the same plot with no distinct row arrangement.

MIXED-ROW CROPPING—growing two or more crops simultaneously in the sample plot intermingled within a distinct row arrangement.

MULTIPLE CROPPING—growing more than one crop in the same plot in 1 year.

MULTIPLE CROPPING INDEX (MCI)—the sum of the areas planted to different crops harvested during the year, divided by the total cultivated area.

PERT(PROGRAM EVALUATION AND REVIEW TECHNIQUE) — a management tool for defining and integrating events and processes that must be accomplished in time to assure completion of project objectives on schedule.

PLOT—a contiguous area of land planted in a homogeneous manner during a defined period, normally 1 year.

PLOT PLAN—a diagrammatic representation of the spatial and temporal combination of crops on a plot during 1 year.

PLUVIC—derived from *pluvia* or rain; descriptive of a land type where water contributed by rain or irrigation does not stay for more than 3 hours on the soil even if the soil has been worked wet (see *Dryland).*

RATOON CROPPING—cultivation of regrowth from stubble after a crop harvest.

RECOMMENDATION (CROP PRODUCTION)—advice in terms of operations, times, equipment, and materials for crop production, presented as worthy of acceptance.

RELAY CROPPING—growing two or more crops in sequence, planting the succeeding one after the flowering but before the harvest of the former.

SEQUENTIAL CROPPING—growing two crops in rapid sequence, planting one after the harvest of the former.

SOLE CROPPING—growing one crop alone or in pure stand, either as a single crop or as a sequence of single crops within the year.

STRIP CROPPING—growing two or more crops simultaneously in alternate plots arranged in strips that can be independently cultivated.

SUPERIMPOSED TRIALS—experiments composed of a small set of treatments that evaluate the performance of alternative component technology for a cropping pattern. The treatments are superimposed, generally without replication, on four or more similar cropping pattern trial fields.

WETLAND—land of which the rooting zone can be kept saturated for a substantial part of the growing season, where necessary, by encouraging accumulation of water on the soil through puddling and the use of bunds or levees.