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# PROJECT LEITE

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# CROPPING SYSTEMS RESEARCH IN THE PANGASINAN PROJECT[1]


## ABSTRACT

The cropping systems research program at the International Rice Research Institute (IRRI) has evolved over the last decade in response to conditions on rice farms in South and Southeast Asia. Crop management research has shifted from the experiment station to farmers' fields. Research methods developed for studies on farmers' fields consider 1) the limited resource base that governs adoption potential; 2) the variability in physical and socioeconomic environments that, by creating many small agroecological zones, hampers wide-scale extrapolation of technology; 3) the importance of indigenous technical knowledge; and 4) the short supply of manpower for staffing field-level agricultural research and development projects. A systems research approach was adopted to draw attention to the linkages between components of a cropping system, and between system components and the environment.

The cropping systems method begins with target area delineation and description, then cropping patterns are designed and tested in farmer-cooperators' fields. Conventional field experiments also are conducted to obtain solutions to production constraints or define optimal levels of variable inputs. Results are subjected to agronomic and economic evaluation. A multidisciplinary staff is used in all phases of research. Promising cropping patterns are passed to a multilocational testing unit for evaluation over a wider area.

Cropping systems research methods are illustrated with results obtained over 4 years at a site in the Philippines. After analyses, the patterns or components of patterns were separated into three adoptability groups: government input unnecessary for adoption, government input necessary for adoption, and unsuitable for adoption. Research institutions should be encouraged to correct defects in the technology placed in the third class.



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# CROPPING SYSTEMS RESEARCH IN THE PANGASINAN PROJECT

Asian rice farms are small, often between 0.5 and 3 ha, and farmers often are illiterate or semiliterate. Many farmers are share-tenants with limited assets. Land, water, and other farm resources are decidedly inferior to those of modern experiment stations on which conventional crop management studies are conducted. While quantitative and qualitative resource differences account for part of the gap between yields on farms and on experiment stations, socioeconomic factors that hinder adoption of modern technology or contribute to inefficient management of adopted modern technology widen that yield gap.

In the late 1960s research on the International Rice Research Institute (IRRI) experiment farm showed the enormous potential for crop intensification in tropical Asia (Bradfield 1972). In response to South and Southeast Asia conditions under which agricultural change must occur, the IRRI cropping systems research program has evolved considerably over the past 10 years. Research has focused on rainfed and partially irrigated land that traditionally produced one rice crop per year (Zandstra 1979). Crop management research has shifted from the experiment farm to farmers' fields, where new production practices are investigated with farmer involvement and scrutiny. In addition to crop management researchers, the IRRI cropping systems program includes a farm management economics research staff, which has become an integral component of the program. The economics component describes farm resources and evaluates the economic viability of alternative cropping patterns and related production technology for the project's target area.

Cropping systems research methods developed for farm-level studies in farmers' fields consider: 1) the limited farm-family and community resource base that governs adoption potential; 2) the great variability in physical and socioeconomic environments that, by creating many small agroecological zones, hampers wide-scale extrapolation of technology; 3) the importance of indigenous technical knowledge; and 4) the limited supply of qualified personnel for staffing field-level agricultural research and development projects.

This report describes IRRI's site-related cropping systems research methods using examples from the Pangasinan Project, a cropping systems research project in the northern part of the Central Luzon Valley, Philippines.

In this paper, we emphasize the need for on-farm research, justify the adoption of a simple applied systems research method, and outline the steps used in the Pangasinan Project. Following these background sections, we describe results collected as the project evolved from the framework outlined in 1975. Only major points are highlighted, but complete research results are reported in the *IRRI annual reports* from 1975 to 1980 (IRRI 1976, 1977, 1978, 1979, 1980, 1981) and in other publications cited in this report. Methodological detail is given in the *Cropping systems research method handbook* (Zandstra et al 1981).

## THE NEED FOR ON-SITE RESEARCH

Cropping systems research methods were formulated to rapidly and efficiently develop improved rice-based cropping patterns that are within the capabilities of small farmers. Research results provide a basis for judging which of 3 adoptability classes cropping patterns or component technology will fall into: 1) technology that is within the management and resource limitations of small farmers and can be adopted without government programs; 2) technology that faces specific resource constraints, weak markets, or managerial deficiencies that limit adoption – information that assists agencies responsible for development projects and extension activities; and 3) technology that encounters problems which cannot be solved or that cannot be overcome by a program of resource augmentation, market development or support, or extension activities. Solutions to the last named problems require thorough research. They are therefore directed toward agricultural research institutions.

### The farm and community resource base

Farmers judge potential benefits from cropping patterns in relation to farm-household factors (family labor, power, cash flow) and community factors (contractable labor pools, credit sources, factor and product market characteristics). Conflicting demand periods for labor, power, or cash at either the farm or community level can make an otherwise attractive cropping pattern unacceptable for wide-scale adoption. Inputs that cannot be purchased locally at farm-level costs that are well below production potential will not be applied. Crops that local markets cannot absorb at profitable prices will not be widely adopted.

### Land evaluation and variability

Modern production methods introduced in many project areas have performed poorly because the advocated technology was unsuited to the site (Anden-Lacsina and Barker 1978, David 1978). Many surveys of physical resources such as soils, physiography, and climate have been conducted for agricultural purposes but because most have surveyed extensive areas, only general statements have been made about the production potential of broad land classes. Soil and climatic variability in the tropics is pronounced, however, and homogeneous agroecological zones in Southeast Asia are small. Because technology extrapolation across ecological boundaries is of questionable validity, on-site research within a zone is an essential support to agricultural development.

**Farmer participation**

Farmers have substantial indigenous agricultural skill and knowledge that can be effectively employed if a research program seeks their input (Howes and Chambers 1979). Furthermore, farmers have resource limitations they are not likely to exceed and, if research methods are properly formulated, farmers can provide an approximate test for the base resource limitation. To obtain reliable feedback, a genuine rapport with farmers must be established. Time and needed to strengthen this rapport.

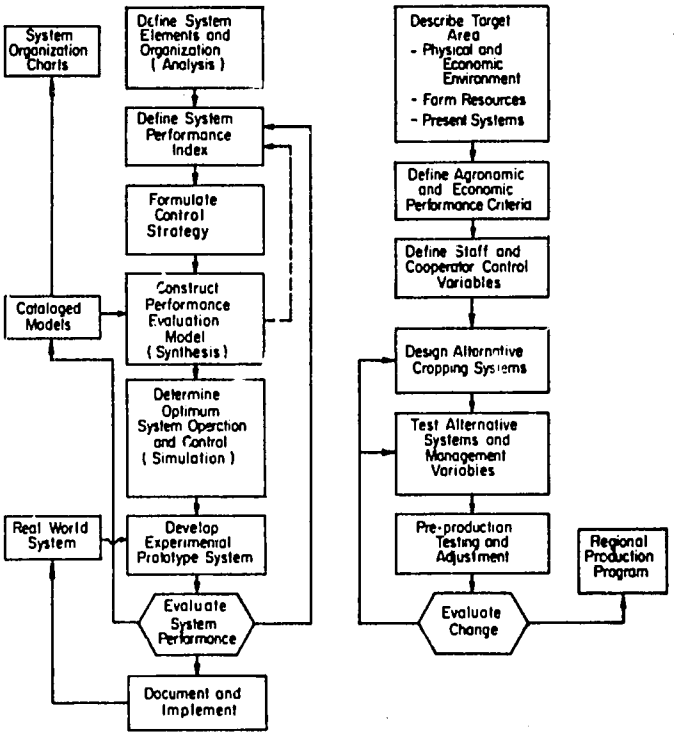
**Staffing limitations**

Administrators of national development agencies, being aware of environmental variability and conditioned by inconsistent performance of agricultural development programs, recognize the value of on-site agricultural research. However, qualified, experienced research personnel to staff projects are too scarce and expensive to consider for many applied research programs. Therefore, research positions in rural projects often are staffed by recent college or technical school graduates and it is necessary to introduce a structured approach to project implementation and research priority identification as a substitute for research experience.

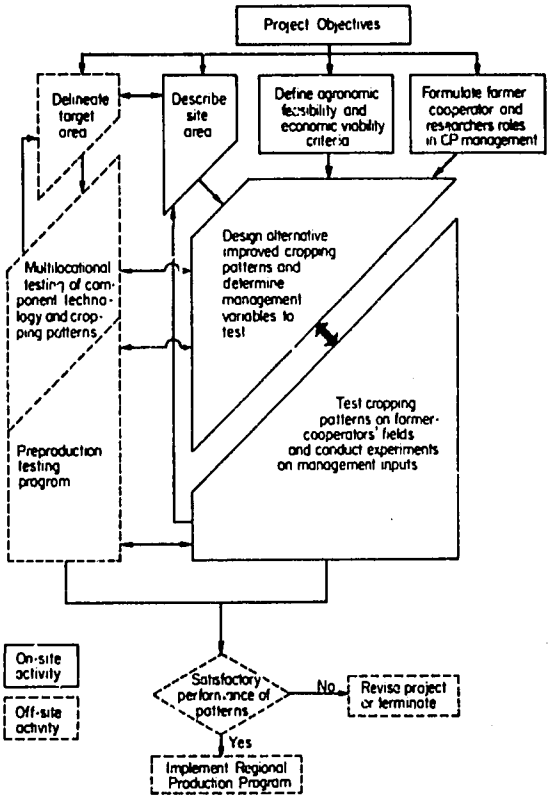
## CROPPING SYSTEMS RESEARCH METHODS

A systems research approach was adopted to structure cropping systems studies. Methods outlined at the 1975 Cropping Systems Working Group (CSWG) meeting were strongly influenced by applied systems research theory. Figure 1 shows the similarity between the applied systems research method described by Witz (1973) and the cropping systems research method outlined by the CSWG (CSWG 1975). A systems approach encourages scientists to comprehend the functioning system, not simply to describe the behavior of separate components. Key systems constraints to increased productivity are exposed by an examination of the entire system. To increase the overall performance of the system, research is directed at removing or reducing these constraints. Moreover, by serving as a frame of reference, a systems model also improves communication between multidisciplinary research units. Increased systems comprehension, refined research focus, and improved interdisciplinary communication are advantages of a systems research approach often stressed by proponents of systems methods (Witz 1973, Ebersohn 1976, and Wright 1971). Another advantage emphasized by Dillon (1976) is that systems research programs are goal-seeking and, therefore, have a problem-solving orientation. The problem-solving characteristic must account for much of the appeal that cropping systems research methods find in national agricultural research agencies responsible for supporting regional development projects.

The schematic version of the cropping systems research




1. Similarities of applied research methods described by Witz (on left) and cropping systems research methods outlined by CSWG (on right) (Witz 1973, CSWG 1975).




2. Cropping systems research methods in a regional program.

methods evolved from 5 years of testing is shown in Figure 2. Slanted box sides are used to indicate that many activities do not start or stop abruptly, but are phased in and out.

**Target area delineation and site description**

A target area is the extensive land area in which cropping patterns developed and tested at a site should be adapted. Land in the target area is classified by soil characteristics, terrain features, rainfall patterns, and irrigation water availability.

A site, usually 1 to 5 villages, is selected to represent typical conditions within the larger target area. Physical and socioeconomic features of the site area are described because cropping patterns must be designed to fit within the physical limitations of the environment and socioeconomic constraints of the typical farm within the site and the target area.

**Agronomic feasibility and economic viability criteria**

Farmers must be able to plant within the period specified in the cropping pattern design for it to be agronomically feasible, and yields must be sufficiently high and reliable to demonstrate that the crops are adapted to farm conditions. Consequently, planting and harvest dates and crop yields are important elements in a test of agronomic feasibility.

Size and dependability of profits determine economic viability. Although technical relationships between environment and crop husbandry may indicate agronomic feasibility, economic viability may not be achieved if product prices are not sufficiently high or production costs not sufficiently low to generate adequate profits.

**Researcher and farmer-cooperator roles**

For two reasons, researcher and farmer-cooperator roles must be well-defined in cooperative research with farmers. First, to assure smooth operations and timely management, confusion must be avoided; second, the contribution of both groups must be understood for interpretive purposes. For example, interpretation will be different between cases where the farmer provides land, draft power, and labor, and the project provides only seeds, fertilizers, and pesticides; and cases where the farmer provides only land. If the farmer provides only land, power and labor constraints may be completely removed by project resources.

**Designing alternative improved cropping patterns and determining management variables to test**

Cropping patterns are designed to fit crops into a cropping system without exceeding environmental or resource limitations. In the dry-wet tropics, to which rice is naturally adapted, the hydrologic growing year, as determined by field water regime, is the major limitation to crop production. Although field water regime depends primarily on rainfall, it is modified by terrain and irrigation. Other factors that govern agronomic feasibility, such as farm power limitations, and economic viability, such as product prices, are considered during the design phase. Traditional cropping patterns will be economically efficient; therefore, new patterns must include modern varieties that have higher yield potential, shorter field duration, or other attributes which would increase returns to farm resources.

In addition to crop variety, there are many practices to be specified for each crop in a cropping pattern. They include tillage and planting methods; rates, materials, methods, and times of fertilizer and pesticide applications; and weed management practices. Many practices can be specified based on local knowledge and general agronomic principles. To optimize management practices, especially those involving high cash or opportunity costs, separate field experiments often are needed. Field experiments replicated within or across fields, or both, are designed to study factors recognized as critical because of high costs or because crop performance is sensitive to the timing of an operation or to input levels.

**Testing in farmer-cooperators' fields and experimentation on management inputs**

By testing a cropping pattern in 5 to 8 farmers' fields each year for 3 to 4 years, data necessary to select agronomically feasible cropping patterns can be generated. Test data also are used to examine sensitivities to terrain features and variations in seasonal rainfall or pest regimes. Field experiments are conducted on selected management variables to determine the sensitivity of critical field operations, practices, inputs, and planting dates. The site staff culls unadapted patterns and refines input levels for each crop within a pattern at an annual workshop.

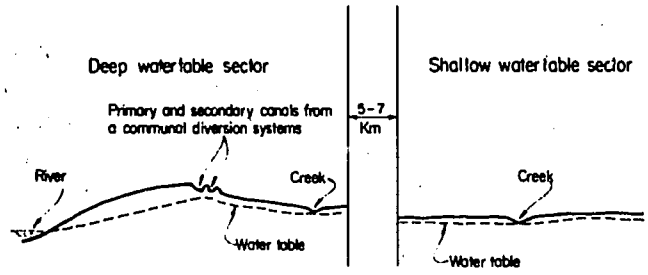
**Multilocation and preproduction testing**

Multilocation testing verifies the performance of cropping patterns throughout the target area, and helps adjust management input levels for differences between the site and other land classes found in the target area but not adequately represented at the site. Farmers are selected for the multilocation testing of patterns and components of patterns based upon land classes identified during target area delineation.

In preproduction testing, several contiguous villages are used to develop and test the organization of a project, which includes extension, marketing, and credit components (where needed), on a limited scale. The experience gained from this limited-scale study forms the basis for expanded coverage throughout the target area.

## EXAMPLES FROM THE PANGASINAN PROJECT

This section uses the Pangasinan Project to illustrate cropping systems research methods, concentrating first on research conducted for a specific pattern, then on site and




3. Schematic cross-section of Pangasinan project site area (Manaoag). No horizontal and vertical scale.

multilocation testing of an upland crop to follow rice.

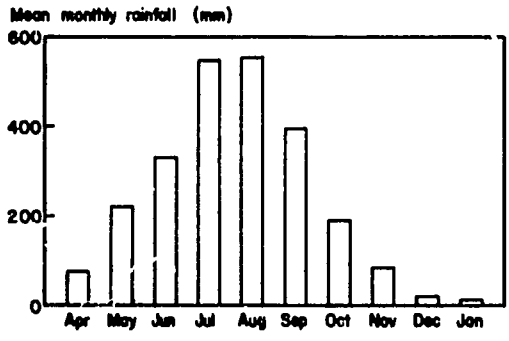
The Pangasinan Project, jointly conducted by IRRI and the Philippine Bureau of Plant Industry, in Manaoag township in Pangasinan Province, Central Luzon, illustrates cropping systems research methods. The project started in April 1975 and terminated in February 1980, although multilocation research is still in progress. Manaoag was one of three sites used to test research methods proposed by the CSWG; therefore, the methods were adjusted as experience was gained.

**Site and target area characteristics**

The general objective of the Pangasinan Project was to develop more productive and economically viable rice-based cropping systems for small-scale farmers in rainfed and partially irrigated sections of the northern part of the Central Luzon Valley. The research site consisted of five villages within Manaoag.

Soils were primarily eutropepts, with pH between 6.7 and 7.4 and clay loam texture. The Pangasinan land system is composed of flat plains and levees of an old alluvial deposit. The site area was divided into several land classes. The main division was based on deep versus shallow water table depths (Fig. 3). Water source was a second division.

The rainfall distribution at Dagupan City, a station with a long and reliable rainfall record, showed there were 5 months with more than 200 mm/month, 2 months which had mean rainfall exceeding 500 mm, and 6 months with less than 100 mm/month (Fig. 4).




4. Mean monthly rainfall for Dagupan City.

Areas with soils and rainfall patterns similar to those found in Manaoag are shown in Figure 5. The western and northern limits of the area were well demarcated by the sea and mountain ranges. The southern and eastern boundaries were not as well defined, being determined by gradual change in rainfall pattern and soils. Wet-dry season transition period rainfall was critical to pattern adaptation, and simple regression techniques were used to analyze short-term records to determine similarities between Manaoag and the 21 hydromet stations shown in Figure 5 (Morris and Rumbaoa 1980). To delineate soils similar to those found in Manaoag, soil types were grouped by textural profile, drainage class, and organic matter content (IRRI 1980).

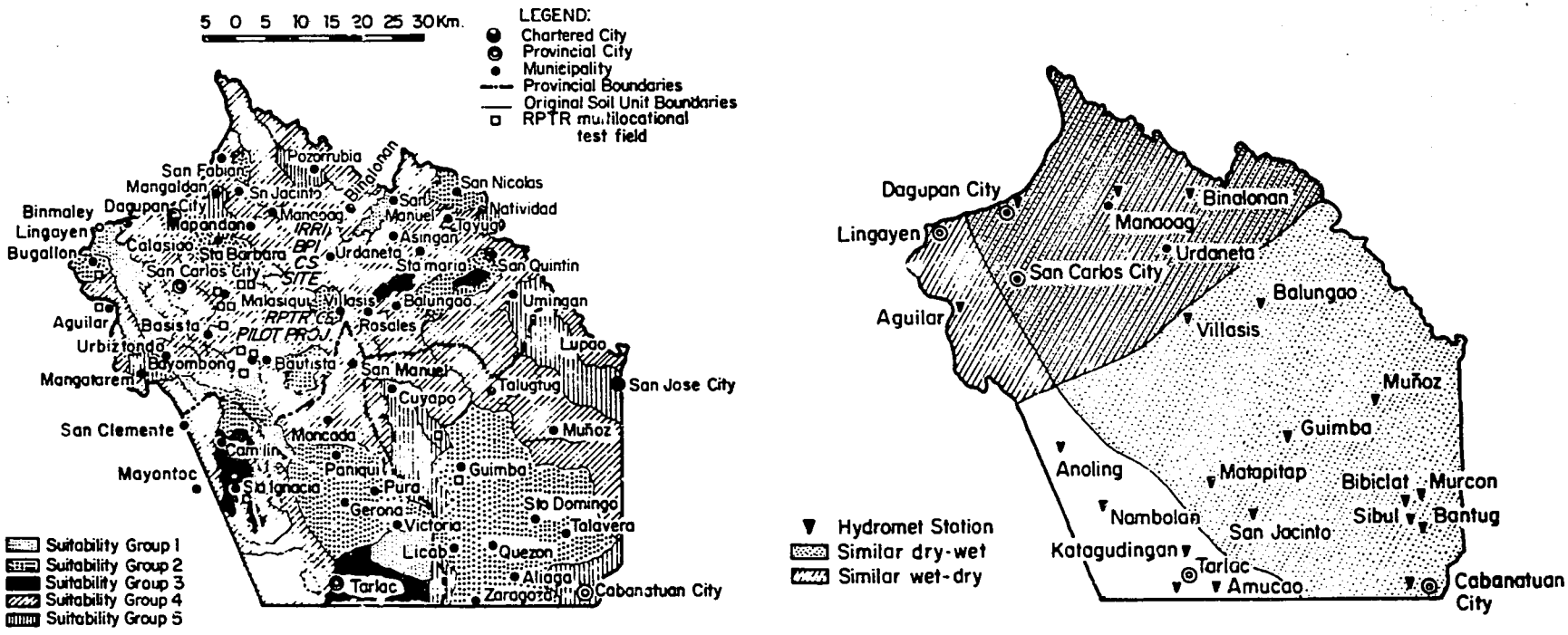
Most farms in the target area were small units operated by owners or share-tenants. Pangasinan Project cooperators were full-time farmers, chosen to represent the majority of farms in the area. They managed from 0.5 to 5 ha, and had either a draft animal or a hand tractor.

The land-use pattern shown in Figure 6 was typical of most of the rainfed area in the northern part of the Central Luzon Plain (FAC-PBS 1972). A single rice crop dominated the area, but in isolated fields, rice was followed by mungbean or other crops. In 1975, most rainfed land in the target area was planted to a single traditional rice crop each year. The crop was usually transplanted in July or August and harvested in November or December.

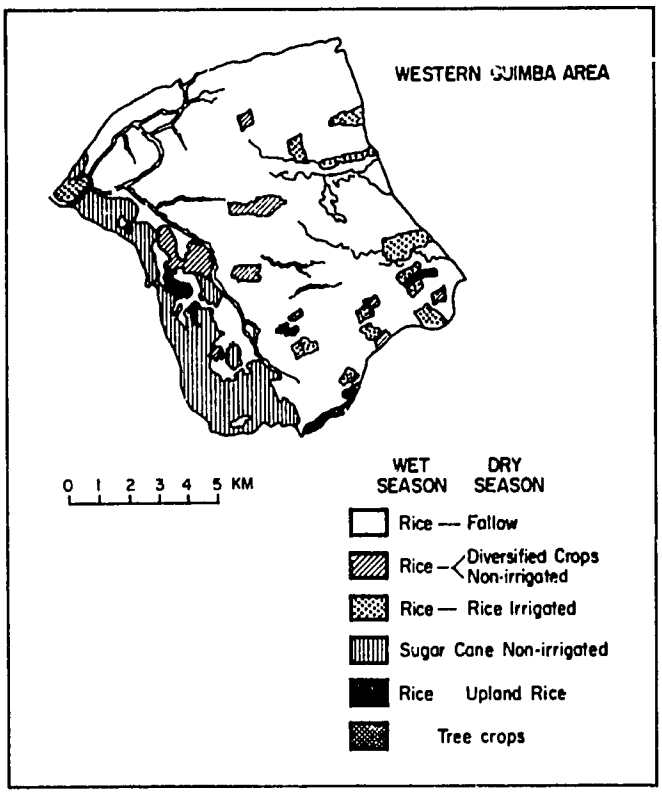
When cropping patterns were designed for the site area, water availability during the year was of key importance. Although the field water regime was recognized as being primarily dependent on rainfall, subsequent analysis confirmed that it was modified by landform and water table factors, and by a small communal stream diversion system (Morris and Zandstra 1978). The cropping patterns designed for 1975 and the patterns tested in 1978 are shown in Figure 7. Patterns found to be agronomically unadapted or economically unviable were eliminated as research progressed. Conditions under which the four patterns at the bottom of Figure 7 were judged most adapted are shown in Table 1. The sequence of three transplanted rice crops was adapted only in a limited area where water from shallow wells was available. Following 1978, the dry-seeded rice (DSR) - transplanted rice (TPR) - mungbean (MG) and DSR - MG patterns were included in the list of adapted patterns assuming that farmers could control weeds in the first crop. However, this assumption is known to be met by only a few skillful farmers.

**The dry-seeded rice - transplanted rice - mungbean pattern**

The DSR - TPR - MG pattern had wide appeal to cropping systems staff because, in the design phase, the DSR crop could be started with light sporadic rainfall early in the wet season, the TPR crop would grow late in the wet season,




5. Soil suitability groups (left) and areas with dry-wet and wet-dry season transitions similar to those of Manaoag (right) on the North Central Luzon Plain.



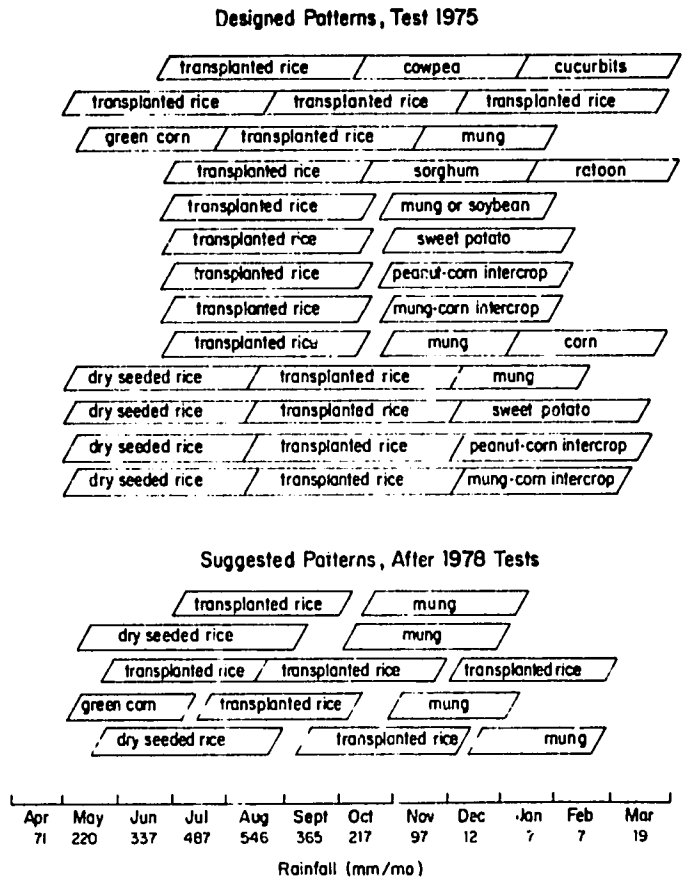

6. Land use map, Western Guimba area (FAO-PBS 1972).

and the MG crop would grow on intermittent rainfall and stored soil moisture. Because poor performance was frequently encountered in the testing phase, the pattern as a whole, individual crops in the pattern, and specific field operations were evaluated to identify constraints.

**Table 1.** Land characteristics to which 4 patterns are agronomically adapted.

| Field situation | Crop pattern[a] |
|---|---|
| *Deep water table* | |
| Rainfed | TPR - MG, DSR - MG |
| Partially irrigated (frequent delivery at end of wet season) (if DSR is established on rainfall by 25 May) | DSR - TPR - MG |
| Partially irrigated (one or two flush irrigations prior to wet season, and frequent delivery at end of wet season) | GC - TPR - MG or DSR - TPR - MG |
| *Shallow water table* | |
| Rainfed, all landscape positions | TPR - MG, DSR - MG |
| Rainfed, low landscape positions (if DSR is established on rainfall by 15 May) | DSR - TPR - MG |
| Partially irrigated (frequent delivery at end of wet season) (if DSR is established on rainfall by 20 May) | DSR - TPR - MG |

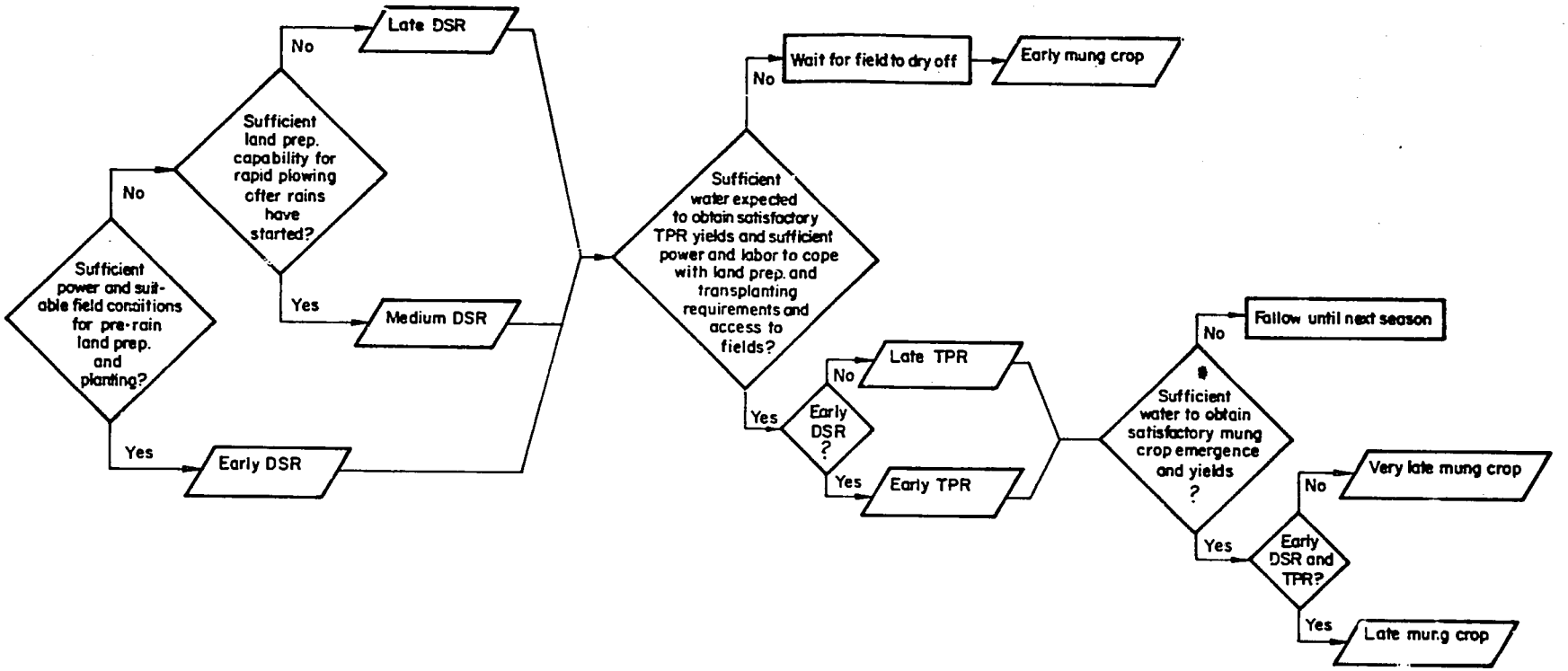
[a]GC = green corn (maize), MG = mung.




7. Cropping patterns tested in 1975 and suggested patterns after 1978 tests. Pangasinan.

Figure 8 shows the sequential decisions farmers must make as they proceed with cropping activities necessary for a DSR - TPR - MG pattern. In this diagram, decisions center on water and power availability. There are, of course, many other factors to consider, but for crops in this pattern, the major constraints were a low tillage-planting capability for the DSR crop, weed control in DSR, and water availability during the last half of the pattern. Early establishment of the DSR crop was the key to completing the full pattern. Alternative methods of tillage, planting, and weed control for DSR were tested. Most attention is devoted to DSR in this discussion, but selected aspects of TPR and MG management relevant to their performance in the pattern are discussed briefly.

*Dry-seeded rice.* The first attempt to dry-seed IR28, a 105-day variety, by 31 farmer-cooperators in 1975 failed, but researchers identified three constraints: 1) severe weed competition in the absence of soil puddling and standing water to aid early weed suppression, 2) incompatibility of tillage and planting techniques with dry field conditions and farmer's capability, and 3) retarded seedling development, caused by iron deficiency, on the high-pH soils common at the site.




8. Schematic diagram for determining which pattern (DSR - MG, DSR - TPR, or DSR - TPR - MG) will be planted in rainfed or partially irrigated fields. Philippines, 1978. DSR = dry-seeded rice, TPR = transplanted rice, MG = mung.

Because initial experiences were unfavorable, only five farmer-cooperators were willing to plant DSR in 1976. Field studies in 1976 on comparatively high-pH soils showed that IR36 was less prone to iron deficiency than the local traditional variety, IR28, and several other high yielding varieties (Fig. 9). The five cooperators who grew IR36 in 1976 had 6.2 t/ha average grain yield. After 1976, with few exceptions, IR36 was used in all experiments and test cropping patterns.

In 1977, 48 farmer-cooperators agreed to test the DSR - TPR - upland crop (UC) pattern, but only 16 of the 48 patterns were completed as designed. To determine UC adaptation, sorghum and cowpea were replacements for mung in about 20% of the designed patterns.

Because success was limited, data were examined to find reasons for the low completion rate. Of 48 farmers who agreed to plant the DSR - TPR - UC pattern, all farmers established a DSR crop and 32 transplanted a second rice crop. Of the 32, 16 planted the third crop, which was MG in 13 cases. Data analysis and discussion with cooperators suggested that four management considerations hampered pattern completion: 1) the DSR crop was delayed because land preparation could not be started until after rains began; 2) nonfarm and other farm activities competed for labor at critical times; 3) risks were high because of likely water shortages for TPR or UC or both; and 4) fields were inaccessible because intervening fields contained standing rice crops that draft animals would damage.

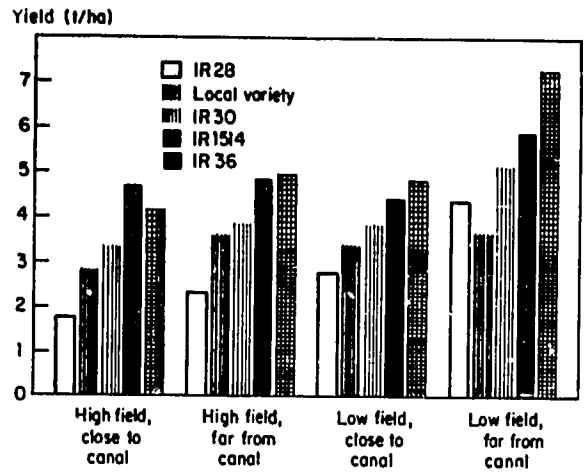
Analysis showed that planting early DSR was critical to the performance of later crops but that most farmers waited for rains before plowing and planting DSR fields, although when under research control, a DSR experiment was started before the onset of the wet season (Fig. 10). Figure 11 shows that 21 of 24 fields on which DSR was planted after May 31 deviated from the designed pattern, whereas 12 of 24 farmers who planted DSR on 31 May or earlier grew the complete DSR - TPR - UC pattern. Yields of the first, second, and third crops are listed in Table 2. Early-planted DSR crops yielded more than late-planted DSR crops, and DSR planting date also affected TPR and UC yields by determining the water regime under which they were grown.

**Table 2. Mean yields of DSR, TPR, and MG[a] by period of DSR seeding in designed DSR - TPR - UC patterns, 1977.**

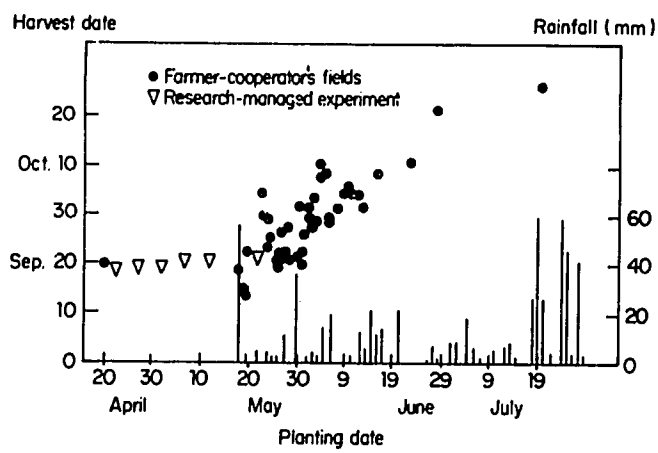
| DSR seeding | Rough-rice yield (t/ha) | | MG yield (t/ha) |
|---|---|---|---|
| | DSR | TPR | |
| 21 May and earlier | 5.3 | 4.0 | 0.36 |
| 22 May-31 May | 4.8 | 2.4 | 0.34 |
| 1 Jun and later | 4.1 | 1.5 | 0.00 |

[a]Thirteen of the 16 observations on the last crop were MG. Yields of cowpea or sorghum crops were converted to equivalent MG yields by comparing yields relative to the highest yielding 4 entries in cowpea, sorghum, and MG variety trials.

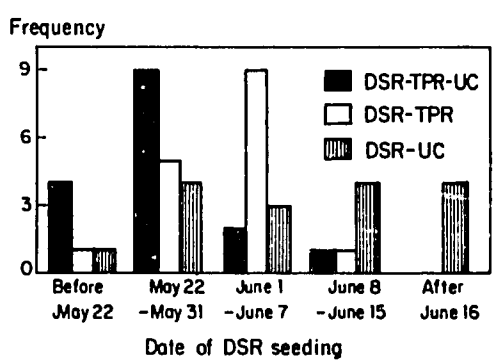
Discussions with cooperators suggested that when soils were dry, farmers could not meet tillage power requirements with draft animals. Follow-up studies in 1978 and




9. Rough rice yield of 5 rice varieties dry-seeded in 4 land positions.



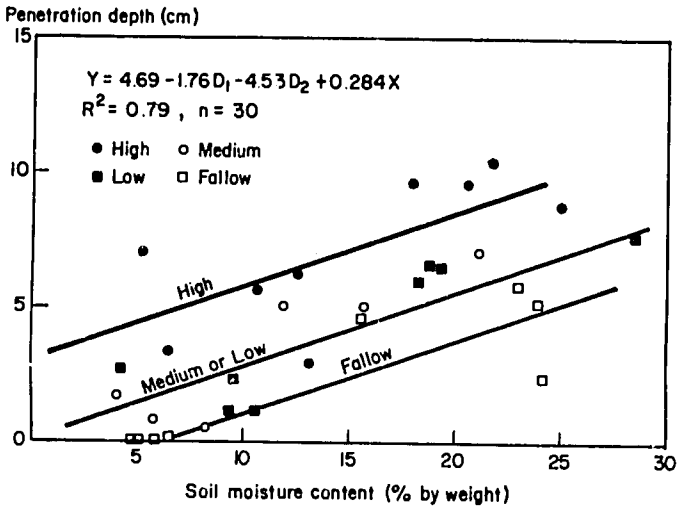

10. DSR planting and harvest dates in farmer-cooperator fields and in an experiment, and daily rainfall during the planting period, 1977.




11. Frequency of pattern completion by DSR seeding date for 48 farmer-cooperators who originally agreed to plant a DSR - TPR - UC pattern.

1979 showed that the power requirements often could not be met with a power tiller, and that large tractors using disk plows encountered steering difficulties, used excessive fuel, and left fields covered with large, harsh clods.

Fuel consumption data in Tables 3 and 4 show that tillage required less energy where medium or high tillage levels were used to establish the preceding MG crop. Other measurements showed that plowing was faster and that fewer large clods were left where a MG crop was grown before the DSR crop. Figure 12 shows that regardless of soil moisture,




12. The effect of soil moisture and preceding season tillage intensity on static-tip penetrometer depth (8 kg/cm²).

Table 3. Average power-tiller fuel consumption and penetrometer depth before and after tillage, as affected by tillage on previous MG crop, 1978.

| Tillage level on MG crop | Fuel consumption (liters/ha) | Depth (cm) of penetration at 16 kg/cm² | |
|---|---|---|---|
| | | Before tillage | After tillage |
| Fallow (after rice) | 44 | <1 | 4.6 |
| Low | 38 | 3.7 | 6.8 |
| High | 28 | 7.8 | 8.4 |

Table 4. Fuel use and operation time for disk-plowing with 4-wheel tractor for DSR as affected by tillage level of the preceding dry season MG crop, 1979.

| Tillage level on MG crop | Fuel (liters/ha) | Time (h/ha) |
|---|---|---|
| Fallow (after rice) | 90 | 5.9 |
| Light | 80 | 5.1 |
| Medium | 63 | 5.3 |
| High | 66 | 3.7 |

a penetrometer sank 3 cm deeper when tillage for the preceding MG crop had been high than when it had been medium or low.

Weed pressure on DSR was intense but it varied across fields and over years, which complicated standardization of control methods. Effects of previous cropping and field management between crops on weed incidence and on effectiveness of control measures were observed. For example, weed control trials in 1977 showed that to obtain highest DSR yields, a weed-free fallow period was superior to weedy fallow or MG production during the dry season (IRRI 1978). Butachlor followed by a hand weeding was more effective than butachlor or hand weeding alone. In 1978, however, an experiment showed that major yield losses occurred when the field had been kept weed-free instead of being planted to MG or leaving weeds uncontrolled during the dry season (Table 5). Grasses were four to six times as numerous in the field maintained as weed-free fallow than in the field previously planted to MG or left as weedy fallow after rice. Butachlor followed by hand weeding 21 days after emergence was the standard weed control practice for testing cropping patterns.

Although weeds were adequately controlled when chemicals and cultural techniques could be properly used, simple, economical, robust control practices for DSR were impossible to specify because weed regimes were sensitive to slight changes in environmental factors (landscape, weather, previous cropping) and the effectiveness of cultural and chemical control methods depended on rainfall.

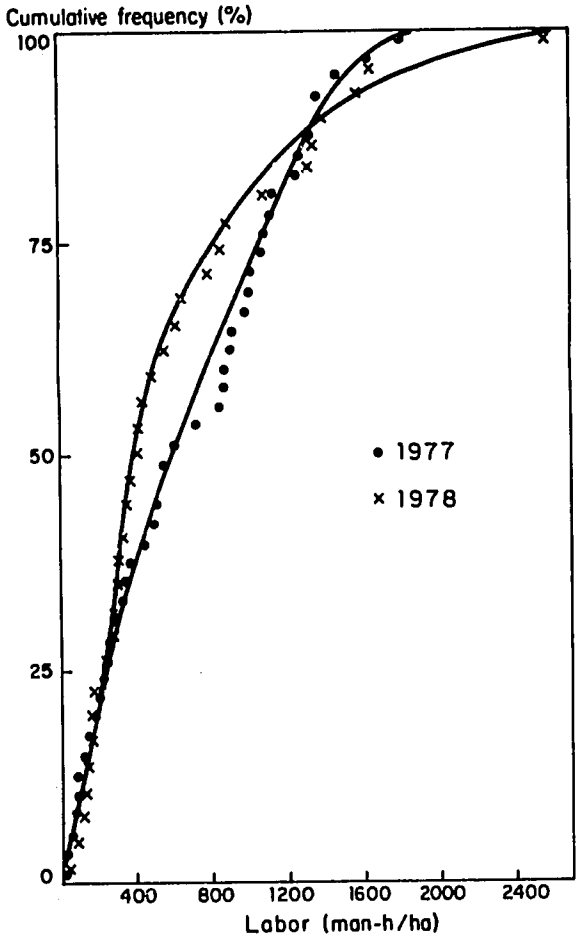
Cumulative distributions of man-hours/ha input in 1977 and 1978 by farmer-cooperators to control weeds are shown in Figure 13. Labor input was a function of the weed pressure in fields and therefore varied greatly and was not associated with final yield. Mean DSR yields were 4.5 t/ha in 1977 and 3.6 t/ha in 1978. By computing the costs of all inputs (labor, draft animal, seeds, chemicals), except hand weeding, and allowing for a 100% return to variable costs, the hand weeding breakeven points for an owner-operator were 1,180 and 618 man-hours/ha in 1977 and 1978. Even though the breakeven points were high, experience had shown that mobilizing and managing the equivalent of 500 man-hours/ha for weeding a test field of only 0.1 ha was difficult for cooperators. Routine use of this much labor on a 0.5-ha field would be nearly impossible to manage, and the increased labor demand would raise the prevailing wage rate.

Assuming a 2/3-1/3 tenant-landlord share crop arrangement, the breakeven points were 242 man-hours/ha in 1977 and zero in 1978. The low enthusiasm for DSR of farmer-cooperators confronted with this weed control task was understandable. Furthermore, under rainfed conditions, the yields from TPR and MG, which were forced late into the season by DSR, were low. Thus the pattern would not be economically viable because the benefits from the following

**Table 5. Effect of weed control practices and land preparation during the dry season on the yield of dry-seeded IR36 rice, 1978 (IRRI 1979).**

| Weed control method[a] | Rate[b] (kg ai/ha) | Rough rice yield (t/ha) in land previously | | |
|---|---|---|---|---|
| | | Weed-free fallow | Weedy fallow | Planted to MG |
| Butachlor fb hand weeding 21 DE | 2.0 | 3.0 | 4.8 | 4.4 |
| Hand weeded at 14 and 35 DE | – | 2.9 | 3.8 | 5.1 |
| Butachlor | 2.0 | 0.2 | 4.2 | 3.3 |
| Unweeded check | – | 0 | 2.5 | 2.0 |

[a]DE = days of emergence, fb = followed by. All herbicides were applied before crop emergence. [b]ai = active ingredient.




13. Cumulative frequencies of hand-weeding labor used by farmer-cooperators, 1977 and 1978.

crops would not compensate for the higher weed control costs in DSR. The DSR - TPR - MG pattern cost US$116/ha more than the TPR - MG pattern, but the additional net benefit was only US$11/ha. For this comparison, DSR - TPR - MG yields on the second row of Table 2 were used. For the TPR - MG pattern, yields of 4.8 t/ha and 0.9 t/ha

**Table 6. Dates corresponding to selected probabilities of received rainfall in Pangasinan (Morris and Zandstra 1979).**

| Rainfall (mm) | Onset dates | | |
|---|---|---|---|
| | P (0.2) | P (0.5) | P (0.8) |
| 50 | 13 Apr[a] | 21 Apr | 5 May |
| 75 | 17 Apr | 27 Apr | 11 May |
| 100 | 19 Apr | 1 May | 15 May |
| 125 | 25 Apr | 7 May | 17 May |
| 200 | 7 May | 19 May | 29 May |

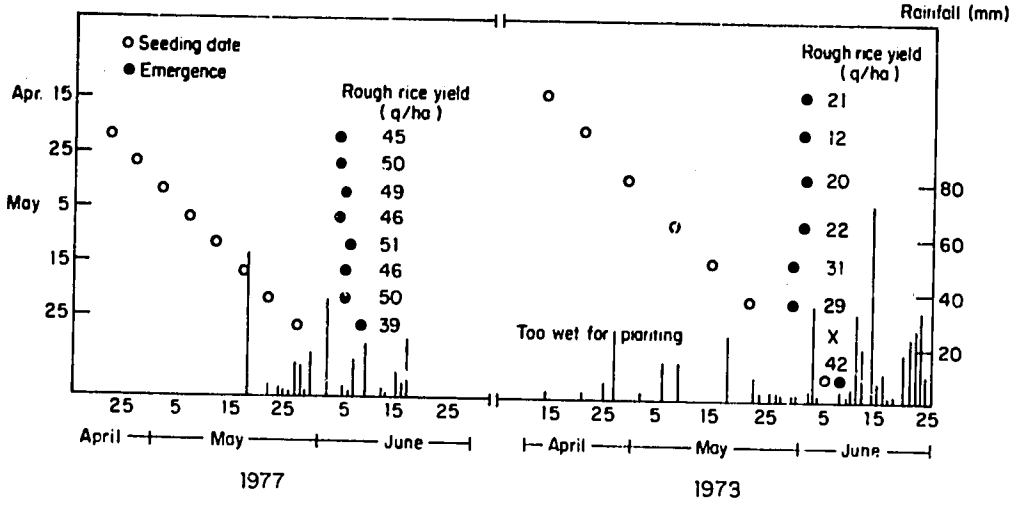
[a]The expected date by which the indicated rainfall will be accumulated, starting from 1 Apr.

were used. Even if weeds were easily controlled, the DSR - TPR - MG pattern was not economically attractive on rainfed land, although where partial irrigation would increase TPR and MG yields to 3.0 t/ha and 0.5 t/ha in the 3-crop pattern, marginal costs of the DSR - TPR - MG pattern were compensated twofold.

Because it was recognized that the date of wet season onset was variable but critical to field operations, long-term rainfall records from Dagupan City were used to derive empirical onset probabilities. The analysis showed that between 75 and 125 mm of rain accumulated by mid-May in 80% of the years (Table 6). In most but not all years, a large fraction of the mid-May accumulation came from one or two heavy rains.

Experiments to determine the effect of rainfall on seed emergence and crop yield were conducted in 1977 and 1978. In 1977 a 54-mm rain on 19 May initiated emergence, but early rains in 1978 were not adequate to produce uniform emergence or sustain early growth (Fig. 14). The 1978 results demonstrated that uneven emergence, low plant density, and poor yield can be expected when early rains are light and irregular.

Tillage, planting, and weed control experiments and rainfall analysis indicated that for early planted DSR to be agronomically reliable (to obtain satisfactory plant populations with weed pressures sufficiently low to assure yields greater than 3.5 t/ha in 4 of 5 years), farmers would need




14. DSR seeding dates, 90% emergence dates, yield and rainfall distribution, 1977 and 1978, Pangasinan.

the capacity to till and seed their fields after the first rainfall exceeding 20 mm but before soil moisture content exceeded the point at which aggregation would be destroyed when the soil is worked. Farmers with only a single draft animal and traditional implements lacked this capacity.

*Transplanted rice.* Traditional technology was the most effective and widely adapted practice for TPR. When TPR follows DSR, however, growth extends into a period of unreliable rainfall and encroaches on the optimum planting time for MG. Therefore, agronomic research on TPR emphasized tillage methods that would reduce the interval between DSR harvest and TPR transplanting and reduce TPR field duration.

Experiments to reduce intervals between crops and lower tillage intensity were conducted in Manaoag and IRRI. Conclusions from both locations were similar but, because of better water control, the experiment at IRRI provided more information (Table 7). To reduce the interval between crops and decrease labor inputs needed in the traditional plowing-harrowing method, a rototiller, a chemical weed control method, and a vaned-roller (an implement indigenous to northwestern Luzon) were used in the experiments. Use of 3-day rototilling or 3-day vaned-roller technique shortens the interval between crops and reduces labor without sacrificing yield.

The effect of seedling age on TPR field duration and yield was tested in an experiment at Manaoag under moderate water stress conditions. Planting 40-day-old seedlings reduced field duration by more than 2 weeks a yield sacrifice of 0.3 t/ha (IRRI 1979). By changing tillage operations to reduce the interval between DSR and TPR and by planting older seedlings to reduce field duration, the probability of late stress could be diminished.

Because water supply during October-November is important for TPR, the target area delineation activity was augmented to include an irrigation system classification component. Areas with irrigation regimes similar to the old

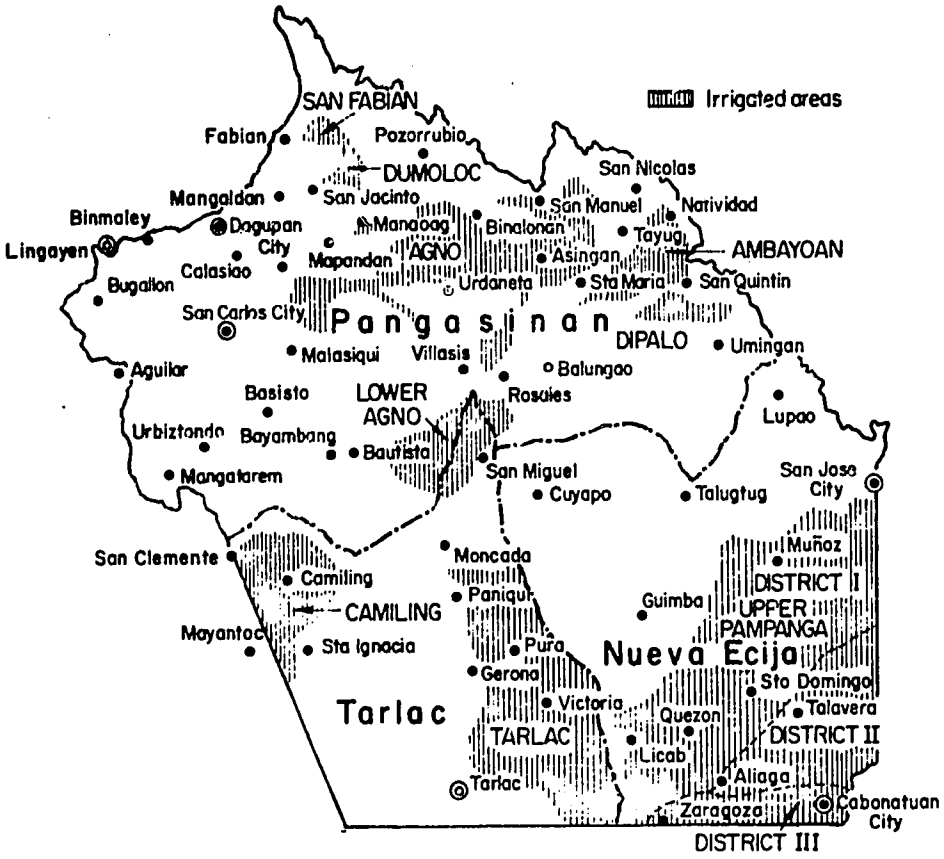
**Table 7. Effects of land preparation technique on tillage labor requirement and grain yield at IRRI, 1977 (IRRI 1978).**

| Land preparation technique | Labor (h/ha) | Grain yield (t/ha) |
|---|---|---|
| Traditional 1 plowing plus 2 harrowings during an 11-day period | 146 | 5.0 |
| Two vaned-roller passings during a 3-day period | 86 | 5.5 |
| Two vaned-roller passings during a 5-day period | 105 | 4.3 |
| Two rototiller passings during a 3-day period | 89 | 5.3 |
| Stubble cutting by hand plus 0.4 kg ai paraquat/ha during a 1-day period | 56 | 3.9 |

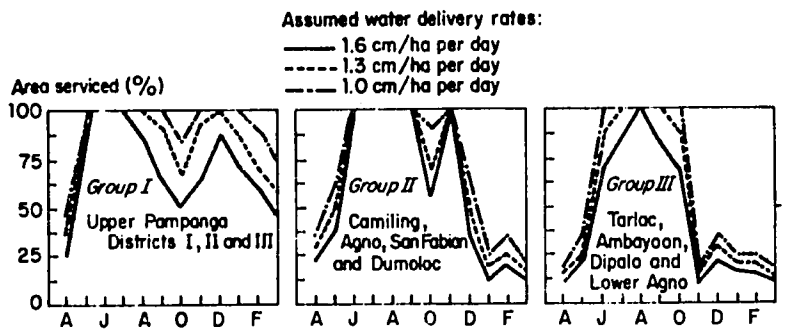
communal system found in parts of Manaoag were identified. In this system, water was delivered from July to November, but September to November deliveries became progressively less reliable.

Data were obtained from the National Irrigation Administration (NIA) for major river irrigation systems, and from provincial irrigation offices for the smaller communal systems. Gross area covered by seven major systems is outlined in Figure 15. Systems were divided into three groups based on delivery patterns. Estimated percentages of areas serviced by these groups are shown in Figure 16 for three assumed water delivery rates. In group I systems, deliveries were sufficient to provide a sequence of two or three TPR crops with reliable water. These areas are devoted to rice throughout most of the year.

In groups II and III, water deliveries shrink substantially as the wet-dry season transition progresses. Figure 16 indicates that TPR would fare better in group II than in group III systems, which have the most severe water deficits. Communal systems, of which there were over 350,




15. Areas covered by large National Irrigation Administration irrigation systems in the northern portion of Central Luzon Valley, Philippines.




16. Estimated percentages of areas serviced by the system during the year, North Central Luzon Valley, Philippines.

Table 8. Insect and weed control effects on MG yields, 1975 (Herrera et al 1978).

| Insect control[a] | MG yield[b] (kg/ha) Without weed control | With weed control[c] |
|---|---|---|
| Without | 660 | 680 |
| With | 1440 | 1690 |

[a]Carbofuran incorporated at planting, monocrotophos sprays at 10 and 18 days after seeding (DS), and methomyl sprays at 42 and 52 DS. [b]Means of 4 replications and 0 and 30 kg N/ha treatments. [c]1.5 kg ai butachlor/ha at planting followed by hand weeding at 15 and 30 DS.

were most often group III systems. The total area covered by group II, group III, and communal systems was estimated at 120,000 ha within the target area. About three-fourths of it was believed to be suitable for the DSR - TPR - MG pattern, provided other constraints could be overcome.

*Mungbean.* Of several crops tested after TPR, MG performed well in early planted trials that were chemically protected against insects. An exploratory experiment in the first year showed that when insects were controlled, an increase of 780 kg/ha was obtained (Table 8). Weed control increased yields significantly when the crop had been protected from insects, but not when insect control was absent. This exploratory experiment also showed that fertil-

izer applications were not necessary to obtain high yields, a fact subsequently confirmed by experiments repeated in six other farmers' fields.

Initial variety trials indicated that the yield potential of local varieties was not as high as that of selections from breeding programs. CES ID-21, an improved line used in all test fields after 1977, was particularly well adapted to the local environment (Carangal et al 1978). It had a green seed coat and large seeds, which made it acceptable in local markets and therefore to farmer-cooperators. The Philippine Seed Board subsequently released it as the variety Pagasa.

In 1976, entomology research in farmers' fields showed that both local and introduced varieties suffered severe yield losses caused by insects (Litsinger et al 1978). Losses were attributable mainly to flea beetle (*Medythia suturalis*), thrips (*Thrips palmi*), beanfly (*Ophiomyia phaseoli*), bean pod borer (*Maruca testulalis*), and gram pod borer (*Heliothis armigera*). Follow-up surveys, however, showed that farmers did not recognize that stand losses and retarded early MG growth were primarily caused by flea beetles and beanflies. From experiments repeated across six farmer fields, the contributions to yield losses caused by insects during selected crop development stages became clearer (Table 9). Using the results shown in Table 9 and from subsequent studies, effective and cheap preflowering and postflowering control methods were developed (Litsinger et al 1980).

Although effective and cheap preflowering and postflowering control methods were formulated, the entomologists also recognized that farmers, when they did use insecticides, applied from one-tenth to one-third of the required dosage (Litsinger et al 1978). Chemical concentration in the spray was low, as was spray volume per application. The low dosages presumably resulted from a combination of ignorance of what is needed, a desire to reduce costs, and reluctance to apply 400 to 1,200 liters/ha using a 20-liter knapsack sprayer. At 20 liters/load, 20 to 60 trips would be needed to obtain an adequate volume per hectare.

Provided that plant density was adequate, the combination of a variety with high yield potential and a simple, cheap, effective means of protecting the crop suggested that farmers should consistently be able to produce higher mung yields. Economic analysis showed that although material inputs increased cooperators' production costs by US$131/ha over the control group, the value of the crop increased by US$297/ha (US$425 vs US$128) (Lavapiez et al 1978).

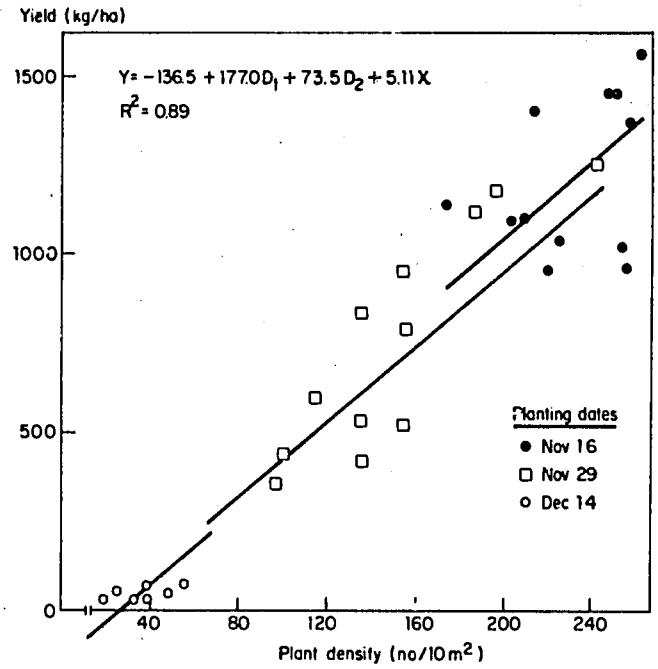
MG yields were high if plant density was over 200,000 plants/ha and if the crop was protected from pests and not subjected to severe stress. However, by late November or early December, the scheduled planting period for mungbean, the surface soil often was dry and establishment was a major constraint. Tillage and planting methods were compared under progressively drier conditions. Yield levels and plant densities dropped rapidly as planting was delayed, regardless of tillage or planting combination. Although some treatments within dates had slight yield advantages, Figure 17 shows that plant density differences between dates overwhelmed tillage and planting treatment differences within dates. Even in the 29 November planting, planting density was not consistently associated with planting technique or tillage.

Because emergence of a November or early December planting depended on the pattern of late rains, long-term rainfall records were analyzed. Computations of rainfall return periods showed that as the wet-dry season transition period progressed, the likelihood of receiving 25 mm in a 3-day period, an intensity regarded adequate for emergence from a previously dry soil, declined from 2 in 3 years for early November to 1 in 10 years for early December, thus reinforcing the significance of early DSR and TPR plantings and the potential contribution of partial irrigation.

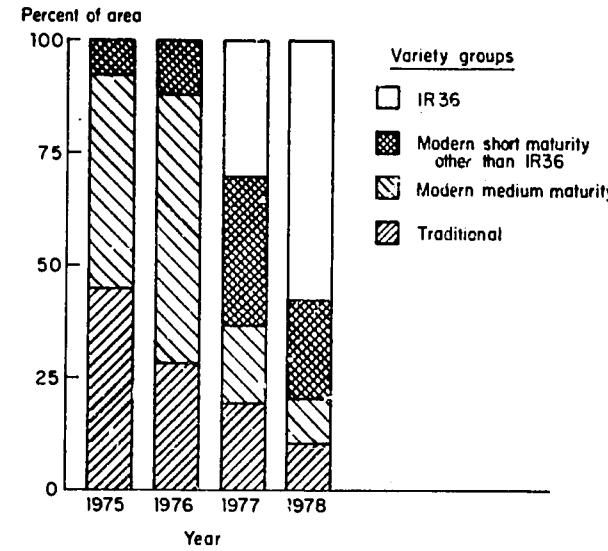
**Table 9. Insect control methods, costs and returns, and MG response to preflowering and postflowering insecticide treatments, 1976 (Litsinger et al 1978).**

| Treatment[a] | Flea beetles (no./10 sweeps) | Beanfly (% infested plants) | Damaged pods (%) | Yield (kg/ha) | Insecticide cost (US$/ha) | B:C[b] |
|---|---|---|---|---|---|---|
| Four applications (monocrotophos sprays at 5, 21, 35, and 45 DE) | 7 | 33 | 16 | 903 | 120 | 3.6 |
| Four applications (monocrotophos sprays at 5, 15, 25, and 35 DE) | 3 | 28 | 29 | 639 | 80 | 3.4 |
| Three applications (basal carbofuran, monocrotophos sprays at 21 and 35 DE) | 9 | 33 | 31 | 396 | 55 | 2.3 |
| No insecticide | 21 | 75 | 24 | 193 | – | – |

[a]DE = days after emergence. [b]Benefit-cost ratio, MG priced at US$0.60/kg.




17. The effect of planting date on plant density and grain yield of mung; X is plant density and $D_1$ and $D_2$ are dummy variables for 16 November and 29 November.




18. Changing percentages of Manaoag site rice area planted to traditional, modern short-maturity, and modern medium-maturity varieties.

## RESULTS OF THE PANGASINAN PROJECT

Based on 4 years of research, it was recognized that weed control reliability in DSR would have to improve for the DSR - TPR - MG pattern to be adopted under target area conditions. Farmers also would need greater tillage capacity to prepare and plant fields between the first rain exceeding 20 mm and before soil moisture exceeded the level at which tillage would cause puddling. Supplemental irrigation should be available so that severe TPR yield losses caused by late stress could be prevented and soil could be moistened to promote MG emergence and early growth when there is inadequate wet-dry season transition rainfall.

Without government programs to support major capital credit for tillage machinery and to modify the NIA irrigation systems, which were designed primarily for rice irrigation, a program to encourage farmers to plant the DSR - TPR - UC pattern would be hopeless. Even with a commitment to finance a credit plan and to modify irrigation systems, the overall operation and coordination requirements would exceed the capacity of existing local government agencies.

Although the vast majority of farmer cooperators rejected the DSR - TPR - MG pattern after testing it, virtually all farmers in the test area replaced medium- and long-duration varieties with the high-yielding, shorter-duration cultivar IR36 introduced by the project. Figure 18 shows that by 1978, IR36 was grown on 71% of the rice land as determined from records kept on a control group of farmers. Other short-duration varieties were planted on an additional 16% of the rice land. Because IR36 matured 20 to 60 days earlier than most varieties it replaced, farmers planted MG earlier. Rapid adoption of IR36 and Pagasa illustrated that sound technology requiring low cash outlays and no major improvements in technical skills will be adopted rapidly without credit programs or extension agency involvement.

As a follow-up to site research, multilocation testing was used to evaluate MG technology in three townships (Basista, Malasiqui, and Santa Maria) in the 1980-81 crop year (IRRI 1983). Superimposed trials and surveys supplemented multilocation trials. Regression analysis of yields across 24 locations confirmed the importance of early planting. In yield comparisons within fields, superimposed treatments showed that 70% of the 0.33 t/ha yield difference between researcher-managed and farmer-managed crops was attributed to insect control, and that the benefit-cost ratio was 1.9 for the insect control recommendation. Surveys, however, highlighted deficiencies in both extension agents' and farmers' knowledge of recommended control measures.

## CONCLUSIONS

Cropping systems research methods that evaluate limitations imposed by the environment and the farm resource base have been successful, as illustrated by the Pangasinan Project. Where components of patterns are economically viable, farmers adopt those components rapidly. When components are not compatible with physical, biotic, or socioeconomic factors, cooperative research with farmers in their fields helps scientists recognize field-level constraints.

**Table 10. Adoptability groups that emerged from the Pangasinan Project.**

| Adoptability group | | |
|---|---|---|
| Technology which does not need a government program to achieve adoption | Technology which will need government assistance to achieve adoption | Technology requiring improvement by research institutions |
| IR36 (as a TPR variety) | Extension focus on insect control methods for MG, with the objective of increasing efficiency | Weed control in DSR |
| Pagasa as a MG variety | Government extension and marketing agency support for cowpea and sorghum as alternatives to MG | Reduction of spray volume requirements for insecticides applied from a knapsack sprayer |
| Increased insecticide application frequency on MG | Government credit agency support to a tillage equipment purchase program to increase tillage capacity | Techniques and small-scale equipment to improve seedling emergence in the postrice environment |
| | Government irrigation agency management support to modify system operations for the irrigation of MG and alternative crops | |

Through DSR - TPR - MG pattern testing, the reliability of late, wet season rainfall was recognized as a physical constraint that was exceeded by the design; weed pressure on DSR emerged as a biotic constraint; and a limited capacity for rapid pre-wet season and between-crop tillage was a socioeconomic constraint.

Conclusions regarding adoptability groups for technology are summarized in Table 10. Within the site area the rate of farmer adoption for IR36 and Pagasa was high even without government programs. However, results showed that to improve insect control on MG, a focused extension effort, in which recognition of insects and insect damage during vegetative growth phases and effective insecticide application methods would be stressed, was needed to help farmers increase the effectiveness of the frequent insecticide application methods they have adopted. Given that a precondition of reliable weed control is satisfied – to achieve timely DSR planting after the first rain, a critical step toward obtaining high yields from all crops in the pattern – tillage capacity must be increased by mechanization. The weed control precondition would also apply to attempts to regulate irrigation water and to organize farmers to comply with schedule demands of the DSR - TPR - MG pattern. Results indicated that although cowpea and sorghum were as well adapted as MG, if they are to be grown government action would be required to overcome weak local markets.

On-site research has identified farmer problems for research institutes. As a result, weed control research for DSR has been increased and related weed ecology studies have been initiated, systemic insecticide seed treatment and low-volume insecticide application equipment are being tested for MG, and planting techniques involving small-scale equipment are being evaluated to improve the reliability of DSR seedling emergence and MG emergence in the postrice environment.

As illustrated by this paper, if a cropping systems project receives proper staffing and logistical support, and the methods are rigorously implemented, tests of alternative cropping patterns and component technology will strengthen development programs by identifying technologies that will require government support via extension, marketing, or credit programs before adoption becomes widespread and will strengthen research programs by identifying factors limiting system performance and on which problem-solving research is necessary.

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