Constraints to high yields on Asian rice farms:

an interim report

THE INTERNATIONAL RICE RESEARCH INSTITUTE

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Foreword

Generally, the average rice yields achieved on farmers' fields in Asia are lower than those commonly obtained in experimental plots. Even in areas where the adoption of modern varieties is relatively high, farmers' rice yields are often lower than the known crop potential. The International Rice Agroeconomic Network (IRAEN) was organized in 1974 to allow cooperating scientists from six Asian countries to identify and study factors constraining rice yields on farmers' fields. Interdisciplinary teams of agronomists, economists, and statisticians in each country focus on both biological and socioeconomic constraints.

Standard research methodologies were developed at a workshop at IRRI in April 1974, by the scientists from Indonesia, Thailand, and the Philippines who conducted the field investigations. The cooperating scientists participated in a subsequent workshop held in November 1974 at IRRI. They invited scientists from other countries to participate in the third workshop at Bangkok in March 1975.

The workshops produced the design and set the procedures for collaborative field research trials and studies, which include work at three sites in the Philippines, two sites in Indonesia, one-site each in Thailand, Taiwan, Bangladesh, and Sri Lanka. A November 1976 workshop, in Yogyakarta, Indonesia, provided IRAEN cooperators a forum for presenting and evaluating the results of their field investigations. This report summarizes the results of the field studies.

There have been several major accomplishments of the project to date.

- A workable methodology for identification of constraints has been developed and applied by seven different groups of researchers in six countries.

- Constraints that have been identified are receiving increased attention from researchers; for example, effective rice insect protection.

- In Indonesia, officials of the BIMAS, a "mass guidance" extension program, have sought information from the IRAEN group on how to diagnose problems.

- Direct contact and interchange between agronomists and economists have been fostered in all cooperating groups. Agronomists have learned how economic forces affect farmers' use of technology. Economists have learned about the production problems faced by rice farmers. This knowledge may help in designing future technology better adapted to farmers' conditions.

- The international exchanges have given participants from the network countries a better appreciation of their own problems.

Research following the pattern discussed in this volume will continue in the cooperating countries through 1977. After, each group will be encouraged to summarize the results of their several years of experience. Thus, the papers in this volume represent progress reports on a continuing research effort.

The International Rice Research Institute is pleased to have the opportunity to participate in the IRAEN constraints studies. The results reported herein can have significant effects on both the research goals of IRRI and on national research programs.

The International Development Research Center (IDRC) of Canada provided funds to support part of the research and to catalyze the overall network activities. The balance of the needed funds and resources were supplied by institutions collaborating within IRAEN.

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ON-FARM ASSESMENT OF YIELD CONSTRAINTS: METHODOLOGICAL PROBLEMS

Kwanchai A. Gomez

ABSTRACT

Major consideration and methodologies for assessing yield constraits in the IRAEN project are briefly presented. Problems encountered during the first two years of the project are discussed, and, whenever possible, solutions are suggested.

BASIC CONCEPTS, OBJECTIVES, AND APPROACH

The IRAEN yield—constraints study was primarily motivated by the fact that yields in farmers' fields are much lower than those obtained at experiment stations. The difference between experiment station yield and actual farm yield is referred to as yield gap and the factors responsible for it as yield constraints. The conceptual model used in the IRAEN project is shown in Figure 1. The key points of the model are

1. Instead of comparing the actual farm yield directly to the experiment station yield, a yield level intermediate between the two is introduced. That yield level is called the potential farm yield and is the yield obtainable in a farmer's field from the improved rice technology.

   The yield gap is thus divided into yield gap I, which corresponds to the difference between experiment station yield and potential farm yield and yield gap II, which corresponds to the difference between potential farm yield and actual farm yield.

2. Yield gap I is hypothesized as caused by either the environmental differences between the experiment station and farmers' fields, or by nontransferable technology; i.e., some aspect of high yield technology developed at experiment stations that does not produce high yield under actual farm conditions, or both.

3. Yield gap II is caused by biological and socioeconomic constraints. Biological constraints refer to the nonapplication of needed production inputs and the socioeconomic constraints to the social or economic conditions that prevent farmers from using the recommended

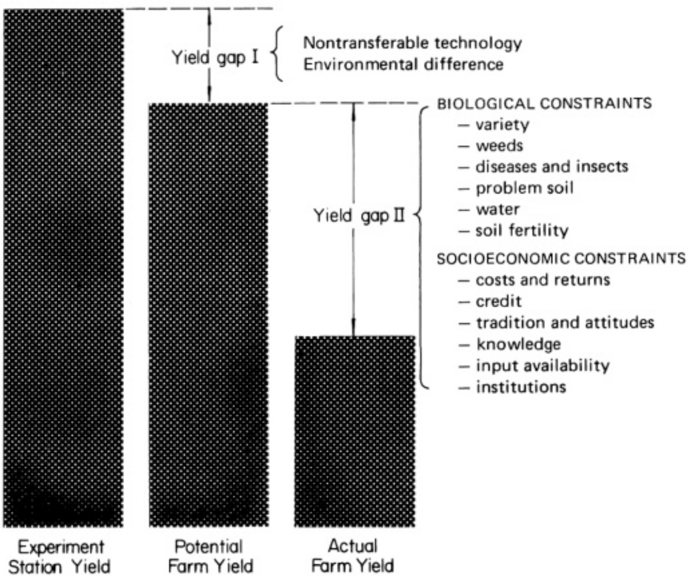

Fig. 1. Conceptual model explaining the yield gap between experiment station yield and actual farm yield.

technology. For example, a biological constraint might be that farmers are not applying enough fertilizer and the corresponding socioeconomic constraint is the lack of credit to buy fertilizer.

Study objectives

The objectives of the IRAEN yield constraints study are to measure yield gap II, to identify and quantify the major biological constraints responsible for yield gap II, and to identify the major socioeconomic constraints responsible for the existence of the biological constraints.

Note that although it is not the objective of the IRAEN yield constraints study to pinpoint the specific constraints responsible for yield gap I, it provides for the assessment of the size of yield gap I. If yield gap I is sizeable, a separate study may be initiated to identify the corresponding constraints and remedial measures.

To achieve the study's objectives, an integrated experimental and survey approach is used. The approach calls for the conduct of both field experiments in farmers' fields and farm surveys. Hence, a research team is usually composed of both agronomists and agricultural economists, and at times, statisticians, *Field experiments and treatments*

The field experiments are done in order to accurately estimate the potential farm yield, the actual farm yield, and the intermediate yield levels representing varying combinations of input use. Two sets of treatments are tested in the experiment, the factorial component and the management packagecomponent.

Factorial component. Treatments consist of either complete or incomplete factorial combinations of n factors (or production inputs) each at two levels. The factors included in the test are those that researchers hypothesize to be the major causes of low yields on the farms. The two levels of each factor are (i) the farmer's practice, and (ii) the improved practice. The farmer's practice refers to what the farmer is actually doing in the current crop season, and it will vary from one farm to another. The improved practice is the one recommended for maximum yield, and it should be fixed for all farms in a given location.

The factorial component supplies data on actual farm yield, potential farm yield, and varying yield levels resulting from a systematic withdrawal of one or more of the inputs. These data are used to estimate the yield gap (i.e. yield gap II of Fig. I) and the individual contributions of the n test factors to the yield gap. The precision of the yield gap estimate depends greatly on the choice of the test factors. As the number of test factors increases, the more accurate is the estimate of potential farm yield and consequently the better is the estimate of yield gap. However, the more test factors there are the more complex the experiment becomes. Hence, the test factors must be chosen carefully to include only the most important ones.

Management package component. Treatments are designed to represent intermediate levels between the farmer's set of practices and the improved or recommended set of practices. The incremental steps between treatments usually involve a simultaneous change in more than one input.

The management package component tests the different input combinations selected to represent different yield levels and production costs. This test does not measure the contribution to the yield gap of a particular input (as is possible with the factorial component), but it allows a meaningful look at the question of costs and returns for each management package. Moreover, one or more management packages could be good candidates for immediate recommendation to farmers.

Experimental technique. The specification of the improved level of each test factor, as well as of the management packages, is done prior to the start of the experiments. The farmer's level of each test factor, on the other hand, is usually not known in advance; but is obtained through observing what each particular farmer does throughout the cropping season. Because farmer's practices can vary from one paddy to another even on the same farm, the technique of comparable paddy is used to facilitate the identification of farmer's level. That is, the same paddy where the experiment is located, or a nearby paddy, is chosen as the comparable paddy prior to the setting up of the experiment. The specified level of test factors used by the farmers in the comparable paddy will be used as the farmer's level.

In the experiment, all other management practices and cultural practices besides the test factors are the same as that of the farmer in whose farm the experiment is located, and as much as possible they are managed by the farmer in the same manner as that for the rest of his farm.

For the field test of each farm, the data collected include grain yield, insect and disease incidences, weeds incidence, rat damage incidence, and water condition.

In addition to records of the farmer's level for each test factor, all other management and cultural practices of the farmer are recorded. When possible, data on physical environments (climate and soils) of the farm are also gathered. Such information is useful to explain the difference in potential farm yields and the difference in yield gaps over farms, seasons, and years.

Surveys

The farm—surveypart of the study (a) supplies preliminary information pertaining to the probable farm practices that need to be improved in order to get higher yield, (b) expands the area of coverage from that possible through field tests, (field experiments are relatively more costly to conduct and thus are not expected to cover a sufficiently large area in any target area) and (c) describes the socioeconomic conditions of the farms (such as age, sex, education, employment of household members, farmers' attitudes and perception, and existing farm practices) and related economic environment (such as marketing, prices of inputs and produce, input suppliers, and credit opportunity). Such information should explain why the inputs required for high yields were not applied by farmers.

Two separate surveys, namely, preliminary survey and follow—upsurvey are undertaken. The interview method is used to obtain the required information, except possible for the determination of yield level, where the crop—cutting technique is employed when the interview method is deemed inaccurate.

The preliminary survey is done prior to the establishment of experiments. It obtains general information in the study area on the farm sizes, tenure status of the farmers, farming practices, productivity level, technology awareness, irrigation facilities, credit and labor availability, and prices. Such information serves as the basis for arriving at (a) a hypothesized set of production constraints to be used as test factors in the experiment and (b) a sampling design for the selection of experimental farms and sample farms in the follow—upsurvey. Size of the preliminary survey questionnaires is generally small so that a larger number of farms can be covered.

The follow—upsurvey is done at the end of the particular crop season in which the experiments were conducted. Information pertaining to that crop season generally taken are

- variety grown,

- farmer's management and cultural practices,
- yield,
- farmer's perception of factors that limited the yield and the remedial measures, if any, taken,
- cost of individual inputs and price of palay.

Analysis of data

Analysis of experimental data includes estimation of yield gap, examination of interaction effects, if any, among test factors, and assessment of contributions of each test factor to the yield gap.

Analysis of both experimental and survey data includes (a) costs and returns analysis on the differement management packages as well as on the varying factorial input combinations to determine the relative costs and returns of each management package or of each test factor, and (b) a comparison of the farmer's level and the economically optimum level of input use. If the difference is appreciable, factors causing the difference, such as farmer's perception, credit, labor and input availability, and technology know—how,are examined.

A SURVEY OF METHODOLOGICAL PROBLEMS

Since the inception of the IRAEN project in 1974, participants in the Philippines, Thailand, Indonesia, Sri Lanka, Bangladesh, and Taiwan have adapted, modified, and tested the IRAEN approach. I attempt in the succeeding sections to describe the different procedures used and the problems encountered by the participating countries. The sequence of presentation will follow the various steps involved in the IRAEN approach. The references listed in Appendix I to this paper served as background material. The IRRI Library has a copy of each reference.

Identification of study area

Depending on the objective of the study, there could be two alternative procedures in identifying study area,

1. Constraints causing low yield in a specific region are of interest. An example of a problem region selected may be one where yields are low despite the high rate of adoption of improved varieties.

2. Constraints causing low yield for the whole country are of interest. In this case, the area of coverage is larger and more diverse and, hence, a larger set of test areas needs to be included.

The problems for implementing the first case are few. The area is relatively small and the required number of test sites is usually within the capabilities of the researchers. In the second case, however, the large area and the diversity of environments necessitate the inclusion of a large number of test sites which is usually beyond the resources available in any one research organization.

For most of the participants of IRAEN, the second case seems to be the more common objective. As expected, the number of test sites included in the study is usually too small for adequate national coverage. Consequently, the interpretation of the results is appropriate only for the limited study area rather than for the whole country. In most instances, however, the participants have generalized their findings to the whole country despite the limited areas covered. This problem is further aggravated by the selection of study areas based on practical considerations, such as accessibility and farmer's cooperativeness.

Selection of sample farms (for experiment and for surveys)

Three sets of sample farms need to be selected -- for the preliminary survey, for the experiment, and for the follow—up survey. The preliminary survey usually covers the largest number of sample farms, which are selected through a simple random sampling scheme. Based on the result of the preliminary survey, a stratification criterion can be devised for selecting the farms both for experiment and for follow—up survey. Some stratification criteria used by IRAEN participants are water condition, distance to the market or to the input suppliers, tenure status, and farm size. To assure a proper linkage between the two sets of farms, it is essential that the sample farms for the experiment be a subsample of those for the follow—upsurvey.

The major problems in the selection of sample farms for the experiment and follow—up survey are

1. Due to the usual separation of responsibilities between the agronomists who conduct the field tests and the agricultural economists who conduct the surveys, the selection of farms for the experiment is generally done independently of that for surveys. This has often resulted in the nonrepresentativeness of the experimental farms to the rest of the farms in the study area.

2. To facilitate field experiments on the farms, accessibility to roads and willingness of farmers to cooperate are frequently used as major criteria for selection, Furthermore, a common tendency is to choose "good" farms, such as those with adequate irrigation facilities, so as to give high potential yields. In both instances bias could easily affect the experimental findings.

3. Because conducting field experiments in farmers' fields is more difficult and more expensive than the survey, the number of farms used for the experiment is usually too small to adequately represent the widely different farming conditions existing in the study areas. Most agronomists responsible for the field tests have the tendency to emphasize the need for more replications at the sacrifice of the requirement for more farms. There is also a tendency to include too many test factors (so as not to miss any major ones), resulting in large experiments and, consequently, fewer experimental farms. Because of familiarity with experiment station trials, there is a tendency to follow the same method of management and data collection. Thus detailed and time—consuming attention is given to each farm making it difficult to cover more farms.

4. One of the more commonly used sampling scheme is a stratified random sampling with sample size proportional to the stratum size. In such a case, each stratum is not equally represented in the sample so that if the researchers wish to test for differences among strata, the number of observations in one or more strata may not be large enough to give reasonable accuracy to the stratum estimate.

Experiments during and plot layout

For experiments in farmers' fields it is desirable to keep the size of the experiment small and the design and plot layout simple.

Design. In a yield constraints study, there are two major sources of variation -- variation among farms and variation within farms. The use of several farms takes care of the first, and replication within a farm takes care of the second type of variation.

Between the two major sources of variation, that among farms is expected to be larger. Consequently, emphasis should be placed on assuring that a sufficient number of farms is included rather than in having a large number of replications per farm. When enough resources are available or when researchers are still not familiar with these studies, the use of two replications may be warranted. In other cases, a partial replication may be all that is needed.

To maintain a reasonable size of experiment, the choice of treatments to be tested is crucial. Too many treatments increased the size of the experiment unnecessarily and too few treatments could result in a worthless experiment.

For the management package component, four to five packages are usually tested. For the factorial component, on the other hand, the number of specific treatment combinations to be tested constantly poses problems to the researchers. First, the decision must be made on the number of factors to be tested. Then a decision on whether to use a complete or incomplete factorial combinations of the test factors must be made.

Four criteria commonly used for including any factor as a test factor are (a) it is expected to be a major yield constraint, (b) the technology involving that particular factor is well established, (c) it is needed for the success of another test factor, and (d) its inclusion as a test factor does not unduly complicate the conduct of the experiment. Some factors such as water management, for example, are not suited for inclusion as test factors in the experiment.

The number of test factors is usually between three and five. The four most commonly used test factors among IRAEN participants are insect control, fertilizer application, weed control, and land preparation. Judgement as to whether a proper choice of test factors has been made should be made at the end of the test. This is done by (a) judging whether the potential farm yield is sufficiently high (if not, other factors not yet included should be examined), and (b) the relative contributions of the test factors to the yield gap. (A test factor giving negligible contribution may be replaced by a new one.)

A complete factorial treatment combination usually requires a larger number of treatments than an incomplete one. The complete factorial is necessary if the assessment of all interaction effects among the test factors is desired. A complete factorial experiment is generally used in the first year. Information on interaction effects obtained is then used to decide on an appropriate set of incomplete factorial treatments to be tested in the succeeding years:

For cases where interaction effects are not expected to be appreciable, the mini—factorial design can be employed. In this design, the number of treatments to be tested is always two more than the number of test factors. For example, if there are three factors to be tested, namely, insect control, fertilizer, and weed control, there will be a total of five treatments to be tested (Table 1).

Table 1. A "mini—factorial" design for studying yield constraints in farmers' fields, involving three test factors: Fertilizer, insect control, and weed control.

Treatment no.	Input levels		
	Fertilizer	Insect control	Weed control
1	R	R	R
2	F	R	R
3	R	F	R
4	R	R	F
5	F	F	F

R - recommended level; F - farmer's level

Plot layouts. The choice of a specific plot layout to be used depends on

- whether plots used are with or without levees,
- whether the farmer's level is simulated by the researchers or actually implemented by the farmer,
- whether one or more of the test factors require a special plot arrangement, e.g. application of high level and low level of insect control in adjacent small—sized plots is expected to bias the effect of insect control.

Test factor choice. In most cases, not enough thought is given to the choice of test factors. The major yield constraints are expected to vary from one area to another, but the uniformity in the choice of test factors among the IRAEN participants is surprising. This may account for the relatively small yield gap detected in some cases. Furthermore, a critical evaluation and judgement as to the proper choice of test factors seems lacking.

Correct design. In some cases, a randomized complete block design is used even when test factors such as insect control is included. In such cases, a design such as split—plotmay be more desirable because it allows for greater separation of plots receiving different levels of insect control.

Simulation of farmer's practices

There are two important concepts in the IRAEN approach to the yield constraints study that differ significantly from most experimental research

1. The improved technology is being compared to the farmer's level and not to the zero level. There is more interest in finding out what improvement can be made over that of the farmer's inputs rather than in studying the effects of various inputs per se. For example, while you may be convinced that proper weed control is better than no weeding, you do not know whether proper weed control is better than the farmer's method (which probably is not a no—weedingcondition) under his own environment.

2. The comparison (or test) is made within each farm. While both physical environment and production practices affect yield, it is the changes in the latter that should be undertaken first. In other words, it is the fitting of technology to a given physical environment that is emphasized rather than the changing of the environment itself. Hence, by comparing within a given farm, the difficulty posed by the differences in the physical environments among farms is avoided.

The key ingredient in achieving the above two concepts is to establish and implement the farmer's level of each test factor in the experiment. The farmer's level is expected to vary from farm to farm; and, hence, the establishment of the farmer's level must be done separately for each farm. Moreover, it should not be determined based on what the farmer says he will do but what he actually does. This indicates that a fair amount of follow—upis needed to obtain an accurate determination of the farmer's level. Some of the problems encountered in the establishment of the farmer's level and in its implementation in experimental plots are discussed below.

Variables practices. The management and cultural practices may not be uniform throughout the farm. Thus, it is not clear as to which of the many levels employed by the farmer the researcher should follow. To remedy this situation, the comparable paddy technique is usually followed. (The technique is discussed above in the section on field experiments andtreatments.)

Marker technique. The constant follow—up on the farmer's activities concerning the test factors is time consuming. Furthermore, frequent inquiries and visits by the researchers could be a nuisance to the farmer. As a remedial measure, a marker technique is used. The technique involves placing distinctive markers (bamboo sticks with different colors painted at the tip of each stick) at the corner of the comparable paddy. The farmer turns the marker upside down whenever an operation concerning one of the test factors is performed. That signals the researcher to contact the farmer for necessary information on the specific operation.

Farmer applied inputs. There are two major difficulties in effectively simulating the farmer's method. First, in some cases the time lag in following the farmer's operation, regardless of how small, can produce a large difference in the outcome. For example, application of insecticides 1 or 2 days later than the farmer's could make a great difference because the effectiveness of insecticides depends on weather conditions, particularly rainfall. Second, some operations are not easy to duplicate or to simulate. For example, it is not easy to determine the exact rate of fertilizer application or the exact degree to which weeds were eliminated by handweeding.

To solve these problems, a procedure that allows the farmer to administer his level of practices as a part of his own normal farm operations could be used. Studies conducted in the Philippines (1974 and 1975 Annual Reports) indicated the feasibility of devising a suitable design and plot layout that would allow the farmer to administer his own insect control, fertilizer application, and weed control practices.

Difficulties in simulating farmers' levels. To avoid the difficulties of simulating the actual farmer's level on each experimental farm, some participants use the average level of practices over the sample farms in the preliminary survey as the farmer's level. Thus, one farmer's level is fixed for all experimental farms. That procedure is not correct.

All other production factors besides the test factors should be kept at the farmer's own level and actually implemented by the farmer. This approach is at times not strictly followed.

One major reason for deviation is that a certain condition such as good water management is deemed by agronomists to be necessary for high yield. Because water control is not usually included as a test factor due to the practical difficulty in managing the desired water levels in the field, some studies have chosen to use the improved water management instead of that of the farmer. Such procedure tends to invalidate the comparison between potential farm yield and actual farm yield.

Another condition for deviation is that in order to have complete control of the experiment, the procedure of having the researchers perform all the cultural and management practices, including those that are not test factors, is employed by some. This procedure faces a more complicated problem of having to simulate not only a few but all the practices and the accuracy can be expected to be poor.

Data analysis

Four major types of data analyses are usually performed:

Analysis I: Estimation of yield gap and contributions of the test factors (either individually or in combinations).

Analysis II: Comparison of yields among the different management packages tested.

Analysis III: Cost and returns analysis to determine relative profitabilities of the management packages and of the test factors either individually or in combinations.

Analysis IV: Simple tabular analysis of farmer's perception of input use and of any other socioeconomic conditions in the test area that may explain farmers' reluctance to adopt new techniques.

Analysis I. For analysis I, not enough attention is paid to the examination of interaction effects among the test factors. The manner in which the contributions of test factors are computed is totally dependent on whether or not interactions are present. When interaction effect is appreciable, the contribution of each test factor computed as an average over all levels of other factors may be misleading. In fact, when the interaction is large, yield constraints should be assessed by calculating the contributions of individual factors when all other factors are kept at the farmer's level, and in addition to the contributions for individual factors, contributions of the particular combination of factors whose interaction is significant should also be computed.

For example, mean yield data from a 2^3 factorial component of one farm in Laguna are given in Table 2. The analysis of variance (Table 3) showed a highly significant interaction between insect control and fertilizer rate. The nature of the interaction is shown in Table 4. Yield increase from improved insect control was larger with a high fertilizer rate than with the farmer's fertilizer rate (0.94 t/ha against 0.17 t/ha, respectively). In the same manner, yield increase from the higher fertilizer rate was larger under improved insect control than under farmer's own insect control (1.11 t/ha against 0.34 t/ha, respectively). In this case, if the usual average contributions of individual test factors were used, the results would have been

Yield (t/ha)	
Farmer's input	3.69
High inputs	4.95
Yield gap (t/ha)	1.26
Contributions (t/ha)	
Insect control	0.55
Fertilizer	0.72
Weed control	0.01
Residual	−0.02

The conclusion would have been that insect control contributed about 0.6 t/ha, and fertilizer 0.7 t/ha, to the yield gap of 1.3 t/ha, while weed control did not contribute any.

It is clear that such conclusion is quite misleading. The results should have been presented as follows:

Yield (t/ha)	
Farmer's inputs	3.69
High inputs	4.95
Yield gap (t/ha)	1.26
Insect control	0.07
Fertilizer	0.11
Weed control	—0.29
Insect control and fertilizer	0.99

The revised presentation shows quite clearly that neither the improved insect control nor the increased fertilizer rate alone can contribute significantly to the yield gap but together they increased yield by 1 t/ha.

Analysis II. In trials where the two components -- factorial and management—package -- are tested separately, there will be two values representing yield at farmer's level one from each of the experimental component. The common practice is to use the value obtained from the factorial component for analysis I and that from the management—package component for analysis II. This practice results in an unnecessary confusion in the presentation of results arising from having two different values and both identified as yield at farmer's inputs. To avoid such confusion, yields should be properly adjusted so that the results from both components are on the same basis.

Analysis III. For the cost and returns analysis (Analysis III), similar problems concerning the proper way to handle interaction effects among test factors as that for analysis I also exist. The cost and returns computed based on average contribution of each test factor when interaction is present could be misleading. Hence, cost and returns analysis based on certain combinations of factors rather than for a single factor should be considered when interaction is appreciable.

Analysis IV. The biggest problem that most participants encountered is in performing analysis IV. That is largely due to the fact that this part of data analysis is the most flexible and least standardized because of its total dependence on the outcome of the experiment, The major objective of this particular analysis is to explain through socioeconanic parameters why inputs shown to give both high yield and high profit were not actually used by farmer. These particular production inputs, which need to be explained, are identified based on results of the previous three analyses and are not known in advance. In fact, when such inputs cannot be identified, analysis IV may not be performed at all.

Table 2. Rice yields under varying combinations of input use and tested in a farmer's field in Laguna, Philippines, 1976 dry season.

Fertilizer level	Weed control level	Yield[a] (t/ha)	
		Farmer's insect control	Improved insect control
Farmer's	farmer's	3.69	3.16
	high	3.40	3.66
High	farmer's	3.80	4.68
	high	3.97	4.95

[a] Data are average of two replications.

Table 3. Analysis of variance of yield data whose means are presented in table 1.

S.V.	D.F.	MS	F
Insect control (I)	1	0.75429	19.34*
Reps within insect control	2	0.03900	
Fertilizer rate (F)	1	1.48474	35.97**
Weed control (W)	1	0.06250	1.51[ns]
I x F	1	0.99900	24.20**
I x W	1	0.00722	< 1[ns]
F x W	1	0.03460	< 1[ns]
I x F x W	1	0.03497	< 1[ns]
Error	6	0.04128	
Total	15		

Table 4. Interaction between insect control and fertilizer rate based on data of table 1.

Fertilizer level	Yield (t/ha)		
	Farmer's insect control	Improved insect control	Difference
Farmer's	3.54	3.71	0.17
High	3.88	4.82	0.94
Difference	0.34	1.11	

Minor analysis. In addition to the four major analyses mentioned earlier, other minor analyses that should be performed are

1. Compare yield and input use between farms with and without experiments in order to determine if both sets of farms may be considered as belonging to the same population.

2. Compare farm yield obtained from crop—cutting (from the comparable paddy of the same farm) and that obtained from the experimental plots in order to assess the degree of success with which simulation of farmer's practices is done.

3. Compare potential farm yield and experiment station yield in order to assess the size of yield gap I of Fig. I.

4. Examine the variation among farms in potential farm yields, especially in relation to some major physical environments, in order to assess the degree of stability of the improved technology.

Appendix I

Papers and reports useful as references in examining methodological problems relating to on—farmassessment of yield constraints. Copies of the papers are held by the IRRI Library.

De Datta, S. K., W. N. Obcemea, W. P. Abilay, M. T. Villa, B. S. Cia, and A. K. Chaterjee. 1976. Identifying farm yield constraints in tropical rice using a management package concept. Peper presented at the 7th Annual Meeting of the Crop Science Society of the Philippines. Davao City, May 10—12, 1976.

Gomez, K. A. 1974. The use of field plot techniques in quantifying yield constraints in farmers' fields. Paper presented at the International Rice Research Conference, International Rice Research Institute, April 22—25, 1974.

Gomez, K. A., D. Torres, and E. Go. 1973. Quantification of factors limiting rice yields in farmers' fields. Paper presented at an International Rice Research Institute Saturday Seminar, November 24, 1973. Los Baños, Philippines.

International Rice Research Institute. 1974. Annual Report for 1973. p. 265—297.

International Rice Research Institute. 1976. Annual Report for 1975. p. 307—322.

Papers presented at the fourth IRAEN Workshop, IRRI, March 7—11, 1976:

Ahsan, A. A. M. Ekramul. Methodology in socioeconomic survey for identifying constraints to higher yields in sample rice farms of Bangladesh.

Barker, R. Socioeconomic methodology in identifying constraints to high yield.

Bhasayavan, N., S. Bangliang, and S. Isvilanonda. Results of agronomic experiments on rice yields constraints in farmers fields, Suphan Buri, Thailand.

Gomez, K. A. The factorial experiment technique for measuring yield constraints in farmers' fields.

Hoque, M. Z. An agronomic analysis of constraints to higher rice yields on the farms of the BRRI Pilot Project Area.

Jogaratnam, T. and H. P. M. Gunasena. Identifying locations, farmers, variables and experimental designs (Sri Lanka).

Li, C. C., C. K. H. Wu, and Y. C. Kuo. Rice yield constraints in farmer's field. Taichung, Taiwan, Second rice crop, 1975.

Morris, R. A., H. Nataatmadja, A. S. Bagyo, and A. M. Hurun. Analyzing constraints to higher yield.

Prajitno, D. Identifying constraints to higher rice yield in Yogyakarta, Indonesia.

Widodo, S., Mudjijo, P., Sumangat, Rumpoko, Sumartono and Widodo. Factors associated with various levels of purchased inputs used in rice farming in Kulon Progo, Yogyakarta, Indonesia.

IRAEN working papers:

No. 1. Identifying constraints to higher yields on Asian rice farms.

No. 2. Methodology of assessing rice yield constraints.

No. 3. Farm yield constraints in Nueva Ecija and Laguna, Philippines.

No. 4. Farm yield constraints in Laguna, Nueva Ecija, Camarines Sur, and Iloilo province sites, Philippines.

No. 5. Constraints to high yield on Philippine rice farms, 1974—1976.

BANGLADESH, AMAN 1975, BORO 1975—76 AND AUS 1976

Ekramul Ahsan and M. Zahidul Hoque

ABSTRACT

Fertilizer applications above the farmers' level resulted in yield increases averaging over 1.3 t/ha in the boro season. High weed control contributed 0.4 t/ha during the same season, while farmers' insect control was adequate. During aus and aman seasons the total yield gap averaged less than 0.2 t/ha and no single input was consistently important. The high level of fertilizer increased profits by Tk 2,700/ha in boro. Modern varieties were planted on 90% of the study area growing rice in the boro and 50% in aman. Farm size, farmers education and technical knowledge were positively associated with the use of modern varieties in aman. Inputs were freely available but only 2% of the sample farmers used production credit.

RICE IN BANGLADESH AGRICULTURE

Bangladesh agriculture is dominated by rice, which occupies about 80% of the country's total cropped area and yields about 1.8 t/ha. Bangladesh agriculture has a low resource base and traditional production technology, resulting in inadequate local production of food grains. Bangladesh has reached the limit of its physical frontier and the hope for added food appears to be technological innovation to get production increases.

The strides made in developing new rice varieties become significant in this regard. Results at research stations reveal that modern rice varieties with improved cultivation technology have the potential of producing up to 6.5 tons of paddy per hectare, but such results are not widespread on farmers' fields.

Modern rice varieties in Bangladesh

Modern rice varieties were introduced in Bangladesh in the mid 1960s when about 400 hectares of the variety IR8 were planted. That variety showed its tremendous yield potential but was not adapted to many of the rice growing conditions in Bangladesh. Since that time, with the intensive effort of rice scientists in Bangladesh, in cooperation with IRRI scientists, a number of rice varieties have been developed. The modern varieties already in farmers' fields are IR5, IR8, Irrisail (IR20), Purbachi, Chandina (BR—1), Mala (BR—2), Biplab (BR—3) and Brrisail (BR—4). Some of these varieties are specifically adapted to particular conditions and seasons.

During 1974—75, the modern varieties were grown on about 15% of Bangladesh's total rice area and contributed about 31% of the total rice production (Table 1).

Table 1. Area and production of 1969—70 to 1974—75modern varieties and all rice in Bangladesh.

Year	Rice area (in 000 ha)			Rice production (in 000 tons)		
	All rice	Modern varieties	% of modern to total	All rice	Modern varieties	% of modern to total
1969—70	10,318	264	2.6	11,816	952	8.1
1970—71	9,917	420	4.2	10,967	1,505	13.7
1971—72	9,302	624	6.8	9,774	1,791	18.3
1972—73	9,634	1,065	11.1	9,930	2,487	25.0
1973—74	9,883	1,549	15.7	11,721	3,949	33.7
1974—75	9,796	1,452	14.8	11,109	3,394	30.6

Source: Bureau of Agricultural Statistics, Ministry of Planning, Bangladesh.

Research objectives

The constraints research has the general objective of determining the potential contribution of modern rice technology and the status of adoption of new varieties and improved technology among the rice farmers in Bangladesh. More specifically, we had four objectives.

1. Determine the yield potential of the modern rice varieties when grown with improved technology on farmers' fields.

2. Determine the gap between farmers' yields and the potential yields of modern rice varieties with the improved technology.

3. Determine the level and efficiency of technology adoption and the impact of adoption on productivity.

4. Identify the factors associated with adoption of modern rice production technology for increasing rice yields.

Methodology

The methodology for the project includes coordinated agronomic field trials and socioeconomic farm surveys in the study areas. The research was supplemented by a series of crop—cuts in the same areas.

The project was initiated in the transplanted *aman* season 1975, and continued into the following *boro* 1975—76 and *aus* 1976 seasons. A description of the rice seasons in Bangladesh are in Appendix 1. Experiments in farmer's fields combined management—package and factorial designs. Factorial experiments were also conducted at the research station for comparison. A series of crop—cuts were made to determine the productivity of rice farms in the study area and to determine the current management levels of the farmers.

Socioeconomic investigations of farmers in a sample survey in the study locations identified the socioeconomic constraints to attaining higher level of productivity by adopting modern rice technology. An economic analysis of the agronomic field trials was attempted to explain the influence of some of the physical and biological factors on adoption of the new technology.

MEASURING PHYSICAL AND BIOLOGICAL CONSTRAINTS

The study was in the Pilot Project area of the Bangladesh Rice Research Institute (BRRI), a consolidated block comprised of 9 *unions* of 4 *thanas* in Dacca district (Figure 1). The area represents one of the important agroclimatic zones of Bangladesh where rice is a main crop. The area is described in Appendix 1. The area is accessible to BRRI and the field work was carried out with few difficulties. Close supervision and frequent contact with the field workers were possible.

During *aus* 1975, *aman* 1975 and *boro* 1975—76, crop—cut studies determined the yields in farmers' fields and the levels of inputs applied by farmers. Beginning in *aus* 1976, experiments in farmers' fields enabled us to explain the influence of some of the physical and biological factors on the yield of modern rice varieties. Experiments were carried out on rainfed, partially irrigated and fully irrigated fields with different varieties as test crops. The major criteria used in the selection of the experimental sites were: the representativeness of the site for the type of rice growing situation, the willingness of the farmer to cooperate, and the accessibility of the site.

Crop cut studies. Crop—cut studies determined the farmers' yields for given levels of farmers' management. In each season, an area was designated for those purposes and divided into routes for specific days of the week. Crop—cut samples were taken at the same time as the farmers' harvest. A team consisting of an agronomist, an economist and fieldmen located fields being harvested, cut a 5 sq m sample, and threshed it on the spot. The grain was weighed, the moisture content determined by a portable moisture meter, and the grain yield adjusted for a 14% moisture content. The farmer was

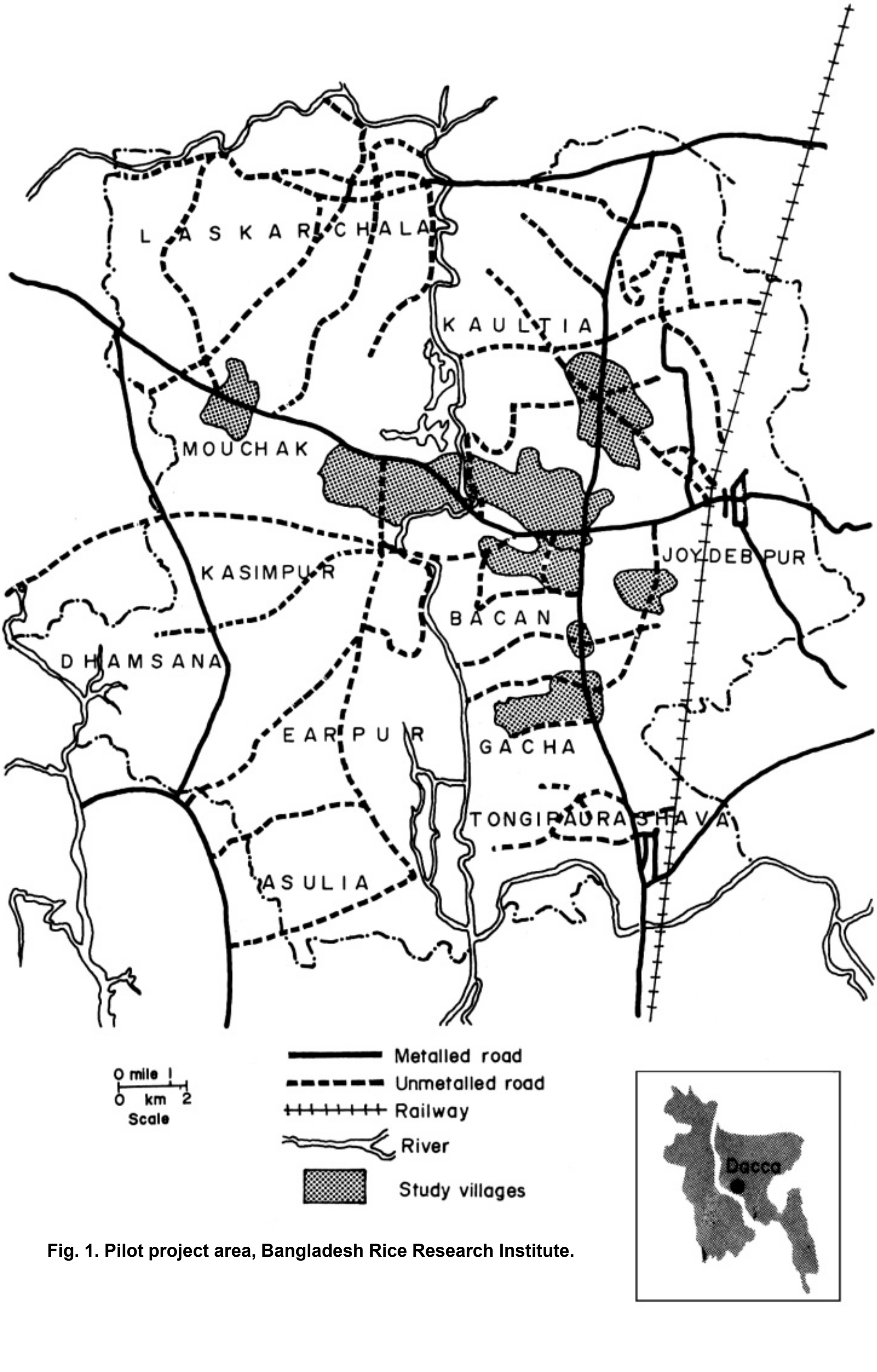

Fig. 1. Pilot project area, Bangladesh Rice Research Institute.

interviewed to determine the timing of different operations, inputs used, and other socioeconomic information.

Experimental factors. Fertilizer, weed control and insect control were considered as the major experimental factors. Earlier, attempts were made to separate the effect of nitrogen, phosphorus and potassium and to study land preparation, but due to difficulties in trying the treatments in farmers' fields, those factors were excluded. Seedling age, spacing and number of seedling per hill were included in some earlier experiments. The levels of fertilizer, weed control and insect control tested were fixed on the basis of earlier results obtained at BRRI and from experience in the field.

In the 1975—76 *boro,* the experiments were either partially irrigated or fully irrigated. Most of the farmers grew modern varieties. Previous studies indicated few insect problems on modern varieties in *boro* and thus fertilizer and weed control were selected as the major variables to be studied. The experimental design during 1975—76 *boro* was a factorial with four levels of fertilizer and two level of weed control. Two or three replications were used per site depending on the area available in the farmers' field. In most cases, factorials were put in randomized complete block design. Figure 2 shows a typical plot lay out.

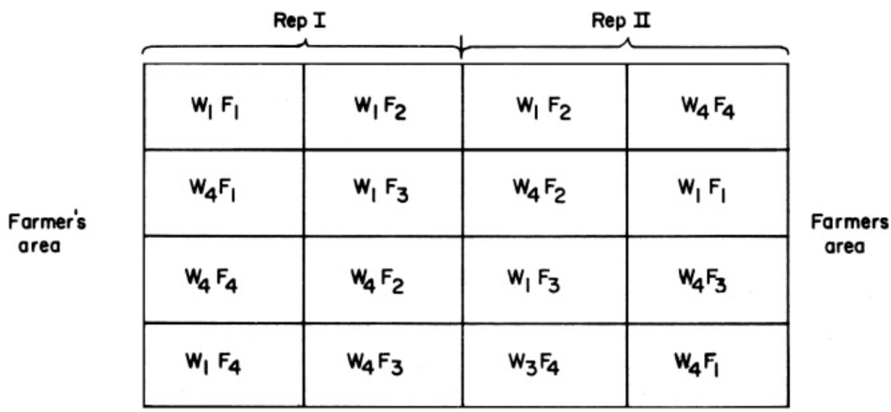

Fig. 2. A typical experimental layout in Boro, 1975–76, season.

In 1976 *aus,* fertilizer, weed control, and insect control were included. Ten treatment combinations of three factors were used, including the 8 factorial treatments of the 3 factors at two levels, plus weed control and fertilizer combined at two intermediate levels. In all cases, the low level in these experiments was an attempt to simulate the farmers' level and method of input.

Data collection and analysis. Continuous observations were made on the experimental sites, particularly to keep records of the farmers' management. For yield determination, a 5 sq m sample was harvested per plot and the grain threshed, cleaned and dried. Moisture content of the grain was recorded and the yield (kg/ha) was adjusted to 14% moisture content.

The primary analysis was to determine the yield gap between the farmers' and the high-input treatments and to determine the contribution of each factor to the gap. In addition, experiments with more than two replications were statistically analyzed when appropriate.

Data from the agronomic experiments were subjected to economic analysis to compare different treatment means. In all cases, partial budgeting was employed to determine the profitability of extra inputs or management above the farmers' treatments. The net return from investment in different treatments above the farmers' level, or the control treatments, was also calculated.

General observations

It was observed that a few important physical and biological factors influence the varietal coverage for different seasons in the BRRI Pilot Project area. For direct-seeded aus farmers prefer varieties with high seedling vigor, resistance to drought in the early growth stages, ability to compete with weeds, and short growth duration. The local aus variety Pukhi is popular.

During the transplanted aman, farmers prefer varieties with taller seedlings for transplanting in areas with deeper water. In case of late planting, they prefer photoperiod-sensitive varieties like the local variety Nizersail. Most of the present modern rice for transplant aman are either nonphotoperiod-sensitive or weakly photoperiod-sensitive and cannot be used by the farmers in case of delayed transplanting. For boro, farmers prefer varieties that are cold tolerant and yield well under irrigated conditions.

Yield and yield gaps in farmers' fields

The average grain yield and the ranges of yield of the varieties grown by the farmers in BRRI Pilot Project area during aus 1975, as determined by crop cutting, are in Table 2. IR8 and Chandina yielded 3,759 and 3,390 kg/ha, respectively, significantly higher than the local variety Pukhi at 1,788 kg/ha. Two-thirds of the farmers applied nitrogen fertilizer and weeded by hand once or twice. Less than one-third applied any pesticides.

The yields of varieties grown by the farmers in the BRRI Pilot Project area in 1975 aman are presented in Table 3. IR5 gave the highest grain yield (3,607 kg/ha) followed by that of Pajam (3,268 kg/ha) and IR20 (3,140 kg/ha). The lowest grain yield in farmer's fields was 991 kg/ha and the highest was 4,710 kg/ha. Farmers applied an average of 45 kg/ha of both nitrogen and phosphorus. One-quarter applied any pesticides and nearly all had good weed control.

The average grain yield and the range of yields of different boro varieties in 1975-76 are in Table 4. The highest average yield was from IR9 (4,620 kg/ha) followed by Pajam (4,352 kg/ha), IR8 (4,147 kg/ha), and BR3 (4,118 kg/ha).

Table 2. Average grain yield, range of grain yield, and field duration of different varieties grown by farmers in the BRRI Pilot Project area. Aus crop—cut studies, 1975.

Variety	No. of samples	Average yield (kg/ha)	SD yield (kg/ha)	Range in yield (kg/ha)	Field duration (days)	Yield/ day/ha (kg)
IR8	22	3759 a*	1946	1270—5398	103 a	36.5 a
Chandina	20	3390 a	1600	1514—4924	88 b	38.5 a
Pukhi	11	1788 h	1446	1035—3605	72 c	24.8 b
All	53	3211				

*Numbers followed by the same letter within a column do not differ significantly from one another at 52 level of confidence.

Table 3. Average grain yield, range of yield and field duration of different varieties grown by farmers, BRRI Pilot Project area. Transplanted aman crop—cutstudies, 1975.

Variety	No. of samples	Average yield (kg/ha)	SD yield (kg/ha)	Range in yield (kg/ha)	Field duration (days)	Yield/ day/ha (kg)
IR5	9	3607 a*	880	2344—4710	138	26.14
Pajam	80	3268 a	570	991—4539	115	28.42
IR20	18	3140 a	720	1514—4552	110	28.55
Nizersail	119	2291 b	380	1503—3059	106	21.61
Chandrasail	38	2263 b	560	1514—2881	102	22.19
Kaocha	5	1967 b	580	1188—2572	108	18.21
Binni	2	2280 b	20	2268—2298	-	-
Total/average	277	2690				

*Number followed by the same letter within the column do not differ from one another at 5% level of confidence.

Quantitative contribution of factors to the yield gap

Experiments at BRRI. The relative contributions of fertilizer, herbicide and insecticide to grain yield in an aus 1975 experiment at BRRI are in Table 5. Fertilizer, herbicide, and insecticide together increased grain yield by more than 20% over no treatment. Fertilizer and herbicide separately increased grain yield by 7 and 10%, respectively. Insecticide application alone did not increase the yield. The increase due to herbicide application was significant while that of fertilizer was not. Fertilizer and herbicide together increased the grain yield by 14%.

Table 4. Average grain yield, range of yield and field duration of different varieties grown by farmers, BRRI Pilot Project area. *Boro* crop—cut studies, 1975—76.

Variety	No. of samples	Average yield (kg/ha)	SD yield (kg/ha)	Range in yield (kg/ha)	Field duration (days)	Yield/ day/ha (kg)
IR9	8	4620 a*	1195	2549—5917	116	39.83
Pajam	18	4352 a	911	2946—6530	125	34.82
IR3	2	4118 a	-	3927-4308	105	39.22
IR8	111	4147 a	1354	1601—7338	126	32.91
Chandina	14	3656 a	1383	977—5605	97	37.69
Muktahar	18	2080 b	625	1214—3226	101	20.59
Latisail	7	1920 b	1090	736—3278	109	17.61
Total/average	178	3853				

*Numbers followed by the same letter within the column do not differ significantly from one another at the 5% level.

Table 5. Yields in factorial experiment with two levels of fertilizer, herbicide and insecticide. Chandina, BRRI, *Aus*, 1975.

Treatment level of					Grain yield (t/ha)
Fertilizer			Herbicide	Insecticide	
N	P	K			
0	0	0	0	0	4.0 de
0	0	0	1[b]	0	4.4 b
40	40	40	0	0	4.3 bc
0	0	0	0	1[c]	3.6 d
0	0	0	1	1	4.3 bc
40	40	40	1	0	4.7 ab
40	40	40	0	1	4.3 bc
40	40	40	1	1	4.9 a

[a] Yields followed by a common letter are not significantly different from one another.

[b] 5% Butachlor + 3.2% 2,4—D granules applied at 2 kg a.i./ha.

[c] Furadan at 1 kg a.i./ha.

The yields with two levels of fertilizer, weed control and insect control to the yield of rice in boro 1974—75 at BRRI are in Table 6. Fertilizer and weed control contributed by 1,748 and 1,705 kg/ha, respectively. The contribution of insect control was negligible.

Table 6. Yields with two levels of fertilizer, weed control and insect control for BR3. BRRI, boro, 1974—75.

Treatment					Grain yield (kg/ha)
Fertilizer			Weed control[b]	Insect control[c]	
N	P	K			
80	60	40	WF	4	4538 a*
80	60	40	WF	0	4486 a
80	60	40	0	4	1544 b
0	0	0	WF	4	1525 b
80	60	40	0	0	1495 b
0	0	0	WF	0	1442 bc
0	0	0	0	4	1069 c
0	0	0	0	0	1065

*Numbers followed by the same letter within the column do not differ significantly from one another at the 5% level.

[a]N, P_2O_5 and K_2O in kg/ha.

[b]WF = weed free conditions, 0 = no weed control.

[c]4 = 4 applications of diazinon, C = no insecticide.

Source: Division of Agronomy, BRRI.

Farmers' field experiments

The results of experiments conducted in 1975 aman in farmers' fields in BRRI Pilot Project area on the contribution of fertilizer, weed and insect control to grain yields in Table 7. Taking the average of the three locations, the contribution of fertilizer was 0.6 t/ha, improved weed control over farmers' management contributed about 0.2 t/ha, and high insect control contributed 0.1 t/ha.

In aus 1976, nine experiments were conducted in farmers' fields in the BRRI Pilot Project area to compare the farmers' levels of inputs with the levels estimated to be necessary for maximum yield (Table 8). The results are presented using the IRAEN yield gap format in Table 9. In

Table 7. Influence of insecticide, fertilizer and weeding on the grain yield of aman rice (IR20) in farmers' fields. BRRI Pilot Project area, *aman* 1975.

Fertilizer N	Fertilizer P	Fertilizer K	Weed[a] control	Insect[b] control	Grain yield (kg/ha) 43-dayold seedlings Konabari	43-dayold seedlings Chaurasta	52-dayold seedlings Chaurasta	Average
0	0	0	0	0	900	1580	2200	1560
0	0	0	WF	0	960	1680	2220	1620
80	60	40	0	0	1040	2500	2740	2093
80	60	40	WF	0	1480	2580	3000	2353
0	0	0	0	3	960	1600	2400	1653
0	0	0	WF	3	1010	2200	2560	1923
80	60	40	0	3	1220	2340	3080	2213
80	60	40	WF	3	1340	2860	3520	2573
Av (kg/ha)					1114	2168	2715	1999

[a] WF = weed free, 0 = no weed control.

[b] Number of applications of diazinon.

Table 8. Farmer's inputs and research management levels in IRAEN experiments. IRRI Pilot Project area, Bangladesh, aus, 1976

Location	Variety	Fertilizer (kg/ha) N	P	K	Hand-weeding (no.)	Insecticide[a]
		Farmer's input levels				
Soydana	Chandina	60	43	21	1	0
Itahata	Chandina	18	19	12	1	0
D. Salna	Chandina	0	26	0	1	0
Kalmeswar	IR8	0	57	0	3	0
Gachha	IR8	19	52	0	3	0
Gogitola	IR8	26	41	26	1	0
Soydana	Pukhi	40	29	36	0	0
Porabari	Pukhi	0	32	0	2	0
Chaurasta	Pukhi	0	64	0	1	0
		High yield input levels				
	Chandina, IR8	60	40	40	Weed-free	3
	Pukhi	60	40	40	Weed-free	2

[a] Number of applications of diazinon.

Table 9. Yield with farmers' inputs and high inputs and contribution of each of three inputs to the yield gap. Farmers' field experiments, BRRI Pilot Project area, aus, 1976.

Location	Variety	Yield (t/ha)			Contribution (t/ha) of			
		Farmers' inputs	High inputs	Gap	Fertilizer	Weed control	Insect control	Residual
Soydana	Chandina	3.9	3.5	−0.4	0.4	−0.8	0.2	−0.2
Itahata	Chandina	4.1	4.5	0.4	0.0	−0.2	0.3	0.3
D. Salna	Chandina	2.0	2.3	0.3	0.3	0.0	−0.2	0.2
Average (3)	Chandina	3.3	3.4	0.1	0.2	−0.3	0.1	0.1
Kalsmeswar	IR8	3.7	3.3	−0.4	−0.2	0.3	−0.2	−0.3
Gachha	IR8	4.2	4.7	0.5	0.0	0.2	0.1	0.2
Gogitola	IR8	3.3	3.3	0.0	0.3	−0.2	-0.1	0.0
Average (3)	IR8	3.7	3.8	0.0	0.0	0.1	−0.1	0.0
Soydana	Pukhi	1.7	2.2	0.5	−0.2	0.2	0.4	0.1
Porabari	Pukhi	1.0	0.9	-0.1	−0.1	0.0	-0.1	0.1
Chaurasta	Pukhi	0.8	0.6	−0.2	0.1	-0.1	0.2	0.0
Average (3)	Pukhi	1.2	1.2	0.1	−0.1	0.0	0.0	0.1
9 site av.	All	2.7	2.8	0.1	0.1	-0.1	0.0	0.0

general, there was no consistent pattern of response to high inputs among locations. Higher levels of fertilizer and weed management over the farmers' level of management did not significantly increase yields of Chandina because the farmers' levels of management were satisfactory. Yields of IR8 and Pukhi at three locations also revealed no significant differences among the different treatments. The average yield of Pukhi was 1 t/ha lower than the other two varieties with both farmers and high inputs.

The 1976 results indicate that the contribution of higher fertilizer, weed and insect pests management over that of farmers' input level in the experimental fields was not significant during aus. Farmers' levels of fertilizer and weed management for the high yielding varieties of rice appear to be satisfactory on the sample farms. Insect pests were not a serious problem. However, it is felt that further studies, including other factors and more locations, should be undertaken in order to determine other possible constraints to higher yields.

During *boro* 1975—76, experiments comparing high levels of fertilizer and weed control with the farmers' level were conducted on farmers' fields. When the farmers used a relatively low yielding variety like Chandina and high level of inputs, the contribution of further inputs was small (Table 10) But when the farmer used a fertilizer—responsive variety like IR8, an increase in inputs brought about a significant increase in yield.

Table 10. Yield with farmers' inputs and high inputs and contribution each of two inputs to the yield gap, experiments on farmers' fields. BRRI Pilot Project area, *boro,* 1975—76.

Location	Variety	Yield (t/ha)			Contribution (t/ha) of		
		Low inputs[a]	High inputs[b]	Gap	Fertil— izer	Weed control	Resi— dual
Soydana	Chandina	3.5	3.9	0.4	0.2	0.2	0.0
Soydana	IR8	5.0	6.9	1.9	1.4	0.4	0.1
D. Salna (1)	BR3	3.7	4.8	1.1	1.0	0.0	0.1
D. Salna (2)	BR3	3.2	4.4	1.2	0.8	0.4	0.0
Shakhipur	BR3	1.7	5.8	4.1	3.4	0.7	0.0
D. Salna	IR8	4.1	5.2	1.1	0.8	0.4	—0.1
Average	All	3.5	5.2	1.6	1.3	0.4	0.0

[a] Low inputs on the first two farms were 50—50—45 fertilizer and three handweedings. On the last four farms, low inputs included 25—20—0 fertilizer and four handweedings.

[b] High inputs on the first two farms were 100—50—45 fertilizer and three handweedings plus one mulching. High inputs on the last four farms included 100—60—40 fertilizer and four handweedings plus one mulching.

Management packages

The contribution of level of inputs in combination or management package, to yields of IR20 in farmers' fields during *aman* 1975 is in Table 11. At Konahari, a yield increase of 940 kg/ha was obtained from the highest level of management. At Chaurasta, increases of 1,660 kg and 1,440 kg per hectare were obtained, and at Autpara, an increase of 1,910 kg/ha was obtained between the highest and lowest level of management.

In 1975—76 *boro,* an experiment at BRRI studied the effect of levels of management on the yield of Chandina (Table 12). Zero and low levels of management gave statistically identical yields but significantly lower yield compared to medium or high levels of management. Medium and high management yields were statistically identical, indicating Chandina may not respond to levels of inputs beyond the medium level reported in Table 12.

Summary of biological constraints. The experiments conducted at BRRI and on farmers' fields during 1974 and 1975 show that levels of fertilizer consisting of 60—100 kg/ha of nitrogen and 40—60 kg/ha of phosphorus result in substantial yield increases over zero fertilizer in the *boro* season. Comparing such high levels with farmers levels roughly half as high resulted in an average yield gap of over 1.3 t/ha from fertilizer alone. Weed control of farmers seemed to be more nearly adequate, resulting in an average gap of only 0.4 t/ha.

Table 11. Influence of management packages on the yield of *aman* rice (IR20) in farmers' fields. BRRI Pilot Project area, *aman* 1975.

	Management package					Grain yield (kg/ha)				Aver- age
	Fertilizer (kg/ha)			Hand weeding (no.)	Insect control (no.)					
	N	P	K			Konabari	Chaurasta	Chaurasta	Autpara	
M1	0	0	0	0	0	1000	1760	2040	2022	1706
M2	60	0	0	1	1	1040	1700	2540	3350	2157
M3	60	40	40	2	2	1600	2500	3120	3214	2608
M4	80	60	40	3	3	1680	3200	3620	3344	2961
M5	100	60	40	WF	4	1940	2200	3700	3657	2874
	Seedling age					43	43	52	38	

Table 12. Contribution of management level to the grain yields of Chandina. BRRI, *boro,* 1975-76.

	Management package					Grain yield (kg/ha)[b]	Contribution (%)
	Fertilizer (kg/ha)			Hand- weeding (no.)[a]	Insect control (no.)		
	N	P	K				
M1	0	0	0	0	0	2416 b	100
M2	40	40	0	1	0	2636 b	109
M3	60	40	20	2	2	3427 a	142
M4	80	60	40	3	3	3384 a	140

[a] Handweedings were given at 25 DAT for M2, 20 and 45 DAT for M3 and 18, 42 and 56 DAT for M4.

[b] Yields followed by a common letter do not differ significantly from one another.

In the *aus* and *aman* seasons, the yield increases from levels of inputs above the farmers levels were much smaller and more variable. Fertilizer and weed control were important on a few farms but in general the contribution of insect control was less than 0.2 t/ha in all seasons.

SOCIOECONOMIC CONSTRAINTS

The crop cutting and experiments showed that many farmers in the BRRI Pilot Project area use fertilizer and practice adequate weed control practices, but that some scope exists for increasing yields by using somewhat higher levels of inputs. In addition, many farmers use little or no inputs. This section examines the profitability of higher input levels and the factors associated with adoption.

Economic evaluation of input contributions

Table 13 shows the economic contribution of the three tested inputs during *aus* 1976. Because the yield increases were small, high levels of weed control were less profitable than farmers levels. High fertilizer increased profit when used with farmers weed control. High insect control was also somewhat more profitable than farmers.

Table 13. Economic contribution of extra fertilizer, weed control and insect control on Chandina and IR8 in experiments on farmers' fields. BRRI Pilot Project area, *aus* 1976.

Treatment[a] Fertilizer	Weed control	Insecticide	Yield (kg/ha)	Added yield over farmers' (t/ha)	Value of added yield[b] (Tk/ha)	cost of added inputs[c] (Tk/ha)	Added profit over farmers' level
F	F	F	2.7	-	-	-	-
F	F	H	2.9	0.2	400	120	280
F	H	F	2.7	0.0	0	240	—240
F	H	H	2.7	0.0	0	360	—360
H	F	F	2.8	0.1	200	162	38
H	F	H	3.0	0.3	600	283	317
H	H	F	2.8	0.1	200	402	—202
H	H	H	2.8	0.1	200	522	—322

[a]F = farmers' level, H = high level. See Table 8 for definitions.

[b]Paddy valued at Tk 75 or 2/kg.

[c]Urea at Tk 1.33/kg, TSP at Tk 1.06/kg, muriate of potash at TK 0.80/kg, diazinon at Tk 40/application, 1 hand weeding cost TK 150.

Table 14 presents the contribution of weeding and different levels of fertilizer in terms of economic profitability for boro 1975—76. Weeding contributed Tk. 650/ha.Fertilizer contributed Tk. 2,252/ha at the farmers' level of weed management. The greatest increase in profit (Tk. 2,903) per hectare was obtained when the high level (100-60-40) of fertilizer was applied with a high level of weed management.

The contribution of different levels of management over farmers' level in terms of economic profitability during transplanted aman of 1975 are given in Table 15. All levels of inputs above M1 gave increased profits. The highest net return came from the M4 level.

The profitability of different levels of management above the simulated farmers' level during the boro 1975—76 is given in Table 16. As it can be seen from this table, the highest profit, Tk 1,206/ha, was obtained from M3 followed by that from M4.

ADOPTION ANALYSIS AND SOCIOECONOMIC CONSTRAINTS

It is assumed that successful adoption of the improved rice technology, including modern varieties, is a function of a number of economic, social and institutional factors. This part of the investigation was designed to understand possible socioeconomic constraints to adoption. The socioeconomic investigations were designed to supplement our field trial results.

Table 14. Economic contribution of extra fertilizer and weed management over farmers' levels. BRRI Project area, boro 1975—76.

Treatment[a]						
Weed control	Fertilizer	Yield (t/ha)	Added yield over farmers' (t/ha)	Value of added yield (Tk/ha)	Cost of added inputs[b] (Tk/ha)	Added profit over farmers' treatment
F	F	3.7	-	-	-	-
F	H	4.9	1.2	2400	148	2252
H	F	4.1	0.4	800	150	650
H	H	5.2	1.5	3000	297	2703

[a] See Table 10.

[b]At input prices given in Table 13.

Table 15. Economic comparisons of different levels of management over farmers' level (M1) rice. BRRI Pilot Project area, T. aman, 1975.

Treatment[a]	Yield (t/ha)	Added yield over M1 (t/ha)	Value of added yield	Cost of added inputs[b] (Tk)	Added profit over M1
Ml	1.7	-	-	-	-
M2	2.2	0.5	1000	367	633
M3	2.6	0.9	1800	695	1105
M4	2.9	1.3	2600	944	1656
M5	2.9	1.2	2600	1193	1407

[a] See Table 11 for input levels.

[b] At input prices shown in Table 13.

Table 16. Profitability of different levels of management as compared to the lowest level in boro, 1975—76.

Management level	Grain yield (kg/ha)	Extra yield over M1	Value of extra yield (Tk/ha)	Cost of extra inputs over M1	Profit over M1 (Tk/ha)
M1	2416	-	-	-	-
M2	2636	220	433	432	1
M3	3427	1011	1992	786	1206
M4	3384	968	1907	1031	876

Survey methodology

We made a sample survey of rice farms in the same areas where experiments were conducted on farmers' fields. The unit of study was a mouza (village). Selection of mouzas depended on the location of agronomic field trials, which were identified after a presurvey was made to become acquainted with the existing fanning practices, socioeconomic and institutional characteristics of potential areas within the BRRI Pilot Project. *Mouzas* were selected by stratified random sampling. The criteria for stratification were the existing cropping patterns (farm types) and the presence or absence of tubewells. *Mouzas* in the study area were classified into four types for sampling.

1. Double cropped with rainfed rice (*aus–aman*).

2. Continuous—cropped with rice (*aus-aman-boro*) and tubewell irrigation.

3. Continuous—cropped, diversified, (rice and other crops) with tubewell irrigation.

4. Single—cropped with rice (traditional *boro* or deep—water *aman* areas).

Sampling. In the 1975 transplanted *aman,* five *mouzas* were selected -- Kalmeshawar, Outpara, Telipara, Dakhin Salna and Konabari (Figure 1). The final sample was a 10% proportionate selection in each *mouza,* giving 100 farms. Four farms were rejected at the time of data processing because of inconsistent information in the questionnaire.

In the 1975—76 *boro,* the study was confined to fewer farms because rice is grown in small areas where irrigation facilities are available, or in low lying areas where available residual soil moisture remains during *boro.* Six *mouzas* were selected -- Soydana, Dakhin Salna, Shakhipur, Baimail, Kodda and Deuliabari. As in the first season, a 10% proportionate selection was made in each *mouza.*

Analysis

The constraints to yield increases were considered to be the constraints to the adoption of modern rice varieties and other components of modern rice technology. These could include the characteristics of the technology, farmers' resource constraints, and various nonfarm factors that prevent successful application of the technology.

An attempt is made here to analyze the characteristics of the technology as well as factors considered important in the spread of modern rice varieties. The analytical models for analysis of the survey data includes parametric and nonparametric techniques and descriptive statistics for analysis of adoption of modern rice production technology, and budgeting to measure the cost and returns and economic interpretations of components of that technology.

The level of adoption of modern rice varieties was expressed as the weighted proportion of the area planted to those varieties.

Because the available technology does not fit well into the local conditions and is unable to overcome the local barriers, and particularly because all the necessary components of the improved technology are not available, the package of technology adaptable to Bangladesh conditions is not a complete package.

The survey revealed that in 1975 *aman,* modern varieties were grown in 51% of the rice area. In 1975—76 *boro,* the modern rice varieties were grown on 91% of the area planted to rice, which was only a small proportion of the total area. The overwhelming coverage of modern varieties in *boro* was related to control water supply because *boro* rice is cultivated only if there is water available from deep tubewell or pumps. Because adoption of the varieties was nearly complete in *boro,* none of the factors that explained adoption in *aman* were related to adoption in *boro.*

Multiple regression

The results of the multiple regression analysis are given in Table 17. Farm size, family labor, farmer's education, and farmer's level of technical knowledge were regressed on the adoption of modern rice varieties. The results from similar studies are also given.

The results revealed that in *boro,* none of the variables used in the multiple regression were significant. This may be explained by the fact that the environmental factors, water availability in particular, were perhaps the most important single factor that influenced rice cultivation in *boro* and it was used to grow the modern rice varieties. The influence of other factors was not reflected.

Table 17. Estimated regression coefficients of socioeconomic factors affecting area under modern rice varieties. BRRI, 1975—76.

	BRRI Project area		Correlation coefficient in other studies[a]		
Factors	*T. aman* 1975	*Boro,* 1975—76	Commilla	Dinajpur	Kushtia
Farm size	.18**	.13	—.01	—.08	.22
Family labor	.06	.08	N1[c]	N1	N1
Farmer's education	.15**	.04	.01	.70**	.72**
Technical knowledge	.62**	RU[b]	RU	.35*	.18
R^2	.80**	.18	-	-	-

[a]Other studies conducted by Ahsan in the areas mentioned.

[b]N1 = not included in the study.

[c]RU = relationship undefined.

*significant at .05 level.

**significant at .01 level.

Farm size. Farm size was found to be significantly related to the area planted to modern varieties in aman. The results revealed that larger farm size favors adoption of modern varieties. Other studies in Bangladesh have shown different results, but with coefficients that were not significant.

Education. The education level of the farmers was found to be a significant factor influencing the adoption of modern rice varieties in aman. Similar results were obtained in another study in Dinajpur and Kushtia districts. The coefficients were highly significant.

Technical knowledge. The level of technical knowledge was derived by scores given for correct answers to a list of questions about techniques of rice cultivation. This variable, technical knowledge of the rice farmers, had the largest coefficient influencing adoption of modern rice varieties. This was also found in another study in Dinajpur district.

Rank correlation

A number of variables that could not be fitted into the regression model were tested the nonparametric techniques of rank correlation. The result of analysis are presented in Table 18. Among the variables included, farmers' hazard experience, input availability, profitability of technology, and extension exposure were significantly correlated.

Table 18. Rank correlation coefficients with intensity of adoption, BRRI, 1975—76.

Factors	BRRI Project area		Other studies		
	T. aman 1975	Boro, 1975—76	Comilla	Dinajpur	Kushtia
Farmer's hazard experience	—.40**	—.53**	—.07	-.17	-.59**
Input availability	.27**	.17	RU [a]	.39**	.31*
Perceived profitability	.53**	.61**	.01	.64**	.75**
Availability of credit	.04	.07	.18	.28	.01
Extension exposure	.23*	.30	.31*	.22	.30*

[a]RU = relationship undefined.

*significant at .05 level.

**significant at .01 level.

Hazard experience. Farmers' experience with different types of hazards and crop failure was scored. Farmers' hazard experience and adoption of modern rice varieties were negatively related so that farmers with more frequent crop failure ranked lower in the adoption of modern rice varieties. This behavior is significant because the adoption of modern rice varieties is associated with the complementary inputs of fertilizer and other practices that result in higher costs and yields than the normal level of inputs and management practices.

Availability of inputs. An attempt was made to determine to what extent the availability of complementary input factors (seed, fertilizer and insecticide) influenced the adoption of modern rice varieties. The corresponding rank correlation for *aman* revealed a positive significant relationship with the adoption of modern rice varieties. This implied that farmers with more area in the modern varieties also believed they had greater access to the complementary inputs. If they also used more inputs, this could increase the productivity and thus the yield of rice.

The survey revealed that availability of seeds of modern rice varieties was not a serious constraint. About 97% of the farmers reported that it was easy to get adequate quantity of seeds when needed (Table 19). There was, however, a problem in availability with respect to fertilizer, insecticides and sprayer machines. Only 6% of the total rice farms received the recommended quantity of fertilizer, while about 2% of the farmers got the insecticides at the time of need. The situation was even worse in case of availability of sprayers.

Table 19. Per cent of 96 farmers indicating familiarity and availability of inputs. BRRI Pilot Project area, 1975—76.

Kinds	Knowledge of input	Generally available	Available on time	Available adequately
Modern seed	100.00	99.05	96.65	96.65
Fertilizer	94.97	86.98	13.02	6.08
Insecticide	42.10	42.10	1.93	-
Sprayer	32.00	-	0.96	-

Credit availability. Credit for rice farming was a serious problem. Among the rice farmers obtaining credit from various sources, only 1% used credit specifically for crop production. The source of credit was Agriculture Bank. Agricultural credit was, however, available to only 2% of all the rice farms and as a consequence, credit availability was not related to cultivation of modern rice varieties.

Perceived profitability. The profitability of the modern rice varieties as perceived was reflected in the farmers' belief that cultivation of modern rice varieties would be more profitable than other varieties. This influenced positively and significantly the adoption of modern varieties.

Extension exposure. The farmer's exposure to extension was scored to determine its relationship with adoption of modern rice varieties. The rank correlation analysis supported the hypothesis that a farmer's extension exposure had a significant relationship with adoption of modern rice varieties in *aman.* In *boro,* however, the coefficient was not significant.

Economic analysis of technology components

The farm survey revealed wide variability in inputs and management practices used by rice farmers. Attempts were made to classify the sample farms according to level of input use and rice cultivation practices. The classifications were made by varieties, level of fertilizer use, level of manure use, level of weeding, and plant protection measures, Costs and returns analysis was conducted for each classification.

Variety. During *aman* 1975, the average yield of paddy for farms growing modern rice varieties was 3.3 t/ha compared to 2.3 t/ha for the traditional varieties (Table 20). The yield difference was statistically significant and was similar to the crop—cut study findings in the same area in the

Table 20. Costs and returns of traditional and modern rice varieties in transplanted *aman* 1975, and *boro* 1975—76. Survey of farmers in BRRI Pilot Project area, 1975—76.

Items	Transplanted *aman*		*boro*	
	Traditional varieties	Modern varieties	Traditional varieties	Modern varieties
Yield (t/ha)	2.3	3.3	2.5	3.8
Cost (Tk/ha)	2093	2093	3115	4170
At actual season's rice prices				
Gross return (Tk/ha)	6177	8172	4216	6371
Net return (Tk/ha)	4084	6678	1100	2231
At average of *aman and boro* rice prices				
Gross return (Tk/ha)	5005	7181	5440	8269
Net return (Tk/ha)	2912	5088	2325	4099

same season (Table 3). Both were substantially lower than the potential yield of the modern rice varieties obtained by rice scientists in the same soil and climatic condition (5.5 t/ha). Farmers growing modern varieties in the *aman* earned about Tk 2,500/ha higher net return than farmers growing traditional varieties.

In *boro* 1975—76, the average yield for the modern varieties was 3.8 t/ha compared to 2.5 t/ha for the local varieties. The yield difference between the modern and local rice varieties was statistically significant. Comparing the yield of the rice scientists, growing modern rice varieties in *boro* in the same soil and climatic conditions have obtained as high as 6.3 t/ha.

Farmers growing modern rice varieties have higher returns per hectare than farmers growing traditional rice varieties in both seasons (Table 20). Although yield was higher in *boro,* the farmers with MVs obtained higher economic returns during *aman.* One reason for that was the difference in paddy price, which was much higher in *aman.* When the same paddy price is used for the two seasons the difference in net returns is smaller, but still remains.

Fertilizer use. The sample farms were classified into three groups of fertilizer users:

1. High - farmers using recommended levels of fertilizer or higher.

2. Medium - farmers using fertilizers less than the recommended level but not less than half of the recommended level.

3. Low - farmers using fertilizer below the medium level.

Most of the farmers in both *aman* and *boro* used a low level of fertilizer. One reason for low level was restricted availability of fertilizers during both seasons. Fertilizers were not available from the usual sources, and although there was a fixed price for each type of fertilizers the farmers had to pay much higher prices.

The yield difference between the farms using fertilizers at a low and high levels was more than 0.6 t/ha in *aman* and 0.9 t/ha in *boro* (Table 21). The cost and returns data show that during *aman* farmers with medium and high fertilizer levels had substantially higher net returns on traditional varieties than those with low fertilizer. The same was true on both modern and traditional varieties during *boro.* Yields and net returns of both types of varieties were higher during *boro.* Farmers spent substantially more on inputs for their modern varieties than for their traditional varieties during *boro,* but because more than 90% of the area was planted to modern varieties, the benefits must have been perceptable to farmers, although the benefits seem small.

Manure use. Manures were used in 95% of the total rice area during *aman.* During *boro,* however, manures were used on only 46% of the total rice area. The yield differences between farms with manure

Table 21. Cost and returns reported by farmers using three levels of fertilizer on traditional and modern varieties. Survey of farmers in BRRI Pilot Project area, 1975—76.

Items	Low fertilizer		Medium fertilizer		High fertilizer	
	TV[a]	MV	TV	MV	TV	MV
			Transplanted aman			
Yield (t/ha)	1.9	3.1	2.3	3.2	2.4	3.2
Gross return (Tk/ha)	5317	8324	6046	8492	6503	8576
Cost (Tk/ha)	2032	2013	2149	2136	2215	2270
Net return (Tk/ha)	3285	6311	3897	6356	4288	6306
			Boro			
Yield (t/ha)	1.4	3.0	2.7	3.7	3.3	4.1
Gross return (Tk/ha)	2338	4992	4505	6272	5485	6988
Cost (Tk/ha)	2980	3937	3034	4021	3117	4195
Net return (Tk/ha)	642	1054	1470	2250	2367	2792

[a] TV = traditional rice varieties, MV = modern rice Varieties.

and without manure were not significant. In terms of net returns, however, the higher cost involved in higher level of manure use brought Tk 500/ha extra net returns for modern varieties during *boro.*

Weeding. Weeding of rice plots had a significant effect on production. Farms were grouped into three classes depending on the intensity of weeding. The cost and returns for different levels of weeding showed that rice farmers with high weeding had higher returns than those with low weeding. The findings are consistent for both transplanted aman and boro (Table 22).

Hand weeding was done in all the rice plots in aman, and intensive weeding was practiced in about 86% of the total rice area. In boro, however, only one of the study plots was not weeded and 97% of the total rice area was intensively weeded. Intensive weeding was a popular and known practice among the rice farmers of the area.

Plant protection. Insecticides were used by the farmers under study both as a preventive practice and as a curative measure. In aman, the yield difference due to different levels of plant protection was low. In boro, however, the yield difference and cost structures for using chemicals and not using chemicals brought a positive return of 0.3 t/ha for traditional varieties and 2 t/ha for modern varieties from applying insecticides.

Table 22. Costs and returns reported by farmers with three levels of weeding in transplanted *aman* 1975 and *boro* 1975—76. Survey of farmers, BRRI Pilot Project area, 1975—76.

Items	Without weeding[a]		Minimum weeding[a]		Intensive weeding[a]	
	TV	MV	TV	MV	TV	MV
			Transplanted *aman*			
Yield (t/ha)	-	-	2.0	2.7	2.3	3.1
Gross return (Tk/ha)	-	-	5268	7138	6244	8354
Cost (Tk/ha)	-	-	2093	2093	2102	2183
Net return (Tk/ha)	-	-	3115	5045	4142	6171
			Boro			
Yield (t/ha)	2.3	-	2.4	-	3.1	4.2
Gross return (Tk/ha)	3852	-	4024	-	6264	1005
Cost (Tk/ha)	2611	-	2713	-	3019	4285
Net return (Tk/ha)	1241	-	1250	-	3244	2720

[a]TV = traditional rice varieties, MV = modern rice varieties.

The use of insecticides in the rice crop was mostly a curative practice and hence the effect of using chemicals was not significant in terms of yield differences, in transplanted *aman.*

The survey revealed that during *aman,* 68% of the rice area was sprayed with insecticides. During *boro,* plant protection measures were taken on 70% of the rice area. All the rice plots with modern varieties were sprayed during *boro.*

SUMMARY AND CONCLUSIONS

It was observed that several physical and biological factors influence the spread of the modern rice varieties in different seasons. For direct—seeded *aus* rice, poor seedling vigor, less ability to compete with weeds, and susceptibility to early drought were constraints to the spread of new varieties. In transplanted *aman,* the spread of modern varieties was limited by deep water, and by the need for photoperiodsensitivity in case of late plantings. Susceptibility to low temperature is a major constraint to modern variety spread during *boro.*

Fertilizer application above farmers' level could contribute 0.1 and 1.3 t/ha of rough rice in *aus,* and *boro,* respectively. The contribution from weeding above farmers' level in boro was 0.4 t/ha. Insecticide contributed barely 0.1 t/ha in any season.

The highest combination of inputs, contributed as high as Tk 1,656 and Tk 1,206/ha *aman* and *boro.* Low levels of management for modern rice in *aus* and *aman* were no more profitable than the farmers' level of management. In *boro,* there was significant difference between the lower levels of management and the farmers' level.

Most of the farmers in the study were aware of modern rice varieties, the importance of chemical fertilizers, weeding, and top dressing. The higher yield potential of the modern varieties was known to the farmers, and the adoption of those varieties was complete in the *boro.* Scope for further spread was limited because of problems of water availability during *boro* and water control during the other seasons.

The modern rice varieties are profitable but their adoption has had relatively little impact on the average rice yield. This is because of incomplete technology adoption and lack of coordination in input use. The farmers inability to adopt all the improved technology resulted from a low resource base and a lack of capital. Credit was generally not used, and the amount of capital available to the farmers was inadequate to purchase the high levels of input needed for optimum crop production.

There was wide seasonal variation in growing the modern rice varieties. This was because the modern varieties did not fit well into the farmers' cropping system, which is primarily a rainfed two—crop (*aus* and *aman*) system. With irrigation, farmers grow a third (*boro*) crop but one of the varieties in the sequence must be a traditional one to fit into the cropping system.

Conclusions

The productivity of rice farms in the study areas can be improved by about 1 t/ha by growing modern varieties with adequate levels of inputs and the average farmers' level of management in the *boro* season.

A better distribution system of the required inputs, namely fertilizers and insecticides, is important for facilitating the adoption of modern rice technology and for improving the level of production. Availability of seeds was not a serious problem in the study area but that may not be true elsewhere in Bangladesh. Credit needs of the farmers must be served.

The available modern rice production technology does not perform well in all the conditions faced by farmers, which means that the improved technology is not available to all farmers. Appropriate breeding, and agronomic and management research are needed to develop suitable technologies to fit Bangladesh's systems and environmental conditions.

APPENDIX: AGRO-CLIMATIC CHARACTERISTICS OF THE PROJECT AREA

Location

The BRRI Pilot Project area lies in the center of the Dacca district about between latitudes 23°N and longitudes 90°E. The area is about 150 sq. km.

Climate

The project area has a tropical monsoon climate distinct rainy (wet) and winter (dry) seasons. The rainy season is from May to October and November to April is considered the dry season. The average annual rainfall in the area is about 1,925 mm.

Geomorphology and soil

The soil of the project area consists primarily of compact clay (Madhupur) and flood plain sediments. The clays have been uplifted technically to form a terrace generally standing 3—4 m above the adjoining flood plains. This terrace is dissected by valleys, most of which are streamless.

The Madhupur tract shows a wide diversity and complexity of soils. There are extensive level areas of deep, friable clay loams to clay varying in color from red through yellow—brown to grey, according to monsoon drainage conditions. The pattern of the flood plain soils ranges from friable silt loams or silty clay loams on the ridges and clays in the basins.

Hydrology

Seasonal flooding is the significant hydrological characteristic of the project area. Flooding is primarily by rain water but flood levels are more or less controlled by the water levels in the adjoining rivers.

In the flood plain ridges, and in the higher valleys flood water recedes in September—October, and from the basins in November—December. However, the deep basins and valley remain wet for the dry season.

Land utilization and chapping patterns

Like elsewhere in Bangladesh, land utilization in the BRRI Pilot Project area is determined primarily by topography, flooding and availability of soil moisture. Land utilization in the project area includes crop land, forest and permanent trees, grassland, settlements and water bodies.

As regards cropping patterns, single—, double— and triple—cropping patterns prevail in the project area. The single—cropping pattern is usually practiced in the low—lying or deep—flooded areas where broadcast aman rice is grown. Less—deep, flooded areas are characterized with a double—cropping pattern, commonly with either two rice crops, jute and rice, or with rice followed by winter crops. The winter rice (*boro*) used to be grown in patches around water sources, but in recent times with greater availability of power pumps and tubewells, winter cropping with rice and other crops (mainly vegetables) is expanding. No matter whether a single—, double—, or triple—cropping practice is followed, rice is essentially the major crop.

KULON PROGO, 1974—75, INDONESIA

Sri Widodo, Djoko Prajitno, Sumartono, Santo Sudjono, Sumangat and Mudjijo

SUBANG 1975—76, INDONESIA

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ABSTRACT

Data from two separate study areas in Indonesia are included. In Kulon Progo in Yogyakarta the yield gap was small in the wet season but equaled 1.3 t/ha in the dry. Fertilizer was the dominant factor in both seasons. High fertilizer increased profits above farmer's levels while other inputs did not. Technical knowledge and accessibility to inputs were strongly associated with average level of input use. In the Subang area no appreciable yield gap was measured between a high level of inputs and the farmers' level. In the wet season excess water and insects that were not effectively controlled prevented any response to high inputs. In the dry season widespread drought kept yields low even with high levels of inputs. In both areas high insect control inputs seemed to depress yields. Farmers' perceived pests as the main yield limiting factor, but the technology tested could not effectively control the pests.

RICE IN INDONESIA'S AGRICULTURE

Rice occupies half of Indonesia's foodcrop land and is the main staple food, although corn, cassava, soybeans, and peanuts are important supplementary foods. Thirty five percent of food expenditures is used to buy rice or rice

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*The paper reports on two separate studies in two parts of Java. The Kulon Progo study was conducted by a team from the Fakultas Pertanian, University of Gadjah Mada, Yogyakarta. The Subang study was conducted by a team from the Central Research Institute for Agriculture (CRLA), Bogor.

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products by the average Indonesian. An estimated 53% of the daily caloric intake and 47% of daily protein intake are met by rice (Sugiyanto and Tedjokosoemo, 1975).

About 85 million out of the total Indonesian population of 125 million families engaged directly in agriculture and of these roughly 50 million are engaged in food crop production. Only a small portion of the latter group would not produce at least a small amount of rice during the year.

Although rice occupies only half of the area devoted to food crop production, van der Goot (1974) estimated that rice cultivation in 1973 accounted for 2,475 million labor days, which was 75% of labor used in food crop production. Rice cultivation uses roughly 87% of female labor employed in food crop production. Of the total labor absorbed by rice production, an estimated 57% is female labor.

Table 1 shows the national rice area, production, yield and imports for 1968 through 1975. During that period, rice production increased more than 4% a year, with substantial growth in both yield and area. The primary increase, however, was from yield.

Table 1. Area, production, yield and imports of rice. Indonesia, 1968—1975.

Year	Harvested area ('000 ha)	Production[a] ('000 t)	Yield[a] (t/ha)	Imports[a] ('000 t)
1968	8,021	11,666	1.45	486
1969	8,014	12,353	1.54	238
1970	8,135	13,451	1.62	324
1971	8,324	13,723	1.65	120
1972	7,897	13,182	1.67	335
1973	8,403	14,607	1.74	1,863
1974	8,537	15,452	1.81	1,132
1975	8,620	15,519	1.80	692

[a]As milled rice
Source: Biro Pusat Statistik, Jakarta.

Harvested area increased at an annual average rate of 1.2%/year between 1968 and 1975, total production increased at 4.8%/year, and yield increased at 3.3%/year over the same period. The corresponding figures for 1955 to 1967 were 0.5%, 1.3% and 0.8%. The slight increases in area can be attributed to spontaneous land opening, irrigation system improvements and new irrigation construction. The latter factor is expected to become a more important contributor to future production increases.

Despite the increasing production in recent years substantial imports have been required. The need for more imports has arisen in part from the government's policy to increase per capita rice consumption at the same time as population increased at an average annual rate of 2.5%. The relative success of this' policy is reflected in the national statistics for rice availability (Table 2). The ready availability of rice at attainable prices was a key tool in the government's strategy for maintaining economic stability.

Table 2. National rice availability, population, and prices Indonesia, 1968—1975.

Year	Production + imports ('000 mt)	Population ('000)	Availability per capita[a] (kg)	Price[b] (Rp/kg)
1968	12,152	112,348	108.2	12.4
1969	12,591	114,880	109.6	36.9
1970	13,775	117,469	117.3	42.6
1971	13,843	120,149	115.2	40.8
1972	13,517	123,115	110.0	49.9
1973	16,470	126,088	131.1	76.5
1974	16,584	129,083	128.5	81.7
1975	16,211	132,104	122.7	98.3

[a] Availability per capita is the total of production and imports for the year divided by the population. It docs not consider seed requirements, losses in storage and transport, and changes in inventory.
[b] Average price for year in rural markets.
Source: Biro Pusat Statistick (1976).

The government has a program to increase rice storage capacity by building 150 regional warehouses to use in rice marketing operations. At completion of the project, government storage capacity will expand by almost one million tons. The warehouses are to be used for the short—term storage required to maintain floor and ceiling prices in the regions, to facilitate regional and seasonal transfers and to stockpile against national emergencies.

Available projections indicate a shortfall of production over the near future (Table 3), although there is much uncertainty about both future output and demand. That uncertainty has led to a range of assumptions about the rates of yield increase and area expansion achievable and maintanable, the constancy of government price policies, and the rates of population and income growth.

Based on several combinations of assumptions about population increase, income and income elasticity, Sugiyanto and Tedjokoesoemo (1976)

Table 3. Short—term rice demand projections. Indonesia, 1974—1978.

Year	Estimated demand ('000 t milled rice)	Estimated production ('000 t milled rice)	Estimated import needs ('000 t milled rice)
1974	16,041	15,032	1,009
1975	16,683	15,633	1,050
1976	17,350	16,383	967
1977	18,044	17,235	809
1978	18,766	18,183	583

Source: Teken (1974).

Table 4. Long—term rice demand projections. Indonesia, 1978—1998

Year	Estimated demand, milled rice ('000 t)		
	High	Medium	Low
1978	18,766	18,766	18,766
1983	25,611	22,832	20,333
1988	32,686	27,779	23,571
1993	51,390	33,797	22,047
1998	68,771	41,120	24,342

Source: Sugiyanto and Tedjokoesoemo (1976).

calculated long—term demands for rice extrapolating from Teken's estimate for 1978 (Table 4).

Characteristics of rice production

Table 5 shows that 62% of the harvested lowland rice area and 66% of the production from lowland are concentrated on the "inner islands" of Java and Bali, which account for only 7.3% of the national land area, but contains 67% of the population. Of the remaining 38% of lowland rice

Table 5. Harvested area, production and yield of lowland and upland rice. Indonesia, 1974.

Province	Lowland rice[a]			Upland rice		
	Harvested area ('000 ha)	Production rough rice ('000 t)	Yield rough rice (t/ha)	Harvested area ('000 ha)	Production rough rice ('000 t)	Yield rough rice (t/ha)
Java	4,438	13,573	3.1	286	345	1.2
Bali	155	569	3.7	16	15	0.9
Sumatra	1,468	4,169	2.8	449	599	1.2
Kalimantan	504	885	1.8	221	234	1.1
Sulawesi	582	1,370	2.4	88	107	1.2
Maluku and Irian Jaya	2	3	1.5	12	7	0.6
Nusa Tenggara	227	617	2.7	90	94	1.0
Indonesia	7,376	21,182	2.9	1,161	1,401	1.2

[a]Dry—wet rice (gogo rancah) included; found only in Java; less than 50,000 ha.
Source: Biro Pusat Statistik (1975).

area, 22% is accounted for by five of the additional 22 provinces (Aceh, North Sumatra, West Sumatra, South Sulawesi and South Kalimantan). Upland rice occupies only 16% of the total rice area. The upland average yield is less than half of the lowland average yield.

The largest rice harvest occurs in April—June at the end of the wet season (55%). A second harvest peak occurs in August—October. The residual 25% of the harvest is distributed over the remaining 6 months. On Java, the seasonal peaks are less pronounced because of the extensive irrigation systems.

Water control. The geographic area used for lowland rice is about 5.6 million ha. Of this 3.5 million ha is served by irrigation systems. At the start of the first 5—yearplan (1968), an estimated 60% of the irrigation systems and flood control structures needed repair and improvement. During the 5—year development period, irrigation systems serving 930,000 ha of lowland fields were rehabilitated by improvements and repairs to primary and secondary canals, dams and irrigation structures. An additional 193,000 ha were provided with irrigation and flood control measures protected an estimated additional 339,000 ha.

The second 5—year program has targets of 835,000 ha of rehabilitated systems and 950,000 ha of new construction. Moreover, programs to regulate rivers and reclaim swamps should improve water control on an additional 680,000 ha.

Varieties, fertilizer and pesticides. Expansion in the use of new varieties, fertilizers and pesticides is closely linked to expansion of the Bimbingan Massal or Nass Guidance (BINAS) program. More will be said about that program in the section on government policies.

Starting in 1953, the Balai Padi began releasing improved varieties some of which are still in use. These are at times referred to as national improved varieties and include Syntha, Sigadis, and others. With the release of shorter, stiff—strawed nitrogen responsive varieties elsewhere, the Bogor breeding program altered its breeding objectives and as a result, developed Pelita I/1 and I/2 which were released in 1971. These modern varieties (MV) possess a grain quality more suitable to Indonesian tastes, and plant—types similar to IR5 but with somewhat stronger bacterial leaf blight resistance. As a result, Pelita varieties have generally replaced IR5 in all areas except parts of Sumatra where dry cooking rice is acceptable. Table 6 gives the area of traditional, national improved and modern varieties harvested in the 1974 dry season and 1974/75 wet season.

Table 6. Area of rice varieties harvested. Indonesia, 1974 dry season and 1974—75 wet season.

Variety	1974 dry season '000 ha	%	1974—75 wet season '000 ha	%
Pelita I/1	345	11.9	855	16.4
Pelita I/2	153	5.3	244	4.7
IR5	398	13.7	663	12.8
C—4	222	7.7	388	7.5
Other modern	76	2.6	96	1.8
National improved	306	10.6	433	8.3
Local	1400	48.3	2521	48.5

Source: Data of Directorate Bina Produksi.

Fertilizer use increased rapidly as both the government and farmers realize its importance in exploiting the yield potential of modem varieties (Table 7). Urea and triple superphosphate are by far the most widely used materials. Insecticides and rodenticides have also been encouraged but their use has not increased as rapidly as fertilizer. Diazinon is the most extensively distributed and used insecticide while zinc phosphide is the major rodenticide.

Mechanical technology. With minor exceptions, recently developed engine—powered production technology has not been introduced into the rice sector. Most land preparation is by animal or hand methods. Weeding

Table 7. Fertilizer and insecticide used on rice. Indonesia, 1968—1975.

Year	N (t)	P_2O_5 (t)	Insecticide (t)[a]	Rodenticide (t)[a]
1968	95,000	24,000	630.6	40.2
1969	155,200	36,200	1,209.3	33.7
1970	162,100	31,300	1,075.6	52.4
1971	219,200	24,200	1,555.6	33.0
1972	257,600	58,400	1,362.7	44.5
1973	307,400	53,800	na[a]	na
1974	277,700	77,300	na	na
1975	308,300	93,000	na	na

[a] na = data not available.
Source: Ministry of Agriculture (1973) for 1968—72and BIMAS project for 1973—1975.

is by hand or with rotary or spike—toothed push weeders. Hand—sprayers have also been introduced by additional sprayers are still needed in many areas.

In contrast to the adoption of mechanical technology in rice production, a wide and rapid distribution of small rice milling equipment has occurred in the post—harvesting operations during recent years. Timer (1973) estimated that the capacity of milling equipment sold on Java and Bali in the 1970—72 period was sufficient to mill 70—80% of the production on those two islands.

Government policies

The tight fiscal (balanced budget) policy of the Indonesian Government established in 1966—67 was designed to reduce inflation and promote economic stabilization. The price of rice, regarded as a barometer for all other prices, influenced the people's inflation rate expectations. The government has attempted to stabilize rice prices by price policy and by increasing production.

Policy. Rice policy had traditionally been consumer oriented with an adequate supply at a low price. There was a ceiling price to protect the consumers. In 1970, the government decided that there should be a floor price harvest time to protect rice farmers.

The operational agency responsible for carrying out the price policy is BULOG (Food Logistic Board). BULOG maintains the stock necessary to keep the rice price above the floor price and below the ceiling price. The direct tool is through market sales when the retail price exceeds (or threatens to exceed) the ceiling price, and through purchases of rice in rural areas to maintain the floor price at harvest time. The indirect tool is rice distribution, as payment in kind, to the military personnel and civil servants.

BIMAS. Following several seasons of successfully operated small, localized extension programs, the government initiated the national BIMAS (Bimbingan Massal or Mass Guidance) program in the 1965—66 wet season, covering 172,500 ha, In the years since the program has changed form and expanded in response to improvements in the government's ability to coordinate a large multifaceted program, the availability of inputs and the means to distribute them, the changes in the production technology and deficiencies in earlier versions of the program.

The objective of the BIMAS program, as a mass extension effort, is to increase agricultural production and farmers' income through crop intensification. The current program version is called the Improved BIMAS and under it, farmers receive loans from village units organized by Bank Rakyat Indonesia. A village unit consists of about four adjoining villages covering 600 to 1,000 ha farmed by 1,800 to 3,000 farmers. Loans are made to individual farmers in the form of vouchers redeemable for seed, fertilizer and pesticides at a retailer in the village area. An additional cash loan is made to cover living expenses. The current BIMAS packages are presented in Table 8.

Table 8. The BIMAS Biasa and BIMAS Baru input packages (per hectare). Indonesia, 1975.

Contents	BIMAS Biasa		BIMAS Baru	
	Quantity	Value (Rp)	Quantity	Value (Rp)
Seed	-	-	25 kg	1,000
Fertilizer				
Urea	150 kg	12,000	200 kg	16,000
TSP	75 kg	6,000	100 kg	8,000
Insecticides	21	1,800	21	1,800
Spraying	-	2,000	0	2,000
Cost of living	-	3,000	-	3,000
		25,800		31,800

As BIMAS areas were judged capable of functioning without the government credit component, they are converted to INMAS program areas, a less intensive, no credit version of the program. The first INMAS areas were designated in advance of the 1967—68 wet season crop. Combined BIMAS/INMAS

Table 9. Annual BIMAS/INMAS hectarage. Indonesia, 1966—1978.

Year	Area ('000ha)	Year	Area ('000ha)
1966	341	1973	4064
1967	522	1974	4306
1968	1596	1975	4616
1969	2130	1976	4995
1970	2084	1977	5344
1971	2886	1978	5632
1972	3263		

Source: 1966—1973 reported hectarage: Badan *Pengendali* BIMAS, 1975; 1974—1978 target hectarage: *Buku Repelita* II, 1974—1975/1978—79.

hectarages, reported from 1966 to 1973 and targeted from 1974 to 1978 are presented in Table 9.

Within the intensification programs, the BIMAS Baru program produced the highest yields as the data from 1969-1973 show (Table 10). An analysis by van der Goot and Shaw (1975), based on national statistics, attributes an increase of 500—550 kg/ha in realizable genetic potential to the modern varieties directly, and another 12 to 13 kg/ha to nitrogen applied.

Table 10. Rice intensification program yields during REPELITA I (kg/ha, milled rice). Indonesia, 1969—73.

Year	BIMAS Biasa	BIMAS Baru	INMAS Biasa	INMAS Baru
1969	1864	2208	1691	1917
1970	2118	2762	1786	2086
1971	1971	2777	1619	2196
1972	2234	2924	1895	2333
1973	2288	3016	1872	2340

Source: *Buku Repelita* II, 1974—75/1978—79.

Potential rice technology

Although average national yields went up in recent years, it is quite apparent that even in the BIMAS Baru program, yields do not approach the levels obtained in experiments conducted on research stations. For example, from experiments grown in four seasons at several stations on Java yields of Pelita at the 100 kg N/ha level averaged 5.4 t/ha and never dropped below 3,000 kg/ha. In 12 of the 22 cases, yields exceeded 5,000 kg/ha. Even at 0 kg N/ha Pelita yields averaged 3.7 t/ha and were below 3,000 kg/ha in only 7 of the 22 cases.

Experiment station trials using insecticides had similar dramatic responses. In summarizing 69 trials conducted between 1968—1973, CRIA scientists found that the most effective treatment per experiment produced yields 70% higher than the untreated plots (5,180 kg/ha vs. 3,024 kg/ha).

When evaluated on farmers' fields in 1970—71 this new seed—fertilizer—insecticide technology had also demonstrated its potential and reinforced the government's decision to make it available to the rice farmer.

There is little wonder that seed—fertilizer—insecticide technology has been a central element in the government's intensification program. That there has been an impact of this technology on rice yields is unquestioned. The yield statistics in Table 10 demonstrate this impact most noticeably under the BIMAS Baru program. However, there is apparent unexploited yield potential, at least in the non—BIMAS Baru program areas, when national statistics are compared with trials conducted either on experiment stations or on farmers' fields.

OBJECTIVES AND METHODOLOGY

Because increased rice production is a major goal of Indonesian government and because there is an apparent gap between farmers' yields and potential yields under most conditions, investigations have been undertaken to identify and quantify the physical and socioeconomic factors that contribute to the gap. After identifying and quantifying the contributing factors, it is expected that future biological and socioeconomic studies will focus on those factors that should yield the greatest return. Furthermore, production program administrators and policy makers may make program and policy adjustments, if warranted by the outcome of our studies.

As in the other studies reported in this volume, field experimentation and survey methods, coupled with appropriate data analysis techniques, were used to achieve our objectives. Field experimentation, employing factorial designs and a series of management package treatments, is appropriate for identifying feasible techniques for higher yields and the biological factors leading to yield increases. These experiments were conducted on farmers' fields. Of the several treatments included in each experiment, one set of treatment was used to simulate farmers inputs. The fertilizer and insecticide treatments were limited to materials available to the farmer.

Surveys conducted to determine the physical, economic and human resources of the farmers and to characterize the institutional structures in which they operate, were used to understand why farmers did not use the inputs needed to get higher yields and to determine whether higher yields could be economically achieved. Data was collected from the farmers in the villages where field experiments were conducted.

THE STUDY AREAS

Two study areas were used: Kabupaten Kulon Progo, 30 km west of Yogyakarta, and Kabupaten Subang, 175 km east of Jakarta (Fig. 1). Although both are on Java, the general characteristics of the two areas are quite different.

Kulon Progo

Kulon Progo is in the Yogyakarta Special District. Lowland rice yields in the Yogyakarta area are relatively high, averaging 3.4 t/ha as compared to 2.9 t/ha for all of Indonesia in 1974. That yield level reflects good water management, high labor input and substantial fertilizer use. Yogyakarta cropping patterns are relatively diversified with 30% of the staple crop area devoted to rice, compared to 33% in East Java, 44% in Central Java and 71% in West Java. Nonfarm employment is an important income component for many families. Most of the area is well to moderately—well irrigated. Drainage is a minor problem. Roads are good except in the rural valley and hillside villages (Fig. 2).

Fig. 1. Location of study areas, Kulon Progo in Yogyakarta and Subang, Indonesia.

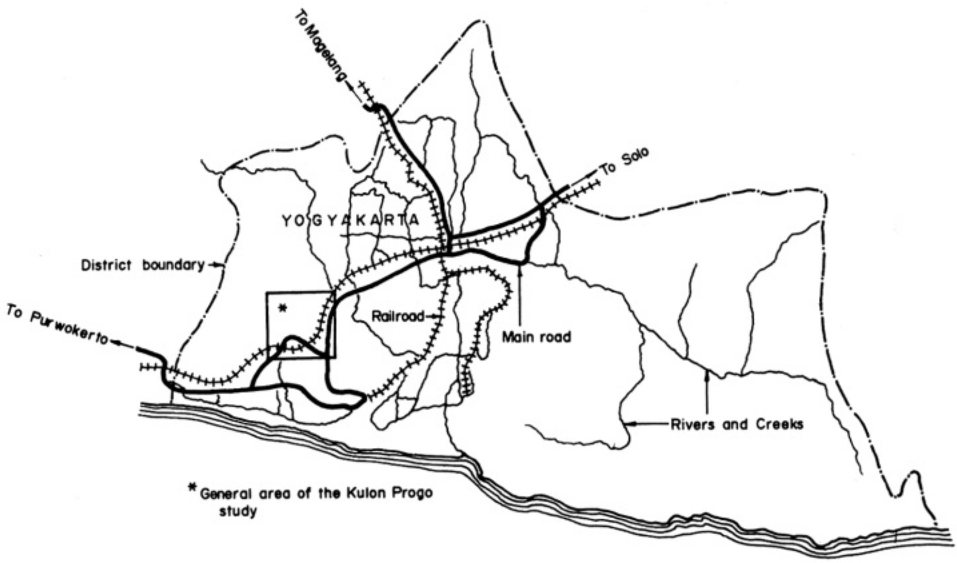

Fig. 2. Map of the Yogyakarta special district.

The Kulon Progo area is close to Gajah Mada University (30 km west), enabling routine visits to the sites by the agricultural faculty staff conducting the investigations. The population density in Kulon Progo is 665/km^2. The farms are small, 0.5 ha on the average, and fields or parcel sizes are extremely small.

Within Kulon Progo, three villages were selected on the basis of irrigation characteristics. Sentolo is located in a flat—to—gently sloping rainfed area between major drainage ways. Sidomulyo is located in a sloping valley area with moderate irrigation. Pengasih is located in a flat, well—irrigated area. The heavy orographic rainfall in mountains to the north is the ultimate source of irrigation water for Sidomulyo and Pengasih.

The three villages are representative of the heavily populated regions found in the high plain and lower mountain valley areas common in Yogyakarta, Central Java, and parts of East and West Java. Average rice yields are high. Land is intensely planted with other crops if conditions are not suitable for growing rice. Sugarcane is commonly grown in rotation with rice on the well—irrigated high plain areas.

The soils of the Yogyakarta study area are productive cambisols, regosols and vertisols. The total area of similar soils in Indonesia is 982,000 ha. About 75% of the area is cultivable.

Climatically, the Kulon Progo area is within category C_2, described by Oldeman (1975) as having 5 or 6 consecutive wet months and 2 to 4 dry months. The C_2 category is found extensively in Central and East Java and parts of West Java.

Subang

The Subang study area is on the north coastal plain of West Java. The average farm size (0.70 ha) is somewhat larger than that commonly found on Java. Except for insignificant fields of secondary crops and house gardens, only rice is grown. Fields in the area are irrigated from two large, recently extended and rehabilitated irrigation systems (Jatiluhur and Rentang, with command areas of 240,000 ha and 91,000 ha, respectively). Population density (448/km^2) is also lower than the Java average. The road network in the area is sparse and, except for the main highway, poorly maintained. During the wet season, rural roads are often impassable except by horse cart or on foot. Lowland rice yields are relatively low (2.8 t/ha). Although the area is extensively irrigated, water control is a problem to farmers. Because natural surface drainage is poor, flooding is common in low—lying areas during the wet season, and a continuous supply of water for the dry season is not guaranteed. Most farmers, however, attempt a second crop of rice, even in areas scheduled for water only 7 months of the year.

The Subang study area has the advantage of being close to CRIA's Pusakanegara sub—station, a small station that has been a center of many entomology studies because of the high incidence of stem borers and gall midge. Variety trials, fertilizer trials and other cultural management experiments are commonly conducted on the station, providing a data base for treatment selection for the Subang study. Moreover, the station has a well—instrumented meteorological facility from which weather data can be obtained.

Although yields are relatively low, the conditions of the Subang area are quite similar to those found in major rice areas elsewhere in Indonesia. The soils of the area are generally medium— to find—textured gleysols. Climatewise, the Subang area falls just within category E, (Oldeman, 1975) with less than 3 consecutive wet months and at least 5 dry months. However, because irrigation is available for 7 or more months during the year, other climatic parameters are of greater significance to cultivation and in many respects the area is similar to other major rice growing areas along the entire north coast of Java and major river flood—plain areas of East Java, which are classified in categories C_3 and D_3.

The combined Jatiluhur—Rentang systems, with 330,000 ha irrigated, and a 170% cropping intensity, constitutes roughly 14% of Java's harvested area. Most of the production area within the command area of the two irrigation systems possess biological, physical and socioeconomic features similar to those found in Pusakanegara area of Subang.

QUANTIFICATION OF YIELD CONSTRAINTS: THE KULON PROGO CASE

Experimental sites were selected in three villages chosen on the basis of levels of water control.

1. Good irrigation area -- area in which lowland rice is grown two times per year (Pengasih village).

2. Moderate irrigation area -- area in which lowland rice is grown one time per year (Sidomulyo village).

3. Rainfed area (Sentolo village).

During 1974—75, the weather was typical of the normal weather conditions in the area. Rainfall was at a minimum during July—September but increased to about 300 mm/month during December, January, February and March when the main season crop was grown. Solar radiation remained at a fairly high level throughout the year, unlike in some parts of Asia where it varies inversely with rainfall.

All sites were typical of the villages in which they were located, and all were in the same great soil group. In a "normal" season, there are usually few occurrences of heavy insect and disease damage. But in this season, there were serious pest and disease incidences in Pengasih, including stem borer, gall midge and Helminthosporium leaf spot.

Selection of experimental factors and design, wet season 1974-75.

From experience elsewhere fertilizer seemed to be the most important factor required for high yields, followed by pest control and weeding. Therefore in our experiments we chose fertilizer, pest control and weeding as the main factors to be studied.

A two—level factorial experiment was used to calculate the contribution of individual components of improved technology to the gap between actual and potential yields. A management package trial was used to assess the economic benefits over a range of factor combinations. A combined factorial—management package experiment was designed in which treatment combinations were reduced to as few as possible. The high levels of all variable factors constituted the highest management package, and the low levels of all variable factors constituted the lowest management package with variables combined at intermediate levels to form other management packages.

A total of 12 treatments having various levels of the three factors were tested. The 12 treatments consisted of

1. Eight complete factorial treatment combinations with each factor alternatively at the M_5 and M_1 levels, and

2. Four management package treatments above the farmer's level (Table 11).

The M_1 level was designed to simulate input levels and methods used by most farmers. The M_5 level was planned as the maximum yield level at which all factors were set at levels sufficient to overcome all yield constraints.

Three replications of a randomized complete block design were conducted in each of the three villages. The total number of plots per village was 36. Plot size was 20 m^2, giving a net harvest area of not less than 6 m^2.

Table 11. Treatments in the management package and yield constraints experiments[a] on three farms. Kulon Progo, Indonesia, wet season 1974—75.

Treatment level	Fertilizer (kg/ha) N[b]	P_2O_5[c]	Hand weeding	Insect control no. sprays Diazinon[d]
Sentolo, M_1	90	35	2	0
Sidomulyo, M_1	45	23	2	0
Pengasih, M_1	45	23	2	0
All sites, M_2	69	0	2	3
All sites, M_3	92	25	3	4
All sites, M_4	115	50	4	5
All sites, M_5	138	75	5[e]	6[e]

[a]Variety is Pelita I/1.
[b]1/3 as basal, 1/3 4 weeks after transplanting, 1/3 at panicle initiation in experiment.
[c]As basal in experiment.
[d]2 ml a.i./liter water; 3 sprayings at 2, 6, 10 weeks after transplanting (WAT); 4 sprayings at 2, 6, 8, 10 WAT; 5 sprayings at 2, 4, 6, 8, 10 WAT; 6 sprayings at 2, 4, 6, 7, 8, 10 WAT.
[e]The number of treatments shown plus as many additional as needed to maintain weed and insect free conditions (the latter proved impossible in one site).

An analysis of variance for the complete factorial treatment combinations was computed. The yield gap resulting from each factor was calculated from the main effects. The contribution of each factor, at the low levels and high level of other factors was calculated as the simple effect.

Results of the experiments

Grain yield data for management package experiments on farmer's field in three villages of Kabupaten Kulon Progo are shown in Table 12.

Serious pest and disease damage occurred in the experiment. The grain yield of each management package treatment in the rainfed area (Sentolo) was higher than the corresponding package yield in the other two sites, which had moderate and good irrigation, respectively. Production of *palawija* (second crops) may be a factor influencing crop response to treatments because farmers in Sentolo cannot grow rice twice a year because of insufficient water. Following wet season rice, Sentolo farmers plant *palawija* and leguminous plants as green manure. The gap between farm level and the highest yield varied from 0.7 t/ha to 1.8 t/ha (in Pengasih and Sentolo respectively).

Table 12. Grain yield data (t/ha) of management package experiments in farmers' fields in three villages. Kulon Progo, Indonesia, wet season, 1974—75.

	Sentolo	Sidomulyo	Pengasih
M_1	5.4	4.4	2.8
M_2	4.5	4.5	2.9
M_3	5.5	5.0	3.5
M_4	6.3	5.0	2.8
M_5	7.2	5.3	3.2
LSD (.05)	0.76	0.43	ns

[a] The M_1 level yield was obtained from the F_1 W_1 I_1 treatment combination.

Table 13. Grain yields from crop cutting on farmers' fields carried out in study villages. Kulon Progo, Indonesia, 1974—75.

Village and hamlet	Pelita I/1			Local & national improved varieties		
	Number of crop cuts	Mean yield	Standard deviation of yield	Number of crop cuts	Mean yield	Standard deviation of yield
			Wet season 1974—75			
Sentolo						
Jlaban	7	5.6	1.6	3	4.4	1.4
Banaran	2	4.9	0.4	8	4.1	0.4
Sidomulyo						
Dukuh	1	5.3	na	9	3.2	0.6
Parakan	2	5.1	1.5	8	3.8	1.0
Pengasih						
Pengasih	6	4.7	0.7	4	5.5	0.4
Clawer	4	5.3	0.9	6	4.9	0.5
			Dry season 1975			
Pengasih						
Pengasih	6	5.1	1.7	6	5.5	1.4

The yields obtained by other farmers in the same villages can be seen from crop cutting data in Table 13. The yields are similar in ranking to the M_1 yields in the experiments, which supports our opinion that a good cropping system is an important factor that can influence yield. For Pengasih and Sidomulyo, farmers yields as found by crop cutting were higher than the M_1, perhaps reflecting the insect and disease damage to our sites.

Pelita I/1 produced higher yields than local varieties (Table 13). In Pengasih hamlet, yields of local varieties were higher than Pelita I/1. In that hamlet, local varieties appeared more resistant than modern varieties against the insects and diseases found in the area. In general, in Pengasih village the yield of modern and local varieties were relatively equal but modern varieties appeared more susceptible to pest and disease incidence.

Table 14 shows the results of the analysis of variance, At all sites fertilizer significantly increased grain yields. Plots receiving high levels of fertilizer gave increases from 0.5 t/ha (Sentolo and Sidomulyo) to 1.0 t/ha (Pengasih) over plots receiving the farmers' level of fertilizer (Table 15).

Table 14. Summary of ANOVA table (variances) on grain yields in factorial treatments. Kulon Progo, Indonesia, wet season 1974—75.

Source of variation	Sentolo	Sidomulyo	Pengasih
Fertilizer(F)	577.43[a]	181.28**	671.61**
Weed control (W)	43.44	12.10	8.78
Insect control (I)	28.70	7.44	140.94*
F/W	179.76*	12.13	7.69
F/I	63.56	19.62	214.69**
W/I	2.70	8.52	37.89
F/W/I	.27	2.55	1.70
Error	37.53	9.75	22.15
CV	9.98%	6.45%	14.18%

[a]Significance determined by F—test.
*Significant at the 5% level.
**Significant at the 1% level.

In the Pengasih experiment, insect control also gave a significant effect. However, in Table 15 we see that in Pengasih, a high level of insect control decreased the yield by 0.5 t/ha. In Pengasih the yield decrease caused by the high level of insect control was greater at the high level

Table 15. Average contribution of three inputs toward increasing rice yields in yield constraints experiments at three locations. Kulon Progo, Indonesia, wet season 1974—75

Site	Grain yield (t/ha)			Contribution (t/ha) from			
	Farmers inputs	High inputs	Difference	Fertilizer	Insect control	Weed control	Residual
Sentolo	5.4	5.9	0.5	0.5	0.2	—0.3	—0.1
Sidomulyo	4.4	5.1	0.7	0.5	—0.1	0.1	0.2
Pengasih	2.8	3.0	0.2	1.0	—0.5	—0.1	—0.2

of other inputs than at the low level of other inputs (1.2 t/ha vs 3.3 t/ha), resulting in the significant negative interaction between fertilizer and insect control.

Damage levels for major insects and diseases found in the experiments are presented in Table 16. Helminthosporium and gall midge damage in Pengasih were higher than at either of the other two villages. Inspection of the data indicated that there was a relationship between gall midge incidence and treatments in Pengasih. Analysis of covariance suggests that gall midge attacks are higher where insecticides have been applied, that the attacks may have been exacerbated by high fertilizer applications and that the attacks caused yield losses.

Table 16. Damage levels caused by insect and diseases in three experiment sites. Kulon Progo, Indonesia, wet season, 1974—75.

	Age (DAT)[a]	Damage levels (X) at farmer's level (M_1)		
		Stem borer	Gall midge	Helminthosporium
1. Pengasih	30	2.75	10.2	60.8
	60	2.40	17.3	65.9
	90	0.47	0.0	n.r.[b]
2. Sidomulyo	30	3.30	0.0	21.6
	60	2.70	0.0	18.3
	90	0.00	0.0	n.r.
3. Sentolo	30	0.00	3.2	11.3
	60	11.40	1.6	28.6
	90	0.00	0.0	n.r

[a] DAT = days after transplanting.
[b] n.r. = no report.

The gap between farmers inputs and high inputs varied from 0.2 t/ha to 0.7 t/ha. The major contribution toward increasing rice yield was fertilizer and its effect at low levels of the other inputs was greater than at the high levels of the other inputs.

Selection of sites and design of experiments, 1975 dry season

In the 1975 dry season, experiments were conducted only in the good irrigation area (Pengasih village). Two sites are chosen to represent different hamlets (Pengasih and Serut hamlets) but were located on the same large rice field.

The same basic treatments were used in the 1975 dry season experiments as in the earlier experiments. An improvement was introduced by using the concept of integrated pest control in the insecticide treatments. Because integrated control is a difficult concept for farmers to implement, we tested it only in the M_5 treatment.

A total of 13 treatments with varying levels of fertilizer, weed control and pest control were tested. The 13 treatments consisted of two levels of three factors in a complete factorial with factors arranged in a split—plot design (Table 17) and five management package treatments (Table 18).

Table 17. Factorial treatments tested in experiments on farmers fields. Kulon Progo, Indonesia, dry season, 1975.

No.	Treatment combination[a]	No.	Treatment combination
1.	$P_1F_1W_1$	5.	$P_4F_1W_1$
2.	$P_1F_1W_4$	6.	$P_4F_1W_4$
3.	$P_1F_4W_1$	7.	$P_4F_4W_1$
4.	$P_1F_4W_4$	8.	$P_4F_4W_4$

[a] P_1 = No pest control, F_1 = 45 kg N/ha, 23 kg P_2O_5/ha, and W_1 = 2 hand weedings.

P_4 = spray by surecide 25 ec at 30 and 50 days after transplanting with dose 3 cc/liter, 400—500 liters solution/ha; Sevin 85 sp at 70 days after transplanting with dose 3 gr/liter, 400—500 liters/ha; Ditane at 30 days after transplanting, 3 gr/liter, 400—500 liters/ha. W_4 = hand weeding at 30, 40, 50, and 60 days after transplanting, F_4 = 115 kg N/ha = 50 kg P_2O_5/ha.

Table 18. Management package treatments tested in experiments on farmers' fields. Kulon Progo, Indonesia, dry season 1975.

	Treatment combination[a]		
Code	Pest control	Fertilizer	Weed control
M_1	0	45 kg N/ha + 23 kg P_2O_5/ha	2 HW
M_2	Surecide 25 ec at 30 days AT, 3 cc/l, 400—500l/ha	69 kg N/ha + 25 kg P_2O_5/ha	2 HW at 30 and 50 DAT
M_3	Surecide 25 ec at 30 and 50 days AT, 3 cc/l, 400—500l/ha	92 kg N/ha + 25 kg P_2O_5/ha	3 HW at 30, 45 and 50 DAT
M_4	Surecide 25 ec at 30 and 50 days AT, 3 cc/l, 400—500l/ha Sevin 85 sp at 70 days AT 3 gr/l, 400—500l/ha Ditane at 30 days AT, 3 gr/l, 400—500l/ha	115 kg N/ha + 50 kg P_2O_5/ha	4 HW at 30, 40, 50 and 60 DAT
M_5 [b]	Full control (integrated control)	138 kg N/ha + 25 kg P_2O_5/ha	clean weeding (free from weeds)

[a] Variety Pelita I/1
Fertilizer: nitrogen as urea in three split doses: 1/3 as basal application, 1/3 was applied at 4 weeks AT and 1/3 at panicle initiation; P_2O_5 as triple superphosphate as basal application.
HW = hand weeding, DAT = Days after transplanting.

[b] The meaning of full pest control in this experiment is integrated control. It means that controlling by insecticide would be done only if the situation need it. The method required continuous observation (every week) in the field according to predict the pest incidence (outbreak). If the level of pest incidence reached the critical point, the best insecticide treatment was used.

Results of the 1975 dry season experiments. Grain yield data of the management package treatment is in Table 19. The response to these treatment packages appear linear at both sites.

The ANOVA on grain yield from the factorial treatments is shown in Table 20. As with results of the wet season 1974—75 experiments, the fertilizer treatment was statistically significant. The high fertilizer level increased grain yield by 0.8 to 1.2 t/ha over farmer's fertilizer level (Table 21).

Table 19. Grain yield data (t/ha) of management package experiments in farmers fields. Kulon Progo, Indonesia, dry season 1975.

Package	Site 1	Site 2
M_1	2.5	3.4
M_2	2.9	3.8
M_3	3.1	4.5
M_4	4.5	4.1
M_5	5.0	6.3
LSD (.05)	ns	1.4

Table 20. Summary of ANOVA (mean squares variances) for grain yields in factorial treatments. Kulon Progo, Indonesia, dry season 1975.

Source of variation	Pengasih	Serut
Pest control (P)	.88	100.00
Main plot error	61.03	1.56
Fertilizer (F)	234.47**	364.06*
Weed control (W)	11.81	126.56
F x W	28.23	3.52
Sub plot x p	12.86	140.89
Sub plot error	15.86	54.62
CV (%)	14.16	23.73

*Significant at the 5% level.
**Significant at the 1% level.

Table 21. Average contribution of three inputs toward increasing rice yield in yield constraints experiments in two sites. Kulon, Progo, Indonesia, dry season 1975.

Site	Grain yield (t/ha)			Contribution (t/ha) from			
	Farmers inputs	High inputs	Difference	Fertilizer	Insect control	Weed control	Residual
Pengasih	2.8	4.0	1.2	0.8	0.0	0.2	0.2
Serut	2.3	3.7	1.4	1.2	−0.5	0.6	0.1

The yield gaps between the high input level and farmer's input level were 1.2 t/ha in Pengasih hamlet and 1.4 t/ha in Serut hamlet. Thus, increased input use increased yields significantly even though the main effect of weeding and pest control were not statistically significant.

Summary of major biological constraints

Analysis of the wet season data showed that low fertilizer use was the factor most significantly contributing to the yield gap. The effect of fertilizer was most noticeable when other factors were used at low rates. Although phosphorus may play a role, nitrogen was most likely the major source of additional yield arising from the fertilizer treatment.

Neither increases in the frequency of hand weeding nor in the amounts of insecticide applied increased yields. Therefore those factors are not considered constraints. In fact, in Pengasih where gall midge levels were high, a yield decrease was attributed to an increase in insecticide application.

The Pengasih fertilizer—insecticide interaction was statistically significant and inspection of the data showed that at the high fertilizer rate, yields decreased by 1.1 t/ha when the high insecticide rate was used. Other studies have shown that parasites and predators play an important role in limiting the population growth of some insect pests. Investigations have shown that some insecticides have a differential effect on species and in this case gall midge predator and parasite populations may have been more reduced than the gall midge population.

The yields from the Sentolo experiment were about double those in the Pengasih experiment. It is believed that the Sentolo results are slightly higher than those obtained by Sentolo farmers growing Pelita with comparable inputs, while the Pengasih results are substantially lower than obtained by Pengasih farmers growing Pelita with comparable inputs. These assessments are supported by crop cut yields obtained in the two villages. For Sidomulyo, the experimental results seemed comparable to crop cutting results. It is believe that the experimental results found in the wet season and the conclusions drawn from them give a reasonable indication of the behavior of the inputs under general farm conditions.

In the dry season, both experiments conducted in Pengasih pointed to fertilizer use as a constraining factor. Although not statistically significant, the pesticide treatment resulted in no increase yield in one case and a yield loss in the other. In Serut, there was again a yield loss under the high pesticide rate when used at the high fertilizer rate. Unlike the wet season, a possible important response to increased weed control was observed under the high fertilizer rate. The input response found in those two dry season experiments is believed to be typical of the response that would be experienced by most farmers in the Pengasih area if they were to apply similar levels of inputs. However, it should be noted that experiment yield levels were lower than crop cut yield results. The block in which the experiments were conducted was affected by Helminthosporium for two seasons, which may be either reducing yields directly or reflecting nutritional deficiencies, that reduced yields.

Economic analysis of biological constraints

The higher yields that were obtained from the high input levels, of course, cost more than the farmers' levels of input. In the 1974—75 wet season, the experimental farmer in Sentolo spent Rp 31,180 for the fertilizer and weed control inputs used (Table 22). The two farmers with experiments in Sidomulyo and Pengasih spent Rp 19,160 for their inputs. The costs of M_5 were Rp 66,080 in both Pengasih and Sidomulyo and Rp 69,070 in Sentolo, which had a higher wage rate.

Table 23 shows the prices paid for inputs by farmers in the area. The prices increased somewhat after the wet season but even after the increase, a heavy government subsidy remained on fertilizer and insecticide prices.

From Table 24 it can be seen that in the wet season in Sentolo M_3 cost more than farmer's level. The Rp 10,000 additional cost gave only Rp 7,000 additional return. But, with the M_4 and M_5 level packages the additional cost was less than the additional return. In Sidomulyo and Pengasih, M_3 had the highest net return.

Table 22. Cost of input packages (000 Rp/ha) in three villages. Kulon Progo, Indonesia.

Package	Fertilizer		Insecticide		Weeding	Total
	Labor	Material	Labor	Material		
			Sentolo 1974—75 wet season			
M_1	4.68	18	0	0	8.5	31.18
M_2	2.34	9	4.2	2.7	8.5	26.74
M_3	3.90	15	5.6	3.6	12.75	40.85
M_4	5.46	21	7.0	4.5	17.00	54.96
M_5	7.02	27	8.4	5.4	21.25	69.07
			Sidomulyo and Pengasih 1974—75 wet season			
M_1	2.16	9	0	0	8.0	19.16
M_2	2.16	9	3.6	2.7	8.0	25.46
M_3	3.60	15	4.6	3.6	12.0	39.00
M_4	5.04	21	6.0	4.5	16.0	52.54
M_5	6.48	27	7.2	5.4	20.0	66.06
			Pengasih 1975 dry season			
M_1	2.52	9	0	0	9.0	29.21
M_2	2.52	9	1.6	1.8	9.0	33.13
M_3	4.20	15	3.2	3.6	13.5	38.38
M_4	5.88	21	6.4	7.58	18.0	43.13
M_5	7.56	27	9.6	11.76	27.0	55.94

Table 23. Prices of input and output, Kulon Progo, Indonesia, 1974—75.

Item (Units)	Wet season 1974—75	Dry season 1975
Urea 6 TSP (Rp/kg)	60	60
Diazinon (Rp/lt)	900	900
Surecide	n.r.	1,200
Labor: Sidomulyo and		
Pengasih (Rp/day)	150	200
Sentolo	200	250
Rough rice (Rp/kg)	60	80

But the 1975 dry season experiment in Pengasih shared a much different result. The highest level management package gave the highest net return and, at all levels of management packages, the additional return substantially exceeded the additional cost. Similar results were obtained from share—tenant budget analyses. In the dry season, M5 seems to be a reliable package to recommend. Additional inputs costing Rp 27,000 gave an additional return of Rp 200,000 - 230,000 for owner operators or Rp 118,000 - 144,000 for share tenants.

From Table 25 we can see that fertilizer gave excess returns over costs in all sites and seasons. The highest excess was obtained in 1975 dry season. Sidomulyo (wet season) had the lowest ratio. The weeding in 1975 dry season gave excess returns over costs in Pengasih 2, but not in Pengasih 1 or at any site in the wet season. Insect control did not have any beneficial effect at any sites in any season and in fact led to substantial losses on two occasions.

IDENTIFYING SOCIOECONOMIC CONSTRAINTS: THE KULON PROGO CASE

The objective of this aspect of the research is to determine factors explaining why farmers are not using the inputs that increased yields -- in this case higher rates of fertilizer. It is hypothesized that factors such as irrigation, input availability, credit limitations, lack of incentive due to tenure status, farm size, etc., influence fertilizer use.

Methodology

Surveys were carried out in the same three hamlets where the experiments were conducted plus three other hamlets matching the first three in physical environment but different in terms of distance from input market and processing facilities. For each irrigation level, a pair of hamlets were selected -- one hamlet relatively near the input market and processing facilities and the other hamlet relatively far from them (Table 26).

Table 24. Economic comparison of four levels of input management package in experiment on farmers' fields. Kulon Progo, Indonesia.

Input package level	Increase over farmers' level				
	Yield (kg/ha)	Gross return ('000 Rp/ha)	Cost* ('000 Rp/ha)	Owners' net return ('000 Rp/ha)	Share tenant's net return ('000 Rp/ha)
		Sentolo 1974—75 wet season			
M_2	—867	—52	—4	—42	—19
M_3	124	7	10	—3	—6
M_4	943	56	24	26	1
M_5	1786	107	38	57	10
		Sidomulyo 1974—75 wet season			
M_2	92	5	6	-1	—4
M_3	630	38	20	13	—3
M_4	615	37	33	-1	-17
M_5	907	54	47	1	—23
		Pengasih 1974—75 wet season			
M_2	98	6	6	-1	—4
M_3	737	44	20	18	-1
M_4	69	4	33	—30	—32
M_5	410	25	47	—26	—36
		Pengasih 1, 1975 dry season			
M_2	379	30	4	22	9
M_3	625	50	9	34	12
M_4	2000	160	14	123	55
M_5	2500	200	27	145	59
		Pengasih 2, 1975 dry season			
M_2	375	30	4	22	9
M_3	1125	90	9	68	29
M_4	750	60	14	37	12
M_5	2875	230	27	170	77

*Does not include cost of harvest, so owners' net return is not the difference between added return and cost.

Table 25. Farmers' cost, increased cost and increased value of output ('000 Rp/ha) from high level of input compared to farmers' levels. Kulon Progo, Indonesia.

Items	1974—75 wet season			1975 dry season	
	Sentolo	Sidomulyo	Pengasih	Pengasih 1	Pengasih 2
Fertilizers					
Farmers' level cost	22.68	11.16	11.16	11.52	11.52
Increased cost	11.34	32.32	22.32	23.04	23.04
Increased value	32.8	32.9	63.5	61.3	93.5
Insect control					
Farmers' level cost	0	0	0	0	0
Increased cost	13.8	12.6	12.6	21.38	21.38
Increased value	13.4	—6.7	—29.6	—3.7	—40
Weed control					
Farmers' level cost	8.5	8	8	9	9
Increased cost	12.75	12	12	18	18
Increased value	—16.4	8.5	—7.3	13.7	45

Table 26. The average distance from depot of input and rice mill (in kilometers). Kulon Progo, Indonesia, 1974—75.

Distance	Good irrigation	Moderate irrigation	Rainfed
Closer	(1) Pengasih	Dukuh	Jlaban
	(2) .84	2.29	1.21
	(3) 1.75	6.08	1.00
Farther	(1) Clawer	Parakan	Banaran
	(2) 2.07	6.00	2.50
	(3) 2.50	8.73	2.35

Note: (1) the name of the hamlet
(2) the distance from depot of input
(3) the distance from rice—mill

The experiment sites were selected in an area which had not yet been planted by the time preparation for the project was completed. Therefore, this area may not be truly representative of rice growing areas in Yogyakarta region, but many of the problems confronting farmers in the chosen area are common to other areas of Yogyakarta.

Because input depots have been well spread out by the intensive BIMAS program, choosing the hamlets was not as simple as we first thought. Distances to input depots were not as far nor as consistent in distance among villages as desired.

A complete enumeration presurvey was conducted to describe the population in each hamlet and to get information about tenure status and farm size to use in sampling.

There were 477 families in six hamlets of which 86% were farmers -- ranging from 60% in Pengasih to 100% in Parakan. Only 52% were rice farmers.

We stratified the population into three strata by tenure status -- owner—operators, share—crop tenants and cash—rent tenants. The owner—operators were the most numerous.

The average size of the rice farms of all six hamlets was 0.18 ha. We stratified the rice farmers into three classes -- small farmers (less than 0.1 ha), medium farmers (0.1 ha up to 0.5 ha), and large farmer (0.5 ha or more). (These strata may not be appropriate for other parts of Java.) The sample of farms was chosen in proportion to the size—tenure categories in each hamlet,

In the dry season, only two hamlets in the good irrigation area (Pengasih village) were surveyed. Those hamlets, Serut and Pengasih, corresponded to the location of the dry season experiments. There were only 17 rice farmers in Serut, making the total of sample farms only 37 for the dry season.

The sampling was essentially proportional sampling. To the extent that it was not precisely proportional, the population proportion was used to weight the samples.

Data collection and analysis. The questionnaire was designed to search for the factors affecting the adoption of new rice technology. Individual interviews were used to collect the data from the farmer respondents. The data were then grouped according to hamlet. Contingency tests and regression analyses were used to analyze the relation between the level of input used and a number of variables that might affect it, such as tenure, farm size, water problems, varieties, credit and input availability, agricultural extension, education, technical knowledge, traditional beliefs, and adoption of technology. Linear regression models were developed to examine adoption of technology.

Descriptions and comparisons of the three villages

The average farm size was largest (0.29 ha) in the moderate irrigation sample and smallest (0.14 ha) in the good irrigation sample. Farm size in the

Table 27. Rice farm size and inputs used per hectare. Kulon Progo, Indonesia, 1974—75.

Hamlet	Rice farm size (ha)	Fertilizer Urea (kg)	Fertilizer TSP (kg)	Pesticides (liters) Diazi-non	Pesticides (liters) Others	Seeds (kg)	Labor[b] (w.h.)	Animals (w.h.)
				Pengasih (GI)[a]				
Pengasih	.14	140	59	.44	.02	59	2,410	34.50
Clawer	.14	134	103	.57	.00	45	2,065	11.91
Average	.14	137	81	.50	.01	52	2,237	23.20
				Sidomulyo (MI)				
Dukuh	.20	53	48	.03	.0	47	2,846	.0
Parakan	.38	54	18	.21	.0	43	2,741	14.80
Average	.29	53	33	.12	.0	45	2,793	7.40
				Sentolo (RF)				
Jlaban	.18	221	38	.0	.0	45	2,610	39.30
Banaran	.21	158	99	.0	.0	48	3,067	31.66
Average	.19	189	68	.0	.0	46	2,838	35.48

[a] GI = good irrigation, MI = moderate irrigation, RF = rainfed.
[b] w.h. = work hours.

rainfed sample was 0.19 ha (Table 27). These sample averages were close to the average of the population from the presurvey data. The population averages were 0.25 ha in the moderate irrigation area, 0.13 ha in the good irrigation area and 0.21 ha in the rainfed area.

The highest level of fertilizer (urea + triple superphosphate) was used in the rainfed area (259 kg/ha). The good irrigation area used slightly less fertilizer. The least fertilizer was used in the moderate irrigation area.

Pesticide was used only in irrigated areas, although only in small amounts. In the rainfed area the pest problem was apparently partially controlled by the break in rice production (fallow) during the dry season. The amount of seed used was almost the same in all areas -- between 45 and 52 kg/ha.

Labor use was highest in the rainfed area, but the differences between villages were small. Also, animal use was highest in the rainfed area. There were greater differences in animal compared to labor use between the villages. The greater input (man and animal) for land preparation might result from difficulty in puddling soil after an upland crop or a greater concern to reduce percolation under nonirrigated conditions. The least animal use was in the moderate irrigation area where animals were less suited for the hilly, terraced topography.

Table 28 shows that urea use in hamlets closer to input depots was high, while TSP use was low. However, the sum of urea and TSP was about the same for both distant and close areas (186 and 188 kg/ha). About the same relationships hold for other inputs -- seed, pesticide, labor, and animal work. The simple correlation between distances and average fertilizer levels for the six hamlets was not significant. It appears that for this sample purchased input use was unrelated to distance from the depots.

Table 28. Input used and the distance from market facilities. Kulon Progo, Indonesia, wet season 1974—75.

Kind of input	Close	Distant
Urea (kg/ha)	138	115
TSP (kg/ha)	48	73
Diazinon (l/ha)	.15	.26
Other pesticides (1/ha)	.0	.0
Seeds (kg/ha)	50	45
Labor (work hours)	2,622.57	2,624.61
Animals (work hours)	24.60	19.45

From Table 28 it is apparent that there are distinctly lower fertilizer input levels in the Sidomulyo hamlets (moderate irrigation). The distance factor for the two hamlets in Sidomulyo is compounded by lack of horsecarts, tricycles, (becak) and motorized vehicles serving the area. Because of poor roads almost all materials must be carried in by people or bicycles. In contrast, the hamlets in the Sentolo area (rainfed area) are served by a major highway, with access to frequent and rapid transportation. Pengasih hamlets also have exceptionally good roads. Thus, quality of transportation facilities do seem to have an input on fertilizer use.

Sidomulyo had the lowest average yields in the three villages judging from farmer interviews, crop cuttings, and experiments (Table 29). Highest average yields according to crop—cut data were in Pengasih, but according to interview responses and experiment results, Sentolo had the highest yields. Only 10 crop cuttings were made, compared to yield estimates given by 40 farmers through the interviews. Thus the interview data might be more valid in making comparisons between villages, especially if respondent biases were of the same magnitude and direction in each village.

Pengasih, under good irrigation, had lower yields than Sentolo, which is rainfed. Sidomulyo, with moderate irrigation, had the lowest yield. Differences in villages yields obviously are not due to the water—control

Table 29. Average and standard deviations of yield, input use and related factors, farm samples in the three villages. Kulon Progo, Indonesia, wet season 1974—75.

	Pengasih		Sidomulyo		Sentolo	
	x	S	x	S	x	S
Yield						
Survey data	26.8	12.87	24.07	6.1	32.38	9.16
Crop cutting	50.62	5.14	37.03	10.19	47.66	10.21
Experiment	31.46	5.84	48.47	3.43	60.09	7.11
Urea (kg/ha)	141	94	54	49	192	103
TSP (kg/ha)	a4	78	28	69	69	92
Pesticide (l/ha)	.52	1.01	.11	.39	0	0
Modern varieties (X of farmers)	55		10		45	
Excess water (% of farmers)	20		75		5	
Shortage water (% of fanners)	12.5		2.5		92.5	
Rice farm size (ha)	.13	.13	.29	.42	.19	.16
Technical knowledge scores	29.08	5.02	20.85	7.49	24.05	6.89
Credit availability scores	2.4	.99	2.23	.60	1.03	1.31
Agricultural extension scores	.45	.88	.2	.79	.7	.97
Traditional belief score	—1.58	1.22	-.98	1.42	-.1	.84
Adoption of technology	38.05	4.99	31.6	10.11	34.6	6.15
Input availability	.9	.41	.40	.67	.98	.16

levels alone. Several other factors, such as the cropping patterns, fertilizer use, varieties, pest damage, technical knowledge, traditional belief and use of improved cultural practices, may all play a role (Table 29).

Sidomulyo farmers used less fertilizer and modern varieties, had lower indexes of technical knowledge, agricultural extension, adoption, and input availability. Those factors may be attributable to poor transport and communication facilities, which may also be why the area is not covered by the BIMAS program.

Insects and diseases were more of a problem in Pengasih than in other villages, which gave Pengasih greater yield variability. The coefficient of variability was 0.48 in Pengasih, compared to 0.25 and 0.28 in Sidomulyo and Sentolo, respectively. The distribution of rice fields in Sentolo and Sidomulyo is less contiguous if compared to Pengasih. Furthermore, no rice is grown in Sentolo during the dry season and the area grown in Sidomulyo during the dry season is a fraction of that grown in the wet season. Thus, conditions for the buildup and maintenance of high pest pressures are not as favorable in Sidomulyo and Sentolo as they are in Pengasih. The small amount of insecticide use reported in the survey was concentrated in the irrigated area, apparently because of the greater insect threat.

Yield averages estimated from sample—farmer responses given for the previous 5 years in Pengasih, Sidomulyo and Sentolo were 2,649, 2,068, 2,331 kg/ha, respectively for the wet seasons (Table 30). These 5—year means suggest that the good irrigation in Pengasih is only slightly more beneficial than the rainfed conditions of Sentolo. However, year—to—year fluctuations in Sentolo were much more noticeable than in Pengasih, despite a greater farm—to—farm variation in that well—irrigated area, which has been attributed to random within—year insect and disease attacks.

Table 30. Yield history from survey data (kg/ha). Kulon Progo, Indonesia.

	Pengasih		Sidomulyo		Sentolo
Years	Wet season	Dry season	Wet season	Wet season	season
1970		2380		1790	
1970—71	2901	2304	1911	1782	2120
1971—72	2661	1921	2000	584	2203
1972—73	2589	2251	1694	2027	1486
1973—74	2412	2455	2326	2119	2616
1974—75	278		2407		3228
Average	2649	2262	2068	1660	2331

Comparison of experimental farmers and average farmers

Land resources. Land holdings in the survey area are generally less than 0.2 ha. However, some progressive farmers and local village government officials have farm sizes of more than 2 ha. There was a significant difference between the farm size of the average farmers and the cooperators on whose land experiments were conducted.

Farm size affects farming efficiency, farm productivity and farmer attitude. Generally the cooperators were more progressive and more dynamic than the average farmer, and more capable of accepting the risks of farming.

Input use. There were differences in production costs among the average of all farmers growing modern varieties, those farmers growing local varieties and the inputs used by the cooperating farmers (Table 31).

The average farmer reported higher levels of nitrogen and phosphate fertilizer on modern varieties than that used by experimental farmers (M_1). For local varieties, nitrogen fertilizer levels were lower than the corresponding M_1 nitrogen level in Sidomulyo and Sentolo villages, but higher in Pengasih.

In the 1974—75 wet season, farmers were not using input levels with the highest net returns as identified in the management package experiments. From Table 32, it is seen that in Sentolo the divergences were greater

Table 31. Comparison of input used per hectare of cooperating and average farmers. Kulon Progo, Indonesia, wet season 1974—75.

	Urea (kg)	TSP (kg)	Diazinon (1)	No. of weeding	Labor and animal cost (Rp)
Pengasih					
Experiment M_1	100	50	.0	2	28,541.66
Farmers' high yielding variety	146	91	.7	2.1	35,499.10
Farmers' local variety	112	83	.0	2	29,294.17
Sidomulyo					
Experiment M_1	100	50	.0	2	28,541.66
Farmers' high yielding variety	131	81	.2	2	12,788.67
Farmers' local variety	75	49	.0	2	13,012.41
Sentolo					
Experiment M_1	200	75	.0	2	35,200
Farmers' high yielding variety	240	137	.0	2.3	21,745.24
Farmers' local variety	172	41	.0	2	24,853.97

Table 32. The divergences between the highest net return of the management package experimental farm and farmer—input level. Kulon Progo, Indonesia.

	Urea (kg/ha)		TSP (kg/ha)		Weeding (times)	
	A	B	A	B	A	B
			1974/75 wet season			
Sentolo	100	0	75	0	3+	0
Sidomulyo	100	0	0	0	1	0
Pengasih	100	0	0	0	1	0
			1975 dry season			
Pengasih	200	200	50	50	2+	2+
Serut	200	200	50	50	2+	2+

Note: A = owner—operator farmers, B = share tenant.

especially in TSP use and weeding, although farmer input levels in Sentolo were higher than in the other villages. But there were no differences in the average share—tenant inputs and the calculated optimum tenant package.

In the 1975 dry season the divergences were greater in almost all cases either on owner—operator farmers or share—tenant farms. The constraint problems were greater in dry season than in the wet season.

Because the model insecticide input for all cases was zero, divergences between farmers' level and optimum—package level were noted. But because the yield effect of insecticide in the factorial experiment was not significant, it was assumed that the divergences did not represent real potential yield contributions. A similar statement could be made about the weeding divergence during the wet season.

Factors associated with purchased input use

In producing rice, some inputs are purchased and others are not. The purchased inputs are fertilizer, pesticides, non—family labor and animal tillage. The experiments reported above showed that pesticides were not effective in increasing yields. Fertilizer inputs were significant and the experiments showed that in the three villages -- in both seasons -- fertilizers were often not used at the calculated economic optimum levels. Therefore an analysis was made to determine what factors were governing the use of purchased inputs with special emphasis on fertilizer use.

It was postulated that environmental factors, institutional factors, land tenure arrangements, knowledge, and beliefs play a role in determining the level of inputs used. In this section, variables of this type are examined in relation to the levels of inputs used, and in some cases in relation to themselves, to determine which may actually he important in determining the level of inputs used. Following the separate assessment of these variables, a simultaneous analyses is attempted using regression methods.

Assesment of variables affecting purchased input use

1. Water problems. To investigate a possible dependence between fertilizer use on modern varieties and water conditions, a X^2—test was computed from the cross tabulation frequencies in Table 33. The significant calculated X^2 value indicates that farmers who experienced water problems tend to apply less fertilizers to modern varieties than farmers without water problems. A similar X^2—test was computed for local varieties but its value was not significant (Table 34) although farmers with excessive water tended to purchase less fertilizer.

To determine if water problems were similar from year to year, a cross tabulation of farmers reporting shortages, excesses or neither, in the 1973—74 and 1974—75 wet seasons was constructed and a X^2 test was applied to test independence in the two years (Table 35). The X^2 value was large indicating that farmers facing shortages in the 1973—74 wet season also faced shortages the following year. A similar dependence was noted for farmers facing excess water conditions. Thus water problems appear

Table 33. Contingency table of water problem with purchased fertilizersused on modern varieties. Kulon Progo, Indonesia, wet season 1974—75.

Purchased fertilizer (Rp)	Water shortage	Excess water	Neither	Total
up to 10000	2	11	8	21
10000 - 20000	7	18	23	38
20000 - or more	0	0	10	10
Total	9	29	41	69

Calculated $X^2 = 14.8$.
Significant at the 1% level.

Table 34. Contingency table of water problem with purchased input used on local variety. Kulon Progo, Indonesia, wet season1974—75.

Purchased fertilizer(Rp)	Water shortage	Excess water	Neither	Total
up to 10000	2	10	15	27
10000 - 20000	4	1	11	16
20000 - or more	1	1	6	8
Total	7	12	32	51

Calculated $X^2 = 7.3$
Significant at the 10% level.

consistent from year to year. Farmers have learned to expect problems and have tended to reduce purchased inputs accordingly in order to avoid heavy losses.

2. *Varieties.* Because of varietal differences in fertilizer responsive, it was reasoned that farmers graving modern varieties would use more fertilizer than those not growing modern varieties. To examine that hypothesis, a cross tabulation of variety type and level of purchased inputs was constructed and a X^2 was calculated to determine if higher levels of inputs were used on the modern variety than on local varieties (Table 36). The significant X^2 value indicates that high levels of fertilizer are associated with modern varieties.

Table 35. Contingency table on water problem between sequence years. Kulon Progo, Indonesia, wet season 1974—75.

Water problem 1973—74 wet season	Water problem 1974—75 wet season			Total
	Shortage	Excess	Neither	
Shortage	12	2	2	16
Excess	1	29	1	31
Neither	29	7	37	73
Total	42	38	40	120

Calculated $X^2 = 87.9$.
Significant at the 0.1% level.

Table 36. Contingency table of purchased fertilizer used and varieties. Kulon Progo, Indonesia, 1974—75 wet season.

Purchased fertilizer (Rupiah)	New modem varieties	National improved variety	Local variety	Total
up to 10000	6	19	25	50
10000 - 20000	24	10	18	52
20000 or more	10	0	8	18
Total	40	29	51	120

Calculated $X^2 = 22.3244$.
Significant at the 1%: level.

3. *Tenure status.* It was postulated that owner—operators would purchase more fertilizer than either share or cash rent tenants. However, analysis of the frequencies in Table 37 indicate that no differences existed between types of tenure. An examination of the amounts of fertilizer used according to variety type for each tenure status showed that the cash—rent farmer growing modern varieties used more fertilizer than owner—operators and share farmers, and the share farmer used more fertilizer on local varieties than owner—operator and cash—rent farmers (Table 38). The cash—rent farmers appeared commercially oriented in their farming practices, because they applied more fertilizer to modern variety, which is more responsive than local varieties. However, the number of cash—rent farmers in the sample was small.

Table 37. Contingency table between purchased input used and tenure status of rice field. Kulon Progo, Indonesia, wet season 1974—75.

Purchased fertilizer used (Rp/ha)	Tenure status			
	Owner	Share	Cash rent	Total
Low (10,000)	38	10	2	50
Medium (10 - 20,000)	35	15	2	52
High (20,000)	13	4	1	18
Total	86	29	5	120

X^2 calculated = 1.2296.

Table 38. The amount of fertilizer (kg/ha) used on various varieties and tenure status. Kulon Progo, Indonesia, wet season 1974—75.

Tenure status	Modern varieties	Local variety	Averages
Owner operators	130.73	28.63	87.8
	(51)	(37)	(88)
Share tenant	134.71	105.88	47.06
	(15)	(12)	(27)
Cash—rent tenants	202.06	80.0	167.19
	(5)	(2)	(7)
Average	136.59	48.82	99.90
	(71)	(51)	(122)

4. Size of rice farm. To investigate a possible farm—size influence on purchased fertilizer, a cross tabulation of farmers by these two classifications was constructed. An analysis of the frequencies indicated that there was no farm size influence on the amount of fertilizer purchased. Howevever, in examining the effect of variety on fertilizer use, it was found that large farmers used more fertilizer especially on modern variety (Table 39). Small farmers used relatively more fertilizer on local varieties.

5. Technical knowledge. To determine how familiar farmers were with, and how well they understand reasons for, good farming practices and modern rice technology, a series of questions was used to test their knowledge. The maximum possible score was 48. The average score in Pengasih was 28, in Sidomulyo it was 21 and in Sentolo it was 24. The differences were not significant.

Table 39. The amount of fertilizer (kg/ha) used on various varieties and farm size. Kulon Progo, Indonesia, wet season 1974—75.

Farm size	Modern variety	Local varieties	Average
Large	194	63	151
Number of samples	6	3	
Medium	133	29	90
Number of samples	44	32	
Small	125	83	107
Number of samples	31	16	
Average	136	48	90

A simple correlation between average scores of technical knowledge and average fertilizer levels for the six hamlets gave a positive correlation (r = .38). A contingency test on the cross tabulation of technical knowledge and fertilizer use was highly significant (Table 40).

Table 40. Contingency table of technical knowledge with purchased fertilizer. Kulon Progo, Indonesia, wet season 1974—75.

Purchased fertilizer levels	Scores of technical knowledge 20	20—30	30	Total
Low	19	25	6	50
Medium	5	29	18	52
High	6	5	7	18
Total	30	59	31	120

Calculated X^2 = 17.4
Significant at the 1% level.

6. *Input availability.* Farmers were asked if they were able to get the rice production inputs they wanted in the proper amount and at the time needed. If they answered "yes" to both questions, the index of input availability was scored as high. If they answered "yes" to only one question, their index was scored as medium, if they answered "no" to both question they scored "low." The input availability scores were cross tabulated with the level of fertilizer purchased (Table 41).

Table 41. Contingency table of score of input availability and purchased input level. Kulon Progo, Indonesia, wet season 1974—75.

Purchased fertilizer level	Score of input availability Low	Medium	High	Total
Low	27	15	8	50
Medium	9	18	25	52
High	1	6	11	18
Total	37	39	44	120

Calculated $X^2 = 26.28$
Significant at the 1% level.

As would be expected, the data shows a strong positive relation between input availability and levels of fertilizer purchased. The main reason given by farmers who were unable to get adequate inputs was the lack of financing caused by the absence of the BIMAS program (in one area). Because of its remoteness and the lack of main roadways leading to it, input availability and, consequently, input use was lower in intermediate—irrigationarea.

7. *Credit availability.* Farmers were asked about credit availability, whether or not they borrowed, and how long it took them to complete arrangements for a loan. One week or less scored two; between one and two weeks scored one and more than two weeks scored zero. If they thought enough credit was available to them they were scored one. The two scores were added together. A cross tabulation of credit availability and level of fertilizer purchased was constructed (Table 42). A contingency test indicated that the lower scores were somewhat associated with lower fertilizer levels and higher scores with higher fertilizer levels.

8. *Extension.* Farmers were asked how often they were contacted by extension workers. Nearly 75% had no contact during the growing season. A contingency test between the number of visits by agricultural extension agents and level of purchased input indicated that the frequency of visits had little influence on the level of inputs used.

9. *Traditional beliefs.* We asked farmers whether they agreed with a set of four statements reflecting traditional ways of thinking about rice production. The statements included belief in the rice god, offerings to make it rain, and the effect of control measures on the population of pests. The scores ranged from —4indicating strong disagreement with the traditional statements to +4 indicating agreement with the statements. Most farmers in Pengasih and Sidomulyo disagreed, while these in Sentolo usually had scores of zero, indicating a somewhat more traditional orientation.

Table 42. Contigency table between level of purchased input and credit availability. Kulon Progo, Indonesia, wet season 1974—75.

Level of input (Rp) / Credit availability	0—1	2	3	Total
10,000	2	8	5	15
10,000 - 20,000	0	6	16	22
20,000	2	2	7	11
	4	16	28	48

X^2 = 12.2714
Significant at the 5% level.

10. Adoption of new technology. Fourteen practices for producing rice were scored according to stages of adoption, The stages of adoption were awareness, evaluation, trial, and adoption. The score of each practice ranged from zero to four corresponding to those farmers who had not heard of the practice and those farmers who were using the practice. Adoption scores ranged from 20 to 56, with the latter representing adoption of all 14 practices. Adoption as measured by this score, was slightly higher in Pengasih, although Sentolo averaged a higher percentage of full adoption. The differences between villages were not significant.

Farmers were cross—classified by adoption score and level of purchased fertilizer (Table 43). Analysis of the data indicates that low adoption

Table 43. Contingency table of adoption of new technology and levels of fertilizer. Kulon Progo, Indonesia, wet season 1974—75.

Level of purchased	Scores of adoption		
fertilizers	Low (30)	Medium (30—40)	High (40)
Low	14	29	7
Medium	7	27	18
High	3	7	8
Total	24	63	33

Calculated X^2 = 9.89
Significant at the 5% level.

scores were related to low fertilizer use and high adoption scores to high fertilizer use. The results of this analysis imply that fertilizer use is accompanied by the adoption of other improved practices.

The regression analysis. A simultaneous analysis of the factors thought important in governing fartilizer use is necessary to obtain an indication of the relative importance each factor. For this simultaneous analysis, two multiple regression models were developed. The first model included almost all factors of interest but a smaller sample. The second model included all samples but fewer variables. The difference in the number of variables in the models arose because not all samples had all information for each factor, e.g., credit—availability scores existed only for farmers who used credit. The first model was

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots\ldots\ldots\ldots\ldots + B_{11}X_{11}$$

where: Y = purchased fertilizers in thousand rupiah.

X_1 and X_2 = dummy variables for water problems, excess water and shortage water respectively.

X_3 = dummy variable for varieties

X_4 and X_5 = dummy variables for tenure, share and cash rental tenants, respectively.

X_6 = size of rice field in hectares

X_7 = technical knowledge score

X_8 = credit availability score

X_9 = agricultural extension score

X_{10} = traditional belief score

X_{11} = input availability score

Table 44 shows that there were no significant F—tests for this model for any village. The tests were relatively insensitive because of the low degrees of freedom associated with the residual mean square. However, some individual factors, when subjected to a t—test, were significant in the good irrigation area. Those factors were water shortage, variety, and cash—rent tenancy.

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5$$

The second model was

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5$$

where purchased fertilizer was the dependent variable Y. Excess water problems, share—tenant and cash—rental tenant dummy variables were X_1, X_2 and X_3 respectively. X_4 was farm size and X_5 was technical knowledge.

Although the second model used a larger sample and fewer variables, results were similar to those found from the first model (Table 45). Only technical knowledge in the moderate irrigation area produced a significant t—test.

Table 44. First—equation regression analyses on factors associated with fertilizer used. Kulon Progo, Indonesia, wet season 1974—75.

Variables	Good irrigation	Moderate irrigation	Rainfed
	Regression coefficients and corresponding t—value		
X_1	—3.78 (—1.02)	—3.96 (-.00)	—
X_2	21.83 (3.62)**	—	5.36 (.57)
X_3	12.80 (3.07)**	—9.95 (-.00)	—
X_4	4.28 (1.29)	—1.88 (-.44)	—8.53 (-.94)
X_5	—9.61 (—2.34)*	—	—21.46 (—.61)
X_6	16.64 (2.00)	9.54 (.66)	23.22 (—.35)
X_7	.18 (.44)	.26 (.46)	—.99 (—1.04)
X_8	2.45 (1.29)	-.91 (—.23)	—11.57 (—.86)
X_9	1.45 (.94)	—2.13 (-.00)	1.33 (.38)
X_{10}	—1.46 (—1.02)	-.43 (—.28)	7.93 (1.58)
X_{11}	—.24 (.05)	—.88 (—.23)	—
F	2.99	.45	3.59
R^2	.80	.58	.83
n	20	13	15

*Significant at the 5% level.
**Significant at the 1% level or less.

Table 45. Second—equation regression analysis on factors associated with fertilizer used. Kulon Progo, Indonesia, wet season 1974—75.

Variables	Good irrigation	Moderate irrigation	Rainfed
	Regression coefficients and corresponding t—value		
X_1	—3.55 (—1.12)	—2.00 (-.87)	—15.89 (—2.04)*
X_2	3.97 (1.32)	-.74 (-.28)	—.90 (—.24)
X_3	—.62 (—.13)	1.34 (.22)	—9.61 (—.78)
X_4	6.78 (.67)	—.53 (-.12)	12.36 (.97)
X_5	.42 (1.59)	.44 (2.90)**	—.07 (—.27)
F	1.21	2.34	1.17
R^2	.15	.26	.15
n	40	40	40

*Significant at the 5% level.
**Significant at the 1% level.

QUANTIFICATION OF YIELD CONSTRAINTS: THE SUBANG STUDY CASE

Subang Kabupaten consists of 11 Kecamatan of which Pusakanegara is one. It is relatively representative of the surrounding area in terms of cropping pattern and geography. Pusakanegara consists of 13 villages shown in Figure 3.

The area is mostly under the BIMAS program and according to official records there are no significant differences between villages in the adoption of new technology except for the rainfed area. Irrigation is common with rainfed areas constituting only 8% of the total lowland area. Most of the rainfed area is located in the southern part of the area.

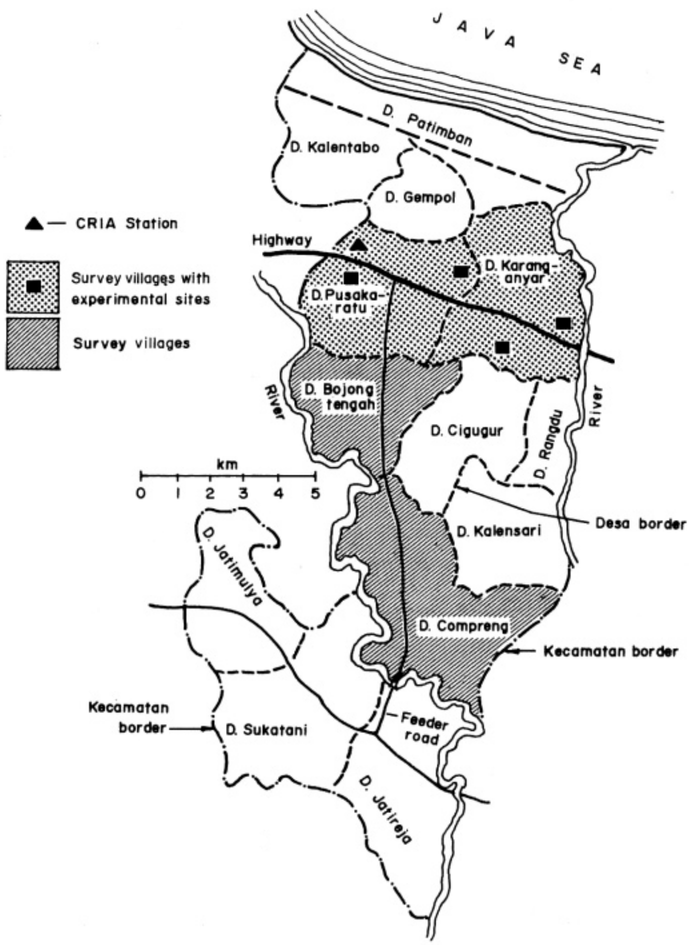

Fig. 3. Map of Pusakanegara Kecamatan in Subang.

Two villages not far from the Pusakanegara Experiment Station were selected as sites for the experiments. Initially, two villages distant from the main road had also been chosen, but because a bridge leading to those villages was impassable and because of the difficulty in travelling during the rainy season, the distant villages were dropped. Instead, sites were selected in four hamlets of the two villages near the main road.

On the coastal plain in which the Pusakanegara Station is located, there are only slight differences in relief and there is a tendency for most fields to be at least slightly flooded at one or more times during the rainy season. Therefore, fields near the lower—lying drainageways were avoided in site selection because they were likely to be moderately to heavily flooded on several occasions during the rainy season.

After consideration of proximity to the main road and topographical position, the sites on which the experiments were located were chosen on the basis of the farmer's willingness to cooperate. They were located from 100 to 400 m from the main road.

Soil data for the sites is given in Table 46. The pH values at all sites were slightly low. Available N and P varied among sites. Potassium availability was high at all locations.

Table 46. Soil analyses[a] from main experiment sites, Subang Indonesia, 1975.

Site	pH	P mg/100 g	N %	K m.e./100 g
Kubangjaran	5.5 ml	0.9 1	0.08 1	1.1 vh
Karanganyar	4.9 ml	0.9 1	0.06 1	1.5 vh
Curugjati	5.1 ml	1.9 1	0.76 h	1.4 vh
Pusakaratu	5.5 ml	6.7 h	1.75 vh	0.4 m

[a] 1 = low; ml = moderately low; m = moderate; h = high; vh = very high. Analyses by Lab. Sub. Hara Tanaman, Bagian Fisiologi, CRIA.

Weather data is presented in Appendix Table 1 for the wet season from November 1975 to April 1976. Heavier—than—average total rainfall occurred in January. Average daily solar radiation, percent sunshine hours, temperature, and evaporation were below normal for that month. Total March rainfall was higher than normal. Although solar radiation appears high for February and March, the average with which the comparison is made is for only two years.

Farmers and farmers technology

The general methodology of the IRAEN project uses a "comparable paddy" technique to simulate farmers practices. That technique has not been followed in our study. Instead we established experiments using a fixed level of inputs as the lowest level. Hence the "gap" is slightly different from that gap identified in other studies.

In order to determine the fixed level of inputs representative of the farmers level we surveyed farms in four villages of Pusakanegara (Figure 3). In each village, 20 farmers were selected from a list using equal interval number with a random beginning.

The survey was designed to be as simple as possible. There was no attempt to obtain detailed labor utilization data or other elaborate technical data, the main objectives being the description of present technology levels.

Two-season lowland rice dominates the cropping pattern in Pusakanegara comprising about 90% of the rice area. This reflects the favorable irrigation conditions of the area.

Land productivity according to the official record, is 4.9 t/ha in the study location and 3.9 t/ha for Subang as a whole. However, a previous farm survey in the Pusakanegara area, conducted by CRIA (1974) indicated a yield level of only 2.5 t/ha, which is not significantly different from the 1975 survey data, shown in Table 47.

Table 47. Yield level[a] of rice in the survey area. Subang, Indonesia, Indonesia, 1974-75.

Village	Wet season Ave. (t/ha)	Wet season Sd	Dry season Ave. (t/ha)	Dry season Sd
Pusakaratu	2.1[a]	.65	1.3	.80
Bojongtengah	3.6	.88	2.7	.61
Compreng	3.2	.45	2.2	.37
Karanganyar	2.7	.71	2.7	.66

[a] Each average was obtained from estimates given by 20 farmers in each village.

The level of farmer technology. Due to the BIMAS program, which was initiated in the study area early in 1964, the level of technology adopted by farmers is relatively high. The high level of adoption is reflected in the 78% of the rice area in Pusakanegara Kecamatan planted to modern varieties, according to official records. A similar level of adoption was recorded in the survey (Table 48).

Seed is available from BIMAS and in the free market. The BIMAS price is Rp 120/kg. Due to brown planthopper damage, farmers reduced the area planted to Pelita varieties and switched to the more-resistant varieties such as IR26 and IR28.

Table 48. Cultivation of modern varieties by sample farmers. Subang, Indonesia, 1974—75.

Data	Pusakaratu	Bojongtengah	Compreng	Karanganyar
Modern variety, wet (%)	100	73	100	100
Modern variety, dry (%)	78	78	100	100
Purchased seed (%)	15	90	50	70

Table 49. Levels of fertilizer and pesticide application, and the associated level of yield. Subang, Indonesia, 1974—75.

Village	Urea kg/ha	TSP kg/ha	Pesticide l/ha	Wet season Yield (kg/ha)	Dry season Yield (kg/ha
Pusakaratu	195.4	51.0	2.04	2,050 ± 650	1,270 ± 800
Bojongtengah	156.6	65.9	1.11	3,630 ± 880	2,650 ± 610
Compreng	177.5	43.8	1.18	3,210 ± 450	2,210 ± 360
Karanganyar	174.7	47.2	1.32	2,740 ± 710	2,670 ± 660

Fertilizer and pesticide applications are relatively high, reflecting the fact that most of the area is included in the BIMAS intensification program (Table 49).

Most farmers apply urea three times; TSP is applied once as a basal dressing. Fertilizer dosages are close to the recommended levels of 200 kg of urea and 50 kg of TSP/ha. The recommended insecticide level is between 2 and 3 liters/ha. Only in Pusakaratu does the level of pesticide application equal the recommended level. Fertilizers and pesticides are also applied in the seedbed. Presoaking and pregermination of seed is done by all farmers. Seedling age averages about 25 days, which is considered appropriate.

Land preparation is mostly without animal traction. Even if animal traction is used, human labor is invariably needed. If no animal traction is used, hoeing three—time is the usual practice.

In the dry season land preparation is much simpler. With the so—called *walik jerami* method, standing rice straw left in the field after the wet season crop is cut by sickle and trampled into the mud. In some cases a large notched wooden cylinder drawn by buffalo is pulled over the field to prepare the land for the dry season crop. The reason for these dry season tillage practices are (1) high labor cost (after wet season harvest), (2) timely preparation to utilize available water and to avoid water shortages, and (3) to effectively curb weed growth.

Selection of experiment factors. It was decided that only three factors should be examined in the experiments because of manpower limitations and lack of experience with the proposed research methods. Using the information obtained in the presurvey, data from the Pusakanegara Station, knowledge of local extension agents, advice of CRIA scientists familiar with the experiments conducted at Pusakanegara, and keeping BIMAS recommendations in mind, the three factors selected for evaluation were nitrogen fertilizer rates, insect control and land preparation. Although varietal differences were considered, variety—nitrogen experiments at the Pusakanegara Station did not show important differences for the varieties currently used by the farmers, barring BPH outbreaks. Rat control was also considered, but limitations in manpower, and control measures available to the farmers, made inclusion of a rat—control treatment unmanageable and of questionable value.

Experimental design and levels of factors. One major, randomized, complete—block—design experiment was conducted in each of the four villages. Ten supplemental tests were also conducted in each village. Because it was felt that the incremental aspects of the insecticide and fertilizer inputs were important for evaluation three levels of each were selected. Two land—preparation levels were used. The result was a 2x3x3 factorial treatment design, replicated twice at each location. Figure 4 presents the layout for Curugjati. The layouts for the other three locations were similar, but had different treatment randomizations and slightly different plot sizes and shapes to accomodate farmers' field dimensions.

Replication I			Replication II		
$L_2F_1I_3$	$L_1F_3I_2$	$L_1F_2I_2$	$L_1F_1I_3$	$L_2F_3I_1$	$L_1F_1I_1$
$L_2F_3I_3$	$L_1F_2I_1$	$L_1F_1I_2$	$L_1F_2I_2$	$L_2F_3I_2$	$L_2F_1I_1$
$L_2F_3I_2$	$L_2F_2I_1$	$L_1F_3I_3$	$L_2F_2I_3$	$L_1F_3I_2$	$L_2F_1I_2$
$L_1F_2I_3$	$L_2F_2I_3$	$L_2F_1I_1$	$L_2F_2I_2$	$L_1F_2I_1$	$L_1F_1I_2$
$L_1F_1I_1$	$L_1F_3I_1$	$L_2F_2I_2$	$L_2F_2I_1$	$L_1F_3I_1$	$L_2F_3I_3$
$L_2F_3I_1$	$L_2F_1I_2$	$L_1F_1I_3$	$L_1F_3I_3$	$L_1F_2I_3$	$L_2F_1I_3$

Fig. 4. Plot arrangement at Curugjati, Subang, 1975–76.

So that plot—to—plotdifferences in water management would not result in yield differences, so that water conditions would be similar to those in nearby farmers' fields, and so that soil in the experimental plots would not be greatly disturbed, only low, temporary levees were constructed between plots and large plots were used to reduce border effects which might arise from nitrogen movement.

The factor levels are described in Table 50. There is some confounding of levels and time of application in the insecticide treatments, and a granular

Table 50. Experiment factors and levels used in the main experiments, Subang, Indonesia, 1974—75.

Landpreparation:[a]			
L_1 -	Hoeing	2 weeks before transplanting (WBT)	
	Parang -	hoeing - trampling	1 week before transplanting
	Weeding	3 weeks after transplanting (WAT)	
	Weeding	6 WAT	
L_2 -	Hoeing	3 WBT	
	Hoeing	2 WBT	
	Trampling	1 WBT	
	Weeding	2 WAT	
	Weeding	6 WAT	
	Weeding	9 WAT	
Fertilizers:			
F_1 -	100 kg urea/ha	(1/3 basal, 1/3 3 WAT, 1/3 10 WAT or at panicle initiation	
F_2 -	200 kg urea/ha	(1/3, 1/3, 1/3) WAT	
F_3 -	300 kg urea/ha	(1/3, 1/3, 1/3)	
Insecticide:			
I_1 -	1 liter Diazinon/ha	at 5 WAT	
	1 liter "	at 9 WAT	
I_2 -	20 kg Furadan/ha	at 2 WAT	
	1 liter Diazinon/ha	at 6 WAT	
	1 liter "	at 10 WAT	
I_3 -	1 liter Diazinon/ha	at 2 WAT	
	1 liter "	at 5 WAT	
	1 liter "	at 8 WAT	
	1 liter "	at 11 WAT	

[a] Hoeing is done with a short—handled, broad—bladed hoe that when swung with force, slices into the soil. As it is lifted for the next stroke, the slice falls from the blade and is partially inverted. A parang is a large knife used to chop straw and stubble. The cutting is often done while the field is slightly flooded, so partial incorporation results. Trampling is usually done at the same time a light hoeing is given. While trampling, the soil is puddled and low areas are filled in from high areas.

systemic insecticide (Furadan) was used in I_2, which complicates interpretation somewhat. Although this material is not readily available in the Pusakanegara area, it is available in other parts of Indonesia. It was included mainly for gall midge control during the tillering stage,

Three fertilizer levels were chosen: the BIMAS recommended level (200 kg urea/ha), with one level above (300 kg urea/ha) and one level below (100 kg urea/ha) the BIMAS level. A basal application of 50 kg TSP/ha was applied to all plots.

Although referred to as a land preparation treatment, the third factor was actually composed of different land preparation and weeding operations. L_2 is a more intense treatment than L_1. Both the land preparation and the weeding operations might be expected to have differential impacts on weed control, percolation rates and urea efficiency. Explanation of the different operations are given in the footnote to Table 54.

No separate management—package plots were used. Instead, certain treatment combinations of the factorial (Table 51) were designated as management—package treatments for purposes of partial budget analyses.

Experiment management was the responsibility of the research field staff, who followed general farmer practices except for those practices linked to the selected treatments. Timing of all practices were specified prior to the season, The main management factor not controlled by the field staff was irrigation and drainage. The farmer himself has little control in the area. The field staff did not spot spray for brown planthoppers and armyworms as some farmers did in the area. However, field staff did harvest ahead of schedule at Karanganyar and Pusakaratu to avoid a severe armyworms attack -- a common farmer practice. It is our judgement that the management level of the experiments would be about average and the results are valid in comparison with many farmers' yields. A comparison of the experimental results with yields from supplemental tests and farmers' fields substantiate our judgement.

In addition to the main factorial experiments, five supplemental pairs of I_1 and I_2 and F_1 and F_2 treatments were located in farmers' fields in each

Table 51. Designated correspondences between factorial treatments and management packages, Subang, Indonesia, 1974—75.

Management package	Treatment combination		
M_1	L_1	F_1	I_1
M_2	L_1	F_2	I_1
M_3	L_1	F_2	I_2
M_4	L_2	F_2	I_2
M_5	L_2	F_3	I_2
M_6	L_2	F_3	I_3

of the four villages. Again, farmer selection was made mainly on the farmers' willingness to cooperate. The field staff applied those treatment pairs, which were applied according to the same schedules for insecticides and fertilizers used in the main experiment, the management of the plots was left to the farmer who considered them as part of his field. The purpose of the supplemental tests was to compare the insecticide and fertilizer response estimates determined at only four locations (main factorial experiments) with a range of responses found in a much greater sampling of farmers' fields. The data generated would also serve as supplemental observations in the regression analyses based on crop—cut data and farmers' input levels as obtained from a farm recording system.

Data collection. Several attributes were measured for each plot in all of the main experiments. Yield data was collected from a 20 m^2 area from within a 30 m^2 plot. Gall midge counts, whitehead counts, deadhearts counts, panicle numbers, tiller numbers and plant height were obtained from random samples of 12 hills per plot. Counts and numbers were expressed on a per hill basis.

Weed counts were obtained from two randomly located 0.4 m^2 sample areas per plot. Individual counts were made of sedges, grasses and broadleaves weeds. In counting, no attempt was made to distinguish between size of weeds.

Rat damage was recorded for each plot at about heading time. To obtain rat—damage recordings, each hill in a plot was examined and damage per plot was expressed as the percentage of hills damaged out of the total of 480 hills per plots. No attempt was made to distinguish light, moderate or heavy damage.

Wet season experiment results

The four main wet—season experiments were transplanted in late November and early December at about the same data as the cooperators' field adjacent to experiment site (Table 52). The cooperators were among the earliest farmers to transplant, and therefore the rat damage to the experiments is believed to be higher than that experienced by the bulk of the farmers. However, the fields adjacent to the experiments were generally affected to the same degree as the experimental plots.

Pest damage in Kubangjaran was especially heavy. Brown hoppers late in the season were sufficiently numerous to cause hopperburn. In Karanganyar and Pusakaratu the crop was harvested a week earlier than scheduled in order to avoid serious damage by armyworms. The level of insect pressure was quite high, and in general, the insecticide treatments did little to control the insects. In addition rat damage was very common, causing substantial increases in experimental variability that were not explained by the treatments.

Because of the extensive pest damage in Kubangjaran, yield levels in the experiment were low and variability was high. As a result, the analysis of variance (AOV) on grain yield showed no significant main effects or interactions. Using rat damage percentages and gall midge counts as covariates, separately and in combination, in an analysis of covariance (ANCOVA), no reduction in experimental error could be obtained. An ANCOVA with

Table 52. Variety, seedling age, transplant and harvest dates, and major problems encountered at four main experiment sites. Subang, Indonesia, wet season 1975—76.

Site	Variety	Seedling age (days)	Transplant date	Harvest date	Major problems
Kubangjjaran	Pelita I/1	25	11/27/75	3/29/76 [a]	rats, gall midge, stemborers, brownplanthopper, flooding
Karanganyar	PB26	21	12/3/75	3/21/76	rats, gall midge, stemborers
Curugjati	Pelita I/1	25	12/17/75	4/20/76	rats, gall midge, stemborers
Pusakaratu	Pelita I/1	25	12/18/75	4/6/76	flooding, stemborer

deadheart counts as the covariate was equally unsuccessful. Apparently, the number and intensity of detrimental factors was too great to allow a clear expression of the relationships between yield and the imposed treatments, and between yield and the uncontrolled, but measured, rat and insect damages.

In the AOV for grain yield, the F—ratio for land preparation approached significance at the 5% probability level but L_1 and L_2 means were reversed in their expected relative sizes. There was no significant difference between the weed counts on L_1 and L_2 plots.

Crop—cutting data from the supplemental plots in Kubangjaran village in the first section of Table 53. Levels of pest damage and flooding similar to that of the main experiment were observed in nearby fields (No. 5 for fertilizer and No. 3 for insecticide) and crop—cuttings from those fields yielded only an average of 1,646 kg/ha. Supplemental fertilizer and insecticide treatments in those fields gave no dramatic increases over the farmer's treatments, although yields increased somewhat. The Kubangjaran crop—cutting average was low in comparison with the other villages. Records of farmers whose yield data is presented in Table 53 indicate that less urea (136 kg/ha) but more insecticides (1.7 kg a.i./ha) were used in the Kubangjaran area relative to the averages of the other villages.

The AOV for grain yield in Karanganyar showed only the fertilizer main effect significant at the 5% level of probability (Table 54). Using the square root of percent rat damage as a covariate to reduce experimental error, an ANCOVA on grain yield was computed (Table 55). In this ANCOVA, the main effects of land preparation (L) and insecticide (I) and the LI interaction were significant while the main effect of fertilizer, significant in the initial AOV became insignificant.

The general yield level in the Karanganyar experiment was roughly the same as that found by crop—cuttings in the farmers fields and in the supplemental fertilizer and insecticide plots. Farmers average urea input levels were less (176 kg/ha) than the BIMAS recommendation as was the average insecticide application (1.3 l/ha). There were tendencies for fertilizer and insecticide responses but the increases were not great and there was substantial variability for each case.

An AOV computed on yield data for Curugjati showed no significant effects caused by the applied factors or their interactions. ANCOVA's were computed using the square root of percent rat damage as a single covariate, and rat damage with gall midge incidence as double covariates, but with both covariance anlyses there was still considerable plot—to—plotvariation in the data after adjustment.

The average yield of all treatments in the experiment was 2,515 kg/ha. This is somewhat lower than yields obtained from the supplemental fertilizer and insecticide trials and crop cuttings from farmers' fields (Table 53). High variability occurred in both the experiment and supplemental trial data. Allowing for heavy damage brought on in part by earlier than average transplanting, the experiment can be regarded as reflecting the same tendency toward response and same variability in response as experienced by many farmers in the area.

The AOV on grain yield for Pusakaratu showed no experimental factor or interaction statistically significant. An ANCOVA using the square root of rat damage as a covariate slightly improved the precision, boosting the F—ratios for I and LFI to slightly above the 10% level of probability and indicating a possible insecticide effect on yields (Table 54). Adjusted treatment means were 2,308, 2,606, and 2,659 kg/ha for the first, second and third insecticide level, respectively.

In comparison with farmer's crop cutting data from the village of Pusakaratu (Table 53) experiment yields were lower, mainly because of the reduced tiller numbers, which is believed to have resulted from moderate flooding during the active tillering stage. The yield average from the Pusakaratu crop cutting data was higher than in any of the other villages. If the highest crop—cutyield (4,892 kg/ha) is omitted from the data, on the basis that is abnormally high given the input levels reported by the farmer (less than average fertilizer and insecticide inputs and average labor input), the crop—cut yield average is reduced to 3,394 kg/ha and is more in line with the experiment results. But the average still exceeds plot yields receiving intermediate fertilizer and insecticide applications (2,904 kg/ha). It is our judgement that the experiment data reflect management conditions and treatment responses somewhat below those of the farmers in the crop—cut sample. The average farmer's urea application was 167 kg/ha and the average farmer's insecticide application was 2 l/ha. There was a general trend toward fertilizer and insecticide responses, but there was large variability in the responses.

Yield gaps. The statistical analysis reveals the rather weak data base that exists for drawing conclusions regarding the gap. Table 56 with the data from the main experiment in the IRAEN format illustrates the lack of any consistent pattern in response.

Table 53. Supplemental treatment yields and crop cutting yields. Subang, Indonesia, wet season 1975—76.

Village	No.	Fertilizer			Insecticide		
		Farmer	F_1	F_3	Farmer	I_1	I_2
Kubangjaran	1	3461	2282	3465	2278	2192	2098
	2	2443	2039	2767	3669	3929	4090
	3	2647	3300	2651	1610	1653	2037
	4	2763	2541	3169	3049	2441	2518
	5	1355	1631	1588	2453	2190	2655
	Average	2534	2359	2728	2612	2481	2680
Karanganyar	1	4263	3678	3927	3551	3857	3420
	2	3000	3198	3639	3316	3506	2973
	3	3392	3386	3439	1824	2139	2827
	4	2139	2149	3053	3712	4296	4222
	5	2169	2214	2451	2667	2127	3376
	Average	2993	2925	3302	3014	3185	3364
Pusakaratu	1	3516	4078	3239	3937	3690	3194
	2	2569	2792	2629	3492	2476	3618
	3	2761	2643	5318	3498	4037	3731
	4	3688	3271	3512	4892	5039	5163
	5	3459	3194	2845	3620	3345	3776
	Average	3199	3196	3309	3888	3717	3896
Curugjati	1	3731	4137	3778	3808	4220	3933
	2	3292	3180	4263	3184	2765	3145
	3	3386	2.986	3488	2782	2380	2824
	4	3531	4257	4041	3588	3618	3951
	5	2880	2959	3035	1280	1455	1786
	Average	3384	3506	3721	2928	2888	3128
Overall Average		3027	2996	3315	3111	3068	3267

Because the design did not utilize the comparable paddy technique, the $L_1F_2I_1$ treatment is used as the low input level. It is approximately equal to the average level of inputs being used by farmers in the area.

It is interesting that only Karanganyar showed a positive yield gap and that it was only in that location where any experimental factor had a significant effect. That fertilizer factor also had the largest contribution to the yield gap.

We believe the experiments represent the general response behavior of the portion of fields in the Pusakanegara area that suffered from moderate to heavy pest and flood damage. There was a tendency for insecticide and fertilizer responses in the experiments but the average response was not large but was highly variable. The yield level achieved under high levels of inputs was low (See Appendix Table 2 for experiment treatment mean yields).

Supplemental trial results

Considering the study area as a relatively homogenous population for which the same fertilizer and insecticide recommendations would apply, we combined the data from all the supplemental trials. Student's t—tests were computed on within—field differences for yields from the farmers' field vs treatment level 1; from the farmers' field vs treatment level 2, and from treatment level 1 vs treatment level 2. No t—value was significant.

Assuming that high variability was masking real but small differences, the yields from each treatment level were ranked from low to high and the data points plotted against ascending intervals of equal probability. A smooth cumulative distribution curve was drawn free—hand for each set of points (Figures 5 and 6). The fertilizer curves were roughly parallel,

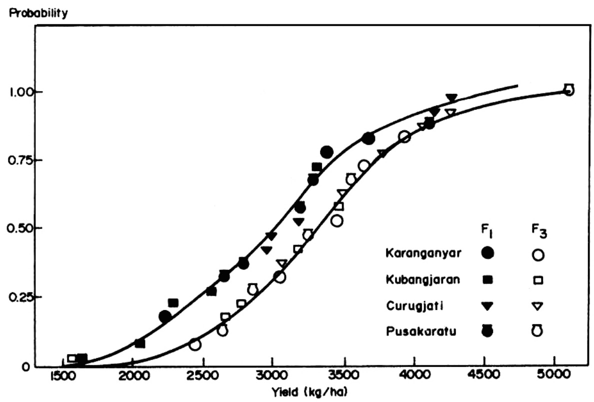

Fig. 5. Distribution of grain yields from supplemental fertilizer trials, Subang, wet season, 1975/76.

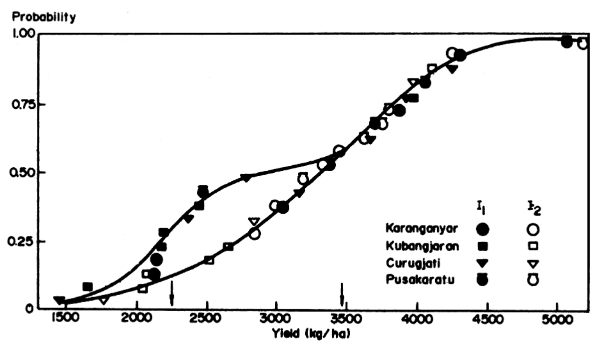

Fig. 6. Distribution of grain yields from supplemental insecticide trials, Subang, wet season, 1975/76.

Table 54. Analysis of variance on grain yield in main experiments. Subang, Indonesia, wet season 1975—76.

		Kubangjaran		Karanganyar		Pusakaratu		Curugjati	
Source[a]	DF	MS	F	MS	F	MS	F	MS	F
L	1	890,000	4.06	567,500	1.13	238,450	1.21	150,150	<1.00
F	2	35,500	<1.00	1,993,600	3.96*	236,025	1.19	78,800	<1.00
I	2	455,250	2.08	600,750	1.19	368,425	1.87	277,775	<1.00
LF	2	373,250	1.70	118,075	<1.00	551,875	2.80	416,650	<1.00
LI	2	142,000	<1.00	107,250	<1.00	132,225	<1.00	426,925	<1.00
FI	4	191,750	<1.00	24,375	<1.00	284,200	1.44	519,725	1.09
LFI	4	241,000	1.10	208,425	<1.00	433,275	2.20	271,250	<1.00
Error	17	218,750		502,400		196,875		477,100	
CV		30.6%		25.2%		17.6%		27.5%	

[a]L = land preparation, including weed control; F = fertilizer, I = insect control.
*Significant at the 5% level.

Table 55. Analysis of covariance on grain yields with square root of rat damage as covariance. Subang, Indonesia, wet season 1975—76.

		Karanganyar		Pusakaratu	
Source	DF	MS[a]	F	MS[a]	F
L	1	673,913	4.74*	155,890	<1.00
F	2	274,561	1.93	268,700	1.46
I	2	583,754	4.10*	429,510	2.33
LF	2	47,661	<1.00	408,160	2.22
LI	2	595,004	4.18	86,960	<1.00
FI	4	91,471	<1.00	272,180	1.48
LFI	4	50,897	<1.00	434,110	2.35
Error	16	142,283		184,210	
CV		13.4%		17.0%	

[a] Adjusted
*Significant at the 5% level.

Table 56. Yield gap between high and simulated farmers' level of input use and contributions of three inputs. Subang, Indonesia, wet season 1975—76.

	Yield (t/ha) at			Yield contribution (t/ha) of			
Location	LIF2I1	L2F3I3	Gap	Land preparation	Fertilizer	Insect control	Residual
Kubarigjaran	1.5	1.4	—0.1	—0.4	—0.3	0.3	—0.3
Karanganyar	2.3	4.0	1.7	0.5	0.6	0.3	0.3
Pusakaratu	2.2	1.9	—0.4	—0.2	—0.2	0.4	—0.4
Curugjati	2.5	2.2	—0.3	—0.3	0.3	0.1	—0.4

with an interval of 200 to 300 kg/ha separating them. The F_3 curve fell to the right of the F_1 curve.

The I_2 curve took a normal sigmoidal unimodal cumulative distribution form but the I_1 curve reflects bimodal behavior or two overlapping unimodal populations. If there are two unimodal populations under the I_1 treatment, it appears that one has a peak at about 2,250 kg/ha and the other has a peak at about 3,400 kg/ha, and may be identical with the I_2 population. The difference suggests that there may have been insect attacks which occurred to some fields and for which the early Furadan and two later Diazinon applications gave some protection. Other fields either escaped insect damage or were exposed to attacks by insects for which the treatment was not effective.

The variable response to insecticide treatments in both the supplemental trials and the main experiments may reflect chance differences in timing of the applications relative to critical stages of insect population development, as well as to differences in amount of material and number of applications. Even with the most effective insect control observed, the insecticide treatments were at best only fractionally effective

The supplemental yield trial data was analyzed in another way, using the model $Y = b_0 + b_1X$, where Y is the within—field response ($I_2 - I_1$ or $F_3 - F_1$), and X = 1 if I_1 (or F_1) were below an arbitrary critical value of I_1 (F_1) and 0 otherwise. With this model, the response data is divided into two populations with means b_0 and ($b_0 + b_1$) based on a critical value of I_1 (or F_1), which produces the maximum R^2 for the model. This maximum value is found by a simple iterative procedure, using a sequence of increasing critical values.

A critical value of 3,650 kg/ha was found from the insecticide data. Twelve of the 20 points fell below this level. The average response for those 12 points was 502 kg/ha, while the average response for the remainder was —123 kg/ha. R^2 for the model was 51%. The data is plotted in Figure 7.

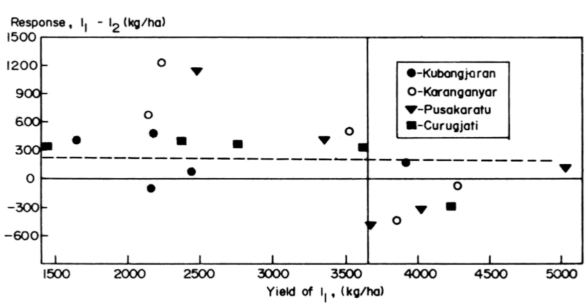

Fig. 7. Division of insecticide responses, I_1–I_2, into two populations, Subang, wet season, 1975-76.

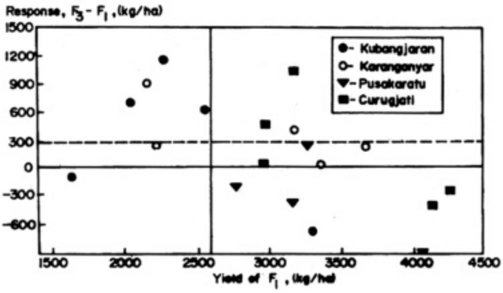

Fig. 8. Division of fertilizer responses, F_3-F_1, into two populations, Subang, wet season, 1975/76.

Before analysis of the fertilizer response data, one observation (2,675 kg/ha) was omitted because it fell well above the response pattern found in the remaining data. The data were divided into two populations at 2,500 kg/ha with 13 points in the low set with a mean response of 5 kg/ha (Figure 8). R^2 for the model was 26%.

Although the models are relatively weak, the analysis suggests that an I_2 insecticide application may produce a substantial yield increase 60% of the time, but this is offset by the possibility of slight lossess occurring about 40% of the time. An overall average yield increase would be about 250 kg/ha. From fertilizer data analysis, it appears that actual physical losses are not likely, but that 70% of the time minor yield increases will occur and 30% of the time substantial increases will be obtained. An overall average yield response would be about 200 kg/ha.

Even before considering additional costs, it appears that substantial risks are involved in the application of insecticides and urea. The farmers in the area seem to be aware of these risks. The urea input of the 40 farmers included in the crop—cut sample averaged 164 kg/ha, which was below the BIMAS recommendation of 200 kg/ha. Only 13 of the 40 farmer cooperators were applying urea at or above the BIMAS recommendation. The average yield of these 40 crop cuttings was 3,069 kg/ha, which was only marginally higher than the average of 3,032 kg/ha obtained in the supplemental trials with 100 kg urea/ha.

The average insecticide applied was the equivalent of 1.6 1/ha, also below the BIMAS recommendation of 2 1/ha. There was only 1 kg/ha difference between the average yield of the 40 farmers and the average yield of the 20 insecticide treatments on which 2 1/ha of diazinon had been applied. Only 14 of the 40 farmers were applying insecticides at or above the BIMAS recommendation.

Dry season experiments

The wet season 1975—76 sites were retained and the treatments were placed in the plots corresponding to the wet—season treatments at the same levels.

Experiments were transplanted on about the same date as the adjacent cooperators' fields. About one month after transplanting water shortages began to affect the plots in three sites. By July water availability was severely limited and the soil was generally cracked. In August irrigation water was available once or twice a week, but it was only enough to bring the soil to field capacity. Only in Curugjati was there adequate water to avoid the drought problem (Table 57).

Table 57. Variety, seedling age, transplant and harvest dates and major problems in main experiments, Subang, Indonesia, dry season 1976.

Site	Variety	Seedling age (days)	Transplant date	Harvest date	Major problems
Kubangjaran	Pelita I/1	25	5/22/76	9/16/76	Drought
Karanganyar	Pelita I/1	25	5/19/76	9/9/76	Drought
Curugjati	Pelita I/1	25	6/5/76	9/29/76	None
Pusakaratu	PB5	25	5/21/76	9/13/76	Drought

Insect trap data indicate that insect pest pressures were considerably lower in the dry season than in the previous wet season.

Factors, factor levels and the experimental design remained unchanged from the wet season, except for land preparation and the distribution of supplemental trials. The land preparation treatments were changed to correspond to the reduced procedures used by the farmers during the dry season. The lower level, L_1, referred to locally as walik jerami, consists of chopping straw and stubble with a parang and then working the straw and stubble into the mud by trampling. Two weedings were done in L_1. In the higher level of land preparation, L_2, one hoeing followed straw and stubble chopping following which the soil was trampled and straw and stubble were worked into the mud. Three weeding were done in L_2.

To reduce the workload associated with record keeping and data collection, the number of farmers with supplemental trials was reduced by half. A single cooperating farmer had both a supplemental fertilizer and a supplemental insecticide trial instead of just one or the other. As a result only one crop cutting was made per two supplemental trials instead of one per trial as was done at the end of the wet season.

Kubangjaran. Yields in Kubangjaran were reduced by the water shortage. Plot—to—plotdifferences in water availability increased experimental error, although rat damage was a factor also (Appendix Table 3). Statistically significant fertilizer effect and fertilizer—by—insecticideinteraction were present (Table 58). Means of fertilizer and insecticide treatment combinations are presented in Table 59. The significant interaction appears

Table 58. Analysis of variance on grain yields. Subang, Indonesia, dry season 1975—76.

Source	DF	Kubangjaran MS	F	Karanganyar MS	F	Curugjati MS	F
L	1	92,500	<1.00	53,650	<1.00	1,015,050	3.32
F	2	2,532,000	6.13**	428,925	3.81*	5,434,150	17.76**
I	2	259,650	<1.00	51,300	<1.00	429,150	1.40
LF	2	189,700	<1.00	365,850	3.25	112,200	<1.00
LI	2	177,300	<1.00	115,025	1.02	100,950	<1.00
FI	4	2,090,300	5.06**	18,175	<1.00	161,950	<1.00
LFI	4	335,575	<1.00	32,050	<1.00	274,575	<1.00
Error	17	412,925		112,625		305,925	
CV		17.3%		14.5%		10.6%	

*Significant at the 5% level.
**Significant at the 1% level.

Table 59. Means (kg/ha) of fertilizer (F) and insecticide (I) treatment combinations. Kubangjaran, Subang, Indonesia, dry season 1976.

	F_1	F_2	F_3	I means
I_1	2855	3570	5059	3828
I_2	3464	3679	4167	3770
I_3	3340	4155	3153	3549
F means	3220	3801	4126	

to have resulted primarily from the reversed impact of insecticide at the high fertilizer level. The data indicate that high levels of insecticide, when applied to high—nitrogen treated plots, depressed yields under the conditions that existed.

The experiment yields were more than double most of the yields in the crop cutting sample from Kubangjaran (Table 60). Farmers in the sample applied high amounts of urea (193 kg/ha), almost reaching the BIMAS recommendation, and no fertilizer response was apparent in the supplemental trials. The large variation between farmers is primarily from differences in water. The experiment does not seem to be representative of the general conditions found in the Kubangjaran sample although it may be similar to some areas of the village not sampled, and to other villages nearby.

Table 60. Supplemental treatment yields and crop cutting yields. Subang, Indonesia, dry season 1976.

Village	No.	Farmer	Fertilizer F_1	Fertilizer F_3	Insecticide I_1	Insecticide I_2
Kubangjaran	1	1500	1790	1429	1388	1557
	2	1035	1173	1292	316	1088
	3	1412	1665	2243	1512	1665
	4	1429	2237	2165	1145	1347
	5	1096	1363	1365	1196	1090
	Average	1294	1645	1698	1112	1349
Karanganyar	1	2592	1596	1612	2416	2714
	2	373	445	310	371	678
	3	1161	2088	1739	1412	1210
	4	0	0	0	2747	3016
	5	1837	2918	3155	2280	1876
	Average	1192	1410	1363	1845	1890
Pusakaratu	1	2929	3743	3153	3122	3512
	2	2657	2284	3104	2088	2512
	3	1547	1894	2555	2627	2947
	4	3810	3580	3910	3261	3247
	5	2061	4753	2676	2502	2857
	Average	2601	3251	3080	2720	3015
Curugjati	1	2978	4704	5500	4278	4929
	2	1649	2116	2116	1724	1763
	3	4849	4724	4045	3537	4739
	4	5855	5659	5959	5655	5651
	5	4235	3857	4502	4039	3910
	Average	3912	4212	4425	3725	4198
Overall average		2249	2631	2691	2351	2612

Karanganyar. The drought in Karanganyar resulted in substantial unexplainable plot—to—plotvariation and low yields. Although only the fertilizer effect was significant, the land preparation by fertilizer interaction approached significance (Table 58).

Yield levels from the experiment appear to correspond to results found in roughly half the crop cuttings and supplemental trials (Table 60), but farm—to—farmvariation is high, reflecting differences in water regimes. Fertilizer response corresponding to that found in the experiment, was not found in the supplemental trials. The average urea and insecticide inputs by the farmers in the crop cut sample were 150 kg/ha and 0.84 liters/ha, respectively. Both inputs were well below the BIMAS recomendations, *Curugjati.* Irrigation water at Curugjati was adequate throughout the growing season resulting high yield. An AOV of the yield data indicated that the fertilizer effect was statistically significant. Although the land preparation treatment did not show a significant difference, nor was the LF interaction significant, the means of fertilizer and land preparation treatment combinations were calculated (Table 61). There was an average difference of 1,345 kg/ha between F_1 and F_3. The fertilizer response was essentially linear between F_1 and F_3. The data analysis indicate that if a real insecticide effect is present, it is small and not detectable within the limits of experimental error, which in this case was relatively low.

Table 61. Mean yields (kg/ha) of fertilizer (F) and land preparation (L) treatment combinations. Subang, Indonesia, dry season 1976.

	F_1	F_2	F_3	L means
L_1	4304	5046	5839	5063
L_2	4806	5428	5962	5399
F means	4555	5235	5900	

The crop cutting and supplemental trial yields (Table 60) were generally high and similar to yields found in the experiment. There was a suggestion of a fertilizer response in the supplemental trials, although the benefits of F_3 were not distinct. There was a similar indication of yield increase from I_2 over I_1. The urea used by the sample farmers in Curugjati was high (191 kg/ha), almost the same as the BIMAS recommendation. Insecticide use exceeded the BIMAS recommendation. Even though no clear yield—increasing effects could be detected in the supplemental trials for either inputs, farmers apparently expect benefits or insurance from their use, especially when water was available in the dry season.

Pusakaratu. An ANOV of Pusakaratu grain yields indicated a large block effect (Table 62). Because Replication I was closer to source of water and lower than Replication II, Replication I has higher yields. To improve the analysis, all plots in each tier were numbered 1 to 6 from west to east, and all plots in each file were numbered 1 to 6 from south to north. The two numbers were added and used as a covariate in an ANCOVA. The covariate value ranged from 2 for the plot closest to the source of water to 12 for the plot furthest. The ANCOVA is presented in Table 63. Sensitivity improved somewhat by using the covariate which appeared to measure relative water supply within each block, but main effects were still not siginificant.

The significant block effect and the strong correlation between the covariate and yield residuals, point out the impact slight differences in water supply have on yields under dry conditions and that those differences can be

Table 62. Analysis of variance, Pusakaratu grain yields. Subang, Indonesia, dry season 1976.

Source	D.F.	M. S.	F—ratio
Blocks	1	40,502,620	166.9**
L	1	39,000	1
F	2	583,550	2.40
I	2	486,050	2.00
LF	2	820,150	3.38
LI	2	361,250	1.49
FI	4	733,225	3.02
LFI	4	424,175	1.75
Error	17	242,643	

cv = 22.1%

**Significant at the 1% level.

Table 63. Analysis of covariance of Pusakaratu grain yields, arbitrary irrigation gradient as covariate. Subang, Indonesia, dry season 1976.

Source	D.F.	M.s.	F—ratio
L	1	65,495	<1
F	2	382,180	2.51
I	2	147,240	<1
LF	2	1,000,737	6.57**
LI	2	82,893	<1
FI	4	89,223	<1
LFI	4	377,777	2.48
Error	16	152,262	2.48

CV = 17.5%

**Significant at the 1% level.

pronounced within a small area. The supplemental yield data also reflect these differences in availability although the distances between farms is much greater.

Supplemental trial and crop cutting data for Pusakaratu showed considerable variation in the crop—cutyields and in the fertilizer and insecticide responses. The major source of the variation was most likely the differences in water availability. There was nu consistent response to either urea or insecticide. However, while there was an average decrease of 84 kg/ha hetween yields of F_3 and F_1, there was an average increase of 144 kg/ha hetween yields of I_2 and I_1. The treatment combination yields in the experimental data and the crop—cutting and supplemental trial yield data are of the same general size, suggesting that the experiment was grown with conditions similar to those experienced by the sample farmers in the village. On the average, the farmers applied less urea (136 kg/ha) and less insecticide (1.3 l/ha) than recommended by BIMAS.

Yield gap

Considering the $L_1F_2I_1$ as the low level, because it is about equal to the farmers' level, the yield gap calculations are shown in Table 64. The gap was negative in two locations and significantly positive only in Curugjati, where water was adequate. At that site fertilizer was the most important factor contributing to the gap.

Table 64. Yield gap between simulated farmers' input level and high level of inputs and contribution of each input. Subang, Indonesia, dry season 1976.

Site	Yield (t/ha)			Yield contribution (t/ha)			
	$L_1F_2I_1$	$L_2F_3I_3$	Gap	Land preparation	Fertilizer	Insect control	Residual
Kubangjjaran	3.4	3.0	—0.4	0.0	0.2	-0.7	—0.1
Karanganyar	2.5	2.8	0.3	0.1	0.1	0.2	0.1
Curugjati	4.9	6.3	1.4	0.3	0.9	0.2	0.0
Pusakaratu	1.5	1.8	0.3	—0.3	0.0	0.3	0.3

Supplemental trials. Dry—season, supplemental trial treatment yields and crop cuttings from the same farmers' field are presented in Table 64. The distinct village differences are due to differences in irrigation water distribution. The yields from farmers' management ranged from total failure to 5,855 kg/ha. Similar wide ranges were found when fertilizer and insecticide treatments were imposed on the farmers' fields. Student's t—tests on the difference between I_1 and I_2 and between F_1 and F_3 indicated that added units of neither factor gave a statistically significant response.

Assuming that the fertilizer treatments could he considered as potential recommendations for the Subang area, the 20 F_1 and F_3 data points were plotted in the form of a cumulative distribution in Figure 9. The curves for each treatment were identical until. the 2,000 kg/ha yield level, at which point the curves diverged. However, the differences from that

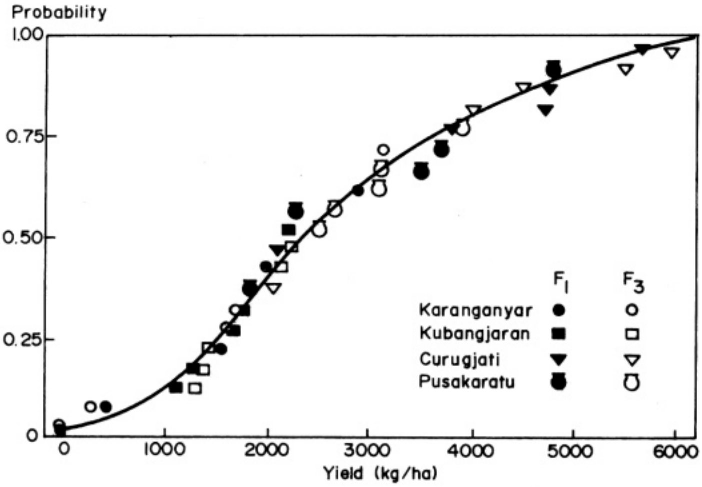

Fig. 9. Distribution of grain yields from supplemental fertilizer trials, Subang, dry season, 1976.

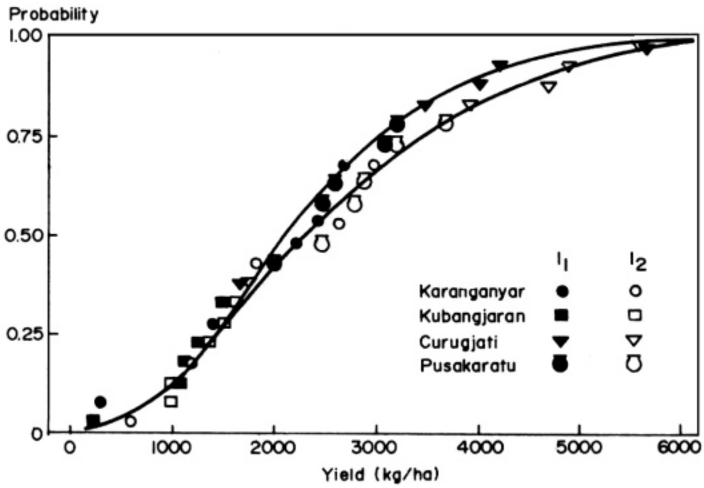

Fig. 10. Distribution of grain yields from supplemental insecticide trials, Subang; dry season, 1976.

point to the yield maximum was never large. The point of deviation is most likely the yield level at which water was the overriding limiting factor. Some nitrogen response would be expected above that point but it is apparently not significant under these conditions.

Similar cumulative distribution plots for I_1 and I_2 data points is presented in Figure 10. The points from both treatments appear to follow the same distribution and therefore a single curve was drawn.

The data were analyzed by the model $Y = b_0 + b_1X$ to separate yield responses into two populations. Y was yield response and $X = 1$, if I_1 (or F_1) were below an arbitrary critical value, and zero otherwise. Although there was a tendency for greater responses to both increased fertilizer and insecticide inputs when yield levels reached 2,500 kg/ha, models for both treatments explained less than 10% of the variation in the dry season data.

As in the experiment situation, the major limitation to increased yields was water availability. There was a tendency toward a response to increased urea inputs but it was weak and variable, in contrast to the experiments. There was no consistent protective effect from an increase in insecticide applications.

Summary of biological constraints

When the wet season main and supplemental experiment results are examined it must be concluded that there is little or no gap in the Subang area. Instead a situation is found in which there are biological constraints that the farmer cannot overcome using the technology he has at hand.

There was evidence of moderate flood damage even in plots that were selected to avoid a flood hazard, implying that other areas probably suffered damage. Rat damage was severe in three of the four main experiments. Losses caused by rats were estimated as high as 1,160 kg/ha and may have been higher in some cases. Insects were also a major constraint. During the wet season, the crop had to withstand attacks by gall midge, stem borers, brown planthoppers and armyworms. Losses caused by gall midge and stem borers were estimated as high as 670 kg/ha and 200 kg/ha, respectively

There was evidence of partial insecticidal control for stem borers but not for gall midge. On the contrary, gall midge damage appeared greater at the high levels of insecticide and nitrogen. The gall midge is widely distributed in the low coastal areas and river flood plains of Java and insect parasites play an important role in curtailing gall midge population buildups. It is conceivable that the insecticides used in the experiment were more effective against parasites than against the gall midge. (Soenarjo and Hummelen, 1976);(Hummelen and Soenarjo, 1976)

The results obtained from the dry season main and supplemental experiments were in some respects similar to the wet season results but for different reasons. From the main experiments, a gap was found that was attributed to limited urea aplications. However, the results obtained from supplemental trials showed only a weak and variable increase from additional urea, which occurred where water was not severely limiting. Neither of the other two experimental factors, land preparation and insecticides, showed pronounced or consistent effects on yields.

Whereas widespread insect damage occurred in the wet season, the dry season was characterized by widespread water shortages. Where water was plentiful, yields near 6,000 kg/ha were obtained in the experiments and by farmers. Water shortages were related to irrigation distribution so that some sections had high yields and others had low yields. In the Pusakaratu experiment, one block received a moderate amount of water while an adjacent block suffered severe water shortage, which gave more than a two—fold difference between the block yield averages. Moreover, within block yield differences could be related to an arbitrary moisture gradient index. Consequently, slight differences in water distribution during the dry season have a pronounced impact on yield.

When an assessment is made based on the results from both season, it is concluded that from the biological standpoint there is little or no gap between the yields farmers are currently achieving and what they might achieve if they used more of the inputs readily available to them. However, substantial gains could be made if effective pest management systems were devised and water control was improved.

IDENTIFYING SOCIOECONOMIC CONSTRAINTS

Six of the treatment combinations were designated as management packages with the levels of inputs as discussed earlier. In this section we estimate the economics of each package with average yields adjusted for rat damage. The cost associated with each treatment has been estimated as shown in Tables 65 and 66. Labor costs include land preparation, weeding, and materials application. Urea and TSP both cost Rp 80/kg. The price of diazinon was Rp 900/lt, and Furadan was Rp 400 per kilogram.

Table 65. Input use in the six experimental treatments designated as management packages. Subang, Indonesia, wet season 1975—76and dry season 1976.

Input	M_1	M_2	M_3	M_4	M_5	M_6
Seed (kg/ha)	25	25	25	25	25	25
Urea (kg/ha)	100	200	200	200	300	300
TSP (kg/ha)	50	50	50	50	50	50
Diazinon (l/ha)	2	2	2	2	2	4
Furadan (kg/ha)	0	0	20	20	20	0
Labor (man days)	115	115	123	161	161	157

Because the high inputs did not give much yield increase net returns were highest with M_1 in the wet season. In the dry season the average yield increase of M_3, although depressed by drought, was high enough to raise net returns Rp 20,000/ha above M_1.

The estimated profitability of the high management packages were appreciably lower than the estimated profitability of farms in the wet season, based on farm record keeping data (Table 67). Pest damage within the experimental plots appeared to be more severe suggesting the tendency for a higher pest damage in the higher level of management.

Table 66. Costs and returns of the six experimental treatments designated as management packages, farmers prices. Subang, Indonesia, 1975—76.

Input	M_1	M_2	M_3	M_4	M_5	M_6
	Input costs, wet and dry seasons					
Seed ('000 Rp)	3.1	3.1	3.1	3.1	3.1	3.1
Fertilizer ('000 Rp)	12.0	20.0	20.0	20.0	28.0	28.0
Pesticide ('000 Rp)	1.8	1.8	9.8	9.8	9.8	3.6
Labor ('000 Rp)	42.3	42.3	46.3	61.0	61.0	59.0
	Harvest costs and returns,[a] wet season 1975—76					
Yield (kg/ha)	2473	2599	2643	2681	2309	2694
Gross return ('000 Rp)	160.7	168.9	171.8	174.3	150.1	157.1
Harvest share (kg/ha)	353	371	378	383	330	385
Net return ('000 Rp)	78.6	77.6	68.0	55.4	26.7	56.3
	Harvest costs and returns,[a] dry season 1976					
Yield (kg/ha)	2920	3065	3575	3595	3535	3465
Gross return ('000 Rp)	189.8	199.2	232.3	233.6	229.8	225.2
Harvest share (kg/ha)	417	438	511	514	501	495
Net return ('000 Rp)	102.9	102.9	122.3	108.7	97.4	98.7

[a]Rice sold for Rp 65/kg.

Table 67. Farm budgets based on farm record data of five farms per study village. Subang, Indonesia.

Item	Wet season 1975—76		Dry season 1976	
	Amount	Rp	Amount	Rp
Seed	25.0 kg	3,125	25.0 kg	3,750
Fertilizer	205.5 kg	16,438	209.8 kg	16,700
Pesticide	1.3 1t	1,153	1.0 1t	865
Family labor	14.5 md	6,685[a]	13.2 md	5,667
Hired labor	94.0 md	47,000	101.8 md	50,868
Harvest share	461.0 kg	28,502	439.0 kg	22,685
Total cost		102,903		100,535
Gross return	3,069.3 kg	199,501	2,441.3 kg	158,681
Net return		105,734		58,146

[a]Valued at Rp 500/md, the same as hired labor.

It is immediately obvious that in the wet season farmers are using the best option among those tested. Increasing the level of fertilizer and pesticide application is not economical. However, lower levels of input, especially pesticide, may be a better option for farmers in the area.

But it is obvious that there is nothing seriously wrong with the farmers' technological level in the area. The large "potential" gap in the area is not the farmers' gap, but the technological gap per se. That is, the recommended technology is not effective. Efforts are needed to increase the effectiveness of the technology itself so farmers can cope with pest problems.

In the dry season the experimental yields, even M_1, were higher than farmers' and M_3 gave roughly double the profit of non—experimental farms in the area (Table 67). The severe drought depressed yields of the non—experimental farmers, and those experiments that had drought.

Perceived difficulties

The relatively high adoption of improved farm practices on the one hand, and the relatively low yields on the other, reflect the nature of the problem at hand. The question becomes: "Why do farmers not use higher levels of inputs?"

The need for proper conduct of experiments on farmers' field becomes immediately obvious. The performances of the new technology is usually derived from fully controlled experiments, reflecting potential yield responses conditional on the elimination of possible production hazards. This does not mean that controlled experiments are not needed, but it signifies that fully controlled experiments alone do not provide us with a relevant set of facts concerning the performance of a given technology. Environmental control on a large—scale poses qualitatively different problem than environmental control in the limited field of an experimental station. Cost, organizational set—up, supporting infrastructure and the type of the adaptive technology itself are problems that are not by themselves equally meaningful on a smaller scale. This suggests a new area of multi—disciplinary research.

To understand the problem properly, we have to know what farmers think about it. But it is clear that we are still at the early stage of research -- the identification stage. We do not know for sure the nature of the problem, which means that we do not know which questions to ask.

After delineating the nature of the problems and devising a proper methodological framework to effectively investigate them, we are now ready to embark on the second stage of research, with new field experiments and a new survey design.

With the above limitations in mind, we present some of the information collected in relation to farmers' perceived difficulties. Farmers were asked whether they had difficulty in relation to input supply, pest hazard, labor availability, effectiveness of pesticide, and water control. The responses are presented in Table 68.

Table 68. Perceived difficulties, expressed in terms of percentages of positive responses. Subang, Indonesia, 1975—76.

Problem perceived	Pusakaratu		Bojongtengah		Compreng		Karanganyar	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Input supply	10	10	10	10	15	50	0	0
Pest hazard	20	20	100	100	5	15	100	100
Pesticide effectiveness	35	35	85	85	50	50	35	35
Water control	0	0	0	0	60	5	5	25
Labor	0	0	0	0	0	0	0	35

The response to pest problem at Pusakaratu and Compreng does not reflect the magnitude of the problem in the area. It suggests the difficulties faced in the attempt to measure this qualitative information. The difficulty in getting proper input supply as shown in responses of farmers at Compreng is easily understood because that village is the farthest from the highway.

The zero response to water control probably reflects the contention that it has been much improved with the Jatiluhur irrigation project. Farmers are facing "normal" difficulties they do not find worth mentioning.

We also see that 35 - 85 % of farmers doubted the effectiveness of pesticide. Most of the pesticide available is provided by BIMAS, and farmers have no choice as to type. Diazinon is readily available through BIMAS. Recently, Sevin was introduced for brown planthopper control, but the pesticide market is still limited in the villages.

Pest losses. To obtain additional insight into the pest damage as perceived by farmers, they were asked to mention the seriousness of damage due to various insects and rats. Farmers considered four major insects, and rats, the most important factors determining the level of yield in the area. Rat damage came after stem borer and gall midge in importance. Hoppers and bacterial leaf blight were important at one site.

From the farmers perceived intensity of pest damage we further tried to estimate the relative importance of each pest in the reduction of yield. From the way the questions were administered, it is implied that:

1. The intensity score for each farmer is comparable, i.e., the score of one means the same intensity of pest damage irrespective of the kind of pest.

   The intensity score for each farmer can be regarded as approximately linear, i.e., the score of two means two times more damage than the score of one.

3. The intensity scores are not cross—comparable among farmers.

To make the damage score cross—comparable, an adjustment of the data was made using the following reasoning:

- A damage level can be found using the level of realized production. For this purpose, an estimated potential production level should be determined.

- The determined level of damage can be scored (say from zero to 25).

- The devised damage score is made equal to the total damage score of each farmer multiplied by the unknown factor proportion, which can then be computed.

Considering the relatively high level of input, the use of modem varieties, and the fact that some farmers did achieve a yield level of 5,000 kg of rough rice per ha, we use 5,000 kg as the potential yield under zero pest damage. The results of the computations are presented in Table 72. There is an assumption in these computations that other factors such as flooding, drought and nutrient shortages are not limiting yields. We therefore believe the results presented in Table 69 only slightly over estimated the causes of wet season yield losses.

What is surprising is the fact that the "traditional" pest (stemborers) is still the most important pest in the area, as shown in the figures below Combined stem borer, gall midge and rat losses are estimated in 1,774 kg/ha

Table 69. The crop losses and relative importance of pest damage as estimated from the perceived intensity of damage. Subang, Indonesia, 1975—76.

Damage		Pusakaratu	Bojongtengah	Compreng	Karanganyar	Ave.
Total (kg/ha)		2,950	1,370	1,790	2,260	2,132
stemborer	(kg)	1,287	244	500	1,023	783
	(%)	43.6	17.8	27.9	45.3	36.9
gall midge	(kg)	613	307	695	346	504
	(%)	20.8	22.4	38.8	15.3	23.6
hopper	(kg)	259	298	192	200	236
	(%)	8.8	21.8	10.7	8.8	11.0
"Lodoh"	(kg)	0	310	0	207	118
	(%)	0	22.7	0	9.2	5.6
Rats	(kg)	791	211	403	484	487
	(%)	26.8	15.3	22.5	21.4	22.8

over the four villages after weighing for areas. Losses by these three pests alone account for 83% of the total losses. That the new pest control technology has not been able to reduce appreciably this pest, is a problem that needs proper solution.

The problem of timeliness is also suggested. But the field experiment suggests that the major problem lies in the effectiveness of the pest control technology itself as developed and recommended by the research institutes and extension agencies.

SUMMARY AND CONCLUSIONS

Comparison of Kulon Progo and Subang

There were some noteworthy similarities and differences between the Kulon Progo and Subang study areas. Pest pressure was much greater in the coastal plain area, which appears to be the main reason for generally lower yields in Subang, although moderate flooding and lower solar radiation may be factors also. Pesticides performed poorly in both areas and actually reduced yields in some instances. In both areas the level of technical knowledge appeared as an important yield—increasing factor, either directly or indirectly through a greater tendency to employ fertilizer. In Kulon Progo, there was a clear relationship between input and credit availability on one hand and fertilizer use on the other, but most of the non—availability occurred in non—BIMAS areas. In Subang, all villages were under BIMAS program. Although there may have been shortages or late deliveries of inputs, few farmers considered availability to be a difficulty, perhaps because their frame of reference was heavily influenced by the pre—BIMAS deliveries.

Implications

Although only two seasons and two locations were examined, the results suggest several priority research topics. The results also have implications for rice—production program recommendations.

Ineffective pest control is a definite yield damaging factor. However, pest regimes (species, intensities and distribution over a season) are different depending on regions and seasons. In the short—run applied research trials using known effective chemicals and methods of application should be undertaken on a regional basis, and if results are successful, insect control recommendations should be altered accordingly.

In the meantime farmers in areas where rice is frequently damaged by gall midge should be cautioned about using diazinon and heavy fertilizer rates. In fact the high pest damage in Pusakanegara and Pengasih suggests that farmers should use lower fertilizer input. The possibility of substituting other chemicals for diazinon in such areas should be explored. As a long—run research subject, detailed ecological studies should be conducted on gall midge and its predators and parasites with the objective of developing sound integrated control methods.

Rat damage is at least a moderate problem, causing losses and perhaps also inhibiting potential early adopters from using production intensification practices that require early planting. Because of the migratory nature of rats, new rat control methods should be investigated for an area 4 to 8 ha in size.

Increasing fertilizer application above the levels now used in the wet-season crop in coastal areas does not seem likely to be profitable, until pests can be controlled. However, in the high-plain and low-terrace areas, increased fertilizer inputs above current levels do give profitable results. Applied research trials, under farmers' conditions, should be implemented to substantiate those findings and to determine how much additional fertilizer might be profitably applied during the wet season in high-plain and low-terrace areas. Substantial increases may also be gained in the dry season by concentrating increased fertilizer inputs only in areas where irrigation water supply is highly reliable.

Slight differences in water availability have made dramatic differences in productivity, a phenomenon that has been demonstrated elsewhere. It was apparent in the Subang area that a uniform distribution of water would have increased total production in the area.

Future constraints emphasis

Ineffective insect control was a major problem in both study areas. Therefore emphasis should be given to insect control measures and the farmers understanding of control techniques. Entomologists should be more involved in the determination of future insecticide treatments and in examining data collected from the plots.

Irrigation is an important consideration in many areas and water control differences should be included in the future studies. A simple quantitative physical measure of water control should be used on the plots. It may be possible to relate this measure to a subjective measure made among farmers and explain semiquantitatively the farm-to-farm yield differences and differences during recent years. The quantitative index may explain differences in input adoption more adequately.

Rat damage is a problem that arises from time to time in all rice growing areas. If rat damage is expected in a study area, control measures should be tried at the experimental sites. But perhaps more significantly, a special survey should be made to determine what factual knowledge farmers have about rats and rat control techniques versus what they believe about rats. Reasons for a general lack of concerted community action against the rat problem should also be sought.

Evidence indicates that technical knowledge is an important factor in determining the adoption of improved practices and increased yields. However, the factors leading to farmer differences in technical knowledge have not been investigated. These differences should be given emphasis in future constraints studies and the findings related back to the sources of information (particularly the elements of extension programs), and ahead to a more precise quantification of their impact on productivity.

Lack of a nationally supported production program in a village is regardly generally to have a limiting effect on input and credit availability. However, INMAS areas are without institutional credit sources. It may be possible to examine the effect of input and credit availability if a BIMAS village, an INMAS village and a nonprogram village with otherwise similar characteristics are studied simultaneously.

Aside from the above, there are general issues about research methods that should be explored as part of the research process. Some of these are: extrapolation of results from a few sites or seasons to a general population; the need for fewer or greater numbers of experiments, both main and supplemental; the merits of recall survey vs farm recording methods for obtaining production input data, and the Validity of measures of such items as traditional belief, stage of adoption anti technical knowledge.

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Appendix Table 1. Weather conditions in the 1975—76 in the Subang area and averages for preceding years.

Month	Average of					Wet season 1975—76				
	Rain—fall[a] (mm total/ month)	Radia- tion[b] (cal/cm2 ave/day)	Sun- shine[b] (% ave/ day)	Temp. mean (ave/ day)	Evapo ration[b] (mm ave/ day)	Rain—fall (mm total/ month	Radia—tion (call cm2 ave/ day)	Sun—shine (% ave/ day)	Temp. mean (ave/ day	Evapo—ration (mm ave/ day
November	128	390	54	27.7	4.9	65	383	42	27.2	5.1
December	211	285	42	27.1	4.5	95	390	37	26.8	5.3
January	317	358[c]	33[c]	26.5	3.7[c]	837	309	14	25.2	3.2
February	211	386[d]	42	26.4	3.9[c]	232	473	55	26.4	5.1
March	178	392[d]	49	26.4	4.0[c]	521	453	42	26.3	4.8
April	109	406	68	27.0	4.1[c]	49	416	62	27.1	5.2
May	99	380	58	27.2	3.8	22	431	68	27.1	5.0
June	95	385	69	26.9	4.2	10	432	75	26.7	5.5
July	41	370	77	26.8	4.3	0	416	79	26.4	5.7
August	27	425	80	26.7	4.7	0	444	76	26.7	5.0
September	34	390	67	26.8	5.0	67	454	76	26.9	6.0

[a] Long term averages.
[b] Average of 1972—1975, except where noted by c and d.
[c] Average of 1973—1975.
[d] Average of 1973—1974.

Appendix Table 2. Treatment yield averages (kg/ha) in the four main experiments. Subang, Indonesia, wet season 1975—76.

Treatment L	F	I	Kubangjaran	Karanganyar	Curugjati	Pusakaratu	Mean
1	1	1	1715	2767	2713	2975	2452
2	1	1	1115	2330	2263	2125	1958
1	2	1	1487	2340	2523	2240	2147
2	2	1	1613	3050	2185	2375	2306
1	3	1	1795	3110	2920	2075	2475
2	3	1	970	3293	2560	2145	2242
1	1	2	1810	2187	2103	2640	2185
2	1	2	1297	2335	3167	1855	2163
1	2	2	693	2560	2603	2755	2153
2	2	2	1503	2407	2730	3195	2459
1	3	2	1760	2825	1955	2335	2219
2	3	2	1273	3227	1680	2885	2266
1	1	3	2000	2425	2783	2745	2488
2	1	3	1603	2920	2530	2645	2424
1	2	3	2233	2795	2377	2615	2505
2	2	3	1575	2890	2725	2875	2516
1	3	3	1695	3160	3255	3070	2795
2	3	3	1410	3998	2217	1885	2377
Average			1530	2814	2515	2524	

Appendix Table 3. Treatment average grain yield (kg/ha) from the four main experiments. Subang, Indonesia, dry season 1976.

Treatment L	F	I	Kubangjaran	Karanganyar	Curugjati	Pusakaratu	Mean
1	1	1	2910	2100	4465	2210	2921
2	1	1	2800	2140	4175	1790	2726
1	2	1	3380	2450	4890	1548	3067
2	2	1	3760	2018	5383	2538	3425
1	3	1	5010	2185	5798	2438	3858
2	3	1	5108	2600	5978	1808	3874
1	1	2	2993	2195	3815	1820	2708
2	1	2	3935	1965	5078	2910	3472
1	2	2	3870	2598	5225	2598	3573
2	2	2	3488	2185	5430	3273	3594
1	3	2	4548	2285	5638	2038	3627
2	3	2	3788	2705	5590	2065	3537
1	1	3	3510	1900	4633	1548	2898
2	1	3	3170	2340	5165	2038	3178
1	2	3	4353	2475	5023	2765	3654
2	2	3	3958	2495	5473	2145	3518
1	3	3	3325	2315	6083	2820	3636
2	3	3	2980	2750	6320	1810	3465
Average			3716	2317	5231	2231	

PHILIPPINES 1974, 1975, 1976

Randolph Barker, Surajit K. De Datta, Kwanchai A. Gomez, Robert W. Herdt

ABSTRACT

Constraints experiments are reported for 2 wet seasons and 2 dry seasons in three areas of the Philippines. ln the wet seasons, the yield gap ranged from 0.4 to 2 t/ha with fertilizer and insect control responsible for nearly equal amounts in most locations. The gap ranged from 0.9 to 2.0 t/ha in the city seasons with fertilizer contributing about two-thirds. The maximum yield input levels cost between 2 and 4 times as much as the farmers were spending and were less, profitable than farmers' input levels in most of the wet season experiments and about half the dry season experiments. Packages of inputs slightly higher than farmers were using increased profits, but increased yields by only about 0.3 t/ha in the wet season and by about 1.0 t/ha in the dry season. Farmers thought inputs were available and cited water-related problem most frequently as constraints.

RICE IN PHILIPPINE AGRICULTURE[1]

Rice contributes 70% of Philippine cereal consumption (Dosayla and Darrah, 1973). More than 30% of all agricultural land, and more than 50% of the food cropland is devoted to rice. Between 1960 and 1974 rice production increased at 2.4% annually, about as fast as population. Yields increased from 1.19 t/ha in 1960—63 to 1.56 t/ha in 1972—75. Despite this, rice has been imported in all but five of the last 15 years (Table 1).

Rice production inputs have increased sharply. Fertilizer—responsive, modern varieties were introduced in 1965 and by 1974 were planted on more than 61% of the rice area. Fertilizer use per hectare of arable land in the Philippines increased from about 15 kg nutrients/ha in the early 1960's to about 25 kg/ha in 1971—72 (Herdt and Barker, 1975). Irrigated riceland has been increased by about 1 million hectares since 1960, totaling more than 1.6 million in 1975 (Table 2).

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[1] If not otherwise specified, data in this section were obtained from the publications of the Bureau of Agricultural Economics, Department of Agriculture and Natural Resources, Republic of the Philippines.

Table 1. Production, area, yield and imports of rice in terms of paddy, Philippines, 1960—1974.

Year	Production (1000 t.)	Area (1000 ha)	Yield (t/ha)	Imports (1000)
1960	3,739	3,306	1.13	a/
1961	3,704	3,198	1.16	186
1962	3,910	3,179	1.23	0
1963	3,967	3,161	1.25	256
1964	3,842	3,087	1.24	300
1965	3,993	3,199	1.25	569
1966	4,073	3,109	1.31	108
1967	4,094	3,096	1.32	291
1968	4,560	3,304	1.38	a/
1969	4,445	3,332	1.33	a/
1970	5,233	3,113	1.68	a/
1971	5,343	3,113	1.72	367
1972	5,100	3,246	1.57	444
1973	4,414	3,112	1.42	311
1974	5,594	3,437	1.63	169
1975	5,660	3,539	1.60	152

[a] Negligible.

Source: Apiraksirikul, 1976.

Table 2. Irrigable areas in the Philippines by type of system for selected years.

Type of system	1960		1965		1970		1975	
	1000 ha.	%	1000 ha.	%	1000 ha.	%	1000 ha.	%
National canal systems	261	35	319	34	420	36	561	35
Communal systems:								
Government assisted	84	11	154	16	199	17	321	20
Private	334	45	374	40	418	36	468	29
Pump irrigation systems	33	4	60	6	89	8	225	14
Others[a]	28	4	29	3	30	3	31	2
Total[b]	740	100	935	100	1,157	100	1,607	100

[a] Includes Friar Land Irrigation Systems and Municipal Systems.
[b] Figures are rounded to nearest whole number and may not add to 100% in each column.
Source: Hayami and Kikuchi, 1975.

Area and production of rice in the Philippines in nine agricultural regions are shown in Table 3. Central Luzon contains 20% of the nation's rice area and produces 25% of the total output. Southern Tagalog, Western Visayas and South and West Mindanao each contribute 12 to 14% of national rice area while three other regions each have about 10%. Field research reported here was conducted in provinces in three important rice producing regions. Nueva Ecija in Central Luzon, Laguna in Southern Tagalog, and Camarines Sur in the Bicol region.

Table 3. Total rice area, area planted to first crop rice, and total regions and national production, Philippines, average 1968—1972.

Region	Total area (ha)	% of national area	Area in 1st crop lowland (ha)	% of national 1st crop area	Total produc—tion (1000 t)	% of national produc—tion
Ilocos	137,596	4.3	113,120	6.2	229	4.7
Cagayan Valley	325,572	10.1	133,332	7.3	551	11.4
Central Luzon	636,832	19.8	504,184	27.5	1,209	24.9
Southern Tagalog	441,800	13.7	234,570	12.7	625	12.9
Bicol	308,976	9.6	149,780	8.2	467	9.6
Eastern Visayas	302,596	9.4	127,740	6.9	306	6.3
Western Visayas	400,888	12.4	263,774	14.4	573	11.8
N & E Mindanao	218,686	6.8	72,174	3.9	271	5.6
S & W Mindanao	448,706	13.9	235,324	12.9	619	12.8
Philippines	3,221,652	100.0	1,883,998	100.0	4,850	100.0

Source: Bureau of Agricultural Economics, Department of Agriculture and Natural Resources.

The lowland, first crop or wet season crop, grown between July and December, accounts for 57% of the total national rice area (Table 4). In the three study areas, the first crop depends largely on monsoon rains. Much is grown under rainfed lowland conditions where the land is puddled prior to transplanting but is dependent on the natural rainfall. Areas served by irrigation systems rely on diversion of river flows and as a consequence are also highly dependent on rainfall.

The area planted to second crop lowland (mainly dry season) is only 30% of the total, while upland rice, grown without standing water, makes up 15% of the area.

Irrigated area in the country has more than doubled since 1960 (Table 2). Much of the growth has been in government—assisted, communal, gravity—irrigation systems, but in recent years pump irrigation has increased rapidly. Most of the irrigated area is devoted to rice production. Modern semi—dwarf varieties have been increasingly planted on both irrigated and

Table 4. Area planted to rice by type of crop and by region, Philippines, average 1968—1972.

Region	Lowland first crop 1000 ha	%	Lowland second crop 1000 ha	%	Upland 1000 ha	%	Total	% of total
Ilocos	113	82	20	15	4	3	137	4.27
Cagayan Valley	133	35	175	54	16	5	325	10.10
Central Luzon	504	79	125	20	8	1	637	19.76
Southern Tagalog	234	53	119	27	88	20	442	13.72
Bicol	150	49	107	35	52	17	309	9.59
Eastern Visayas	128	42	148	49	26	9	303	9.39
Western Visayas	264	66	93	23	44	11	401	12.45
N & E Mindanao	72	33	76	35	70	32	219	6.79
S & W Mindanao	235	52	116	26	97	22	449	13.93
Philippines	1,834	57	980	30	407	13	3,221	100.00

Source: Bureau of Agricultural Economics, Department of Agriculture and Natural Resources.

rainfed—lowland rice fields (Table 5). By 1974 the modern varieties were planted on 80% of the irrigated and 64% of the rainfed lowland. Virtually all of the upland area was planted to traditional varieties.

Despite these favorable trends, and despite (or perhaps because of) the rapid increase in area devoted to the new varieties, the yields registered were low -- averaging only 13% more than other varieties on the irrigated land, and only 9% more than other varieties under rainfed conditions (Table 6).

Three hypotheses are advanced to explain the disappointing performance record

1. Modern varieties actually have no greater production potential than the old varieties;

2. Farmers are not growing the modern varieties "properly," thus the lack of farmers inputs accounts for low yields;

3. Modern varieties have no higher yield potential under farmers' environments than the old varieties.

The data in Figure 1 show the effect of nitrogen on the yield of three varieties and provide some tentative tests of the three hypotheses. Peta is a variety typical of the best of the traditional varieties. IR8 is the prototype, first—generation, modern variety, which gives high yields but is susceptible to many insects and diseases. IR20 is a widely grown, second—generation, modern variety, which is resistant to several of the most damaging pests of rice. Maximum dry season yields of IR8 in these

Table 5. Rice area harvested, irrigated and rainfed, by variety type ('000 ha), Philippines, 1968—1974.

Crop year	Irrigated		Rainfed			Total
			Lowland			
	Modern[a] varieties	Other varieties	Modern[a] varieties	Other varieties	Upland	
1967—68	447	862	256	1259	480	3303
1968—69	912	570	439	968	442	3332
1969—70	826	519	527	828	412	3113
1970—71	985	485	580	697	365	3113
1971—72	977	355	850	699	366	3246
1972—73	873	368	807	629	434	3112
1973—74	1194	299	982	551	409	3437
1974—75	1109	303	1066	608	453	3539

[a] Include IR—series, BPI—series and C—series.

Source: Bureau of Agricultural Economics, Department of Agriculture and Natural Resources.

Table 6. Palay yield (kg/ha) irrigated and rainfed, by variety group, Philippines, 1968—1974.

Crop year	Irrigated		Rainfed			Average of all
			Lowland			
	Modern[a] varieties	Other varieties	Modern[a] varieties	Other varieties	Upland	
1967—68	1967	1613	1307	1239	825	1380
1968—69	1778	1617	1125	1089	792	1333
1969—70	2155	1886	1487	1527	1026	1680
1970—71	2023	1930	1614	1580	1025	1716
1971—72	2053	1723	1443	1350	855	1571
1972—73	1950	1741	1276	1110	786	1418
1973—74	2051	1887	1531	1252	939	1627
1974—75	2222	1879	1430	1179	854	1602

[a] Includes IR—series, BPI—series and C—series.

Source: Bureau of Agricultural Economics, Department of Agriculture and Natural Resources.

experiments at four Philippine stations averaged 6.8 t/ha over the six—year periods, while at the same stations maximum yields of Peta averaged 4.4 t/ha. Comparable wet season yields were 4.6 for IR8 and 3.1 for Peta. Average yields of IR20 were similar to those of IR8.

The data clearly show maximum yields about 50% higher for the modern varieties. Hence, we can reject the first of the above hypotheses. The advantage exists and is appreciable. It is true that the yield advantage varies between locations and seasons. At the Visayas experiment station, IR8 and Peta have about the same average yield during the wet season. That suggests that there may be some validity in the hypothesis that under different environmental conditions, the yield advantage of the modern varieties is reduced. In almost all cases, the yields of the three varieties are nearly identical at the zero level of nitrogen. That lends support to the second hypothesis that farmers' yields with modern varieties may be low because they use low levels of inputs.

These conclusions are highly tentative, because the evidence examined was designed to answer other questions and the trials were conducted on the well protected environments of experiment stations. Other experiment station evidence could be examined, but it has the same basic limitations. The use of experiments in farmers' fields overcomes these limitations, and the data examined in the rest of the paper is derived from such trials.

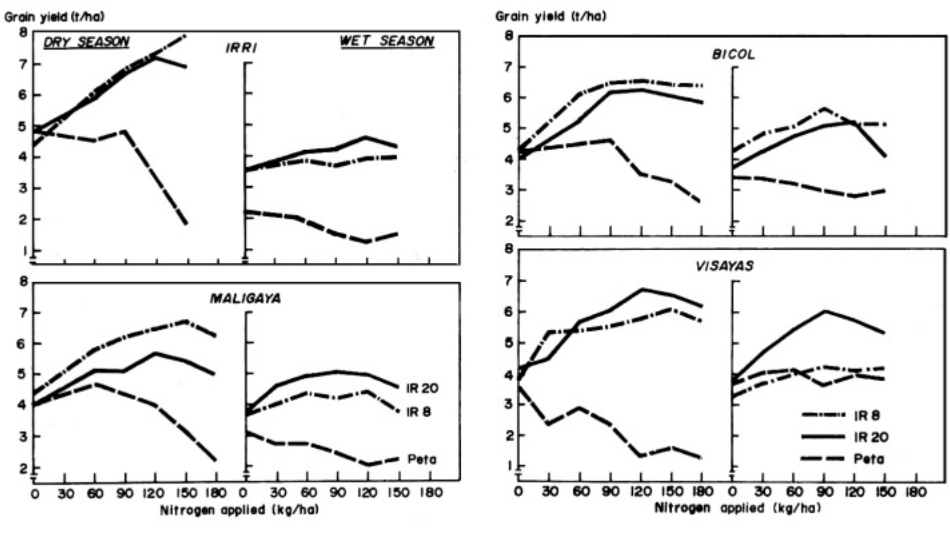

Fig. 1. Effects of nitrogen on grain yield of three varieties, 1968–1973. (Source: IRRI Agronomy Department)

METHODOLOGY

Selecting study areas

The major criteria for selecting study areas was that rice be an important crop for income and employment and that the area had to be accessible from IRRI or another research center. Background research on the development of methodology for use in the project had been conducted in Laguna Province in 1972 and 1973 (IRRI, 1974). Research information was available from the Maligaya Rice Research and Training Center (MRRTC) in Nueva Ecija Province, Central Luzon, and the Bicol Rice and Corn Experiment Station (BRCES) in Camarines Sur Province, Bicol region. We, therefore, decided to continue the research in Laguna, to begin research in Nueva Ecija in the wet season (July—November) of 1974, and to begin research in Camarines Sur in the dry season (December—May) of 1975 (see map in Fig. 2). This report summarizes the results of two years of farmers' field experiments research in Laguna and Nueva Ecija and three seasons of research in Camarines Sur.

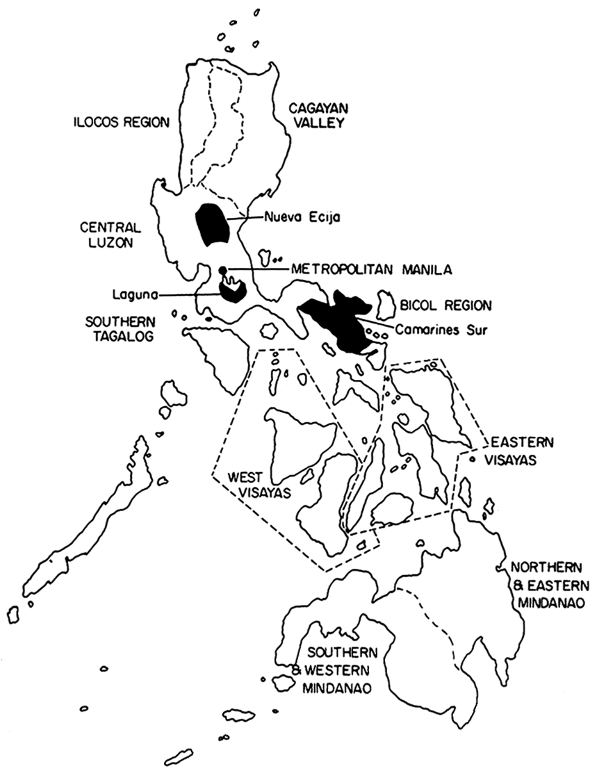

Fig. 2. Ten Development Regions of the Philippines and three Provinces Studied in the IRRI Constraints project, 1974–1976.

In addition to the farms where the experiments were placed, we selected samples of farmers in the same and nearby barrios to interview. In 1974—75, we spread the surveys throughout Central Luzon, selecting 60 farmers near MRRTC, another sample of 60 about 100 km south, just outside Manila in Bulacan Province, and a third sample of 60 about 70 km north of MRRTC in Pangasinan Province. In 1975—76, we conducted interviews of the same farmers near MRRTC, but instead of continuing with the other two interview samples in Central Luzon, we chose samples of 40 farmers in Laguna Province and 40 in Camarines Sur Province including some of the farmers on whose fields experiments had been located and other nearby farmers.

Measuring biological yield constraints

About one—half the lowland rice in the Philippines depends entirely on rainfall, about one—fourth is grown during the wet season with some irrigation and the remainder is divided between upland rice and dry—season, irrigated rice. Study areas include rainfed and irrigated farms and we conducted some of our wet season experiments under rainfed conditions. Most Laguna experiments were irrigated. Soils in the Nueva Ecija sites were largely silt loam, while in Laguna they had a higher clay content.

Growing conditions. Weather conditions in Nueva Ecija during the 1974 wet season (July—December) were abnormal, particularly late in the season when typhoons struck with unusual frequency (Fig. 3). Seven typhoons went through the area during the late stages of crop growth. This compares to an average of less than one typhoon that passed through the area during the corresponding periods of the preceeding eight years.

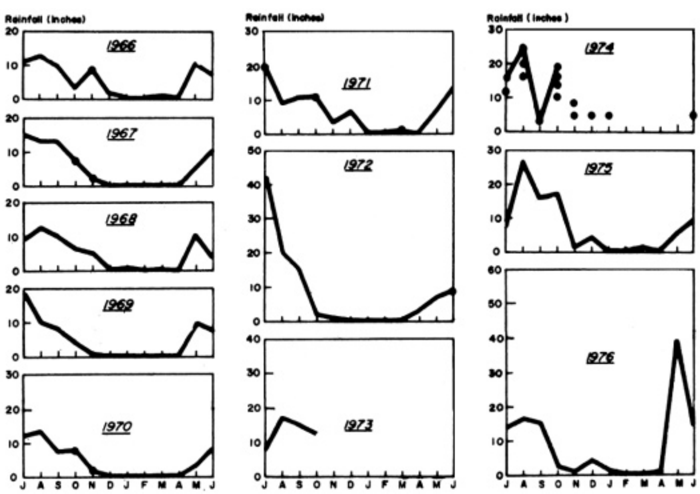

Fig. 3. Distribution of total monthly rainfall (inches) and occurrence of typhoons (•), Maligaya Rice Research and Training Center, Philippines, 1966–1976.

Brown planthopper also proved to be a moderately important pest during 1974. Weather in 1975, in contrast, was almost ideal for rice production and brown planthopper was not a problem. One result of the weather during the two study years was that there was little difference between rainfed and irrigated farms because both received plenty of water.

Weather in Laguna and Camarines Sur was within the normal range. Although typhoons occurred, those typhoons came at more usual times and with more usual frequency than in Nueva Ecija.

Experimental factors. Four factors were selected for the 1974 wet season Nueva Ecija experiments: fertilizer, weed control, insect control and land preparation. We chose these factors because we believed that farmers in Nueva Ecija were using too low a level of fertilizer for maximum yields, and that increasing the level of fertilizer would bring about intensified weed and insect problems. It was believed that land preparation might be inadequate, especially at the high level of fertilizer, so it was included as a fourth factor.

Fertilizer, weed control and insect control were included in the Laguna and Camarines Sur sites. Earlier Laguna studies had shown that the seeds used by farmers were of high quality so seeds were not included as a factor (IRRI, 1974).

Most farmers in the study areas had used modern varieties for some time, so it was believed unnecessary to test them. However, as there is sometimes a lag in the availability of the latest variety to farmers, the latest variety was tested in a supplementary experiment in Nueva Ecija and Camarines Sur. After the first season, we realized that Nueva Ecija farmers generally transplant seedlings older than the recommended age, transplant randomly rather than in regularly spaced rows and use more than the recommended number of seedlings per hill. These cultural practices were subsequently tested as a set of “high cultural practices” in Nueva Ecija and Camarines Sur.

Water is perhaps the most important variable for high yields but as its inclusion in field plot experiments on farmers’ fields is laborious and costly, it was not included, although it had been tested in 1972 research in Laguna (IRRI, 1974). Instead, we attempted to represent a range of water control conditions by placing experiments on rainfed as well as on irrigated farms.

Land preparation was dropped after the first year because the 1974 experiments in Nueva Ecija convinced us that land preparation practices of most farmers in the area were adequate and because there was little yield impact from the land preparation treatment.

Experimental design. The basic experimental design included two components: a two—level factorial and a four—or five—level management package. The experimental factors discussed above were included in the factorial at the farmers’ level and at the high level. The average farmers' levels and the high levels used in the study sites are shown in Table 7. The management packages consisted of M1 with all factors at the farmers' level, M5 with all factors at the maximum yield level, and the intermediate levels of M2, M3, and M4. In the latter three treatments, all of the tested factors were increased between levels. For example, M2 included 30 kg N/ha, 2 insecticide sprays and no weeding, M3 included 60 kg N/ha, 3 insecticide treatments, and a low cost weed control, and so forth up to the M5 level. Two replications were used in the management package (De Datta, et. al.)

Figure 4 shows a typical plot design used in some of the research. Plots were 3.2 x 5.6 m with 10 sq m harvested. Previous research suggests that a harvest area of 6 sq m to 8 sq m per plot is adequate (Gomez, Torres, and Go, 1973). To minimize the amount of land used and still provide a basis for statistical analysis the technique of partial replication was sometimes used. In the case illustrated, the experiment was replicated twice.

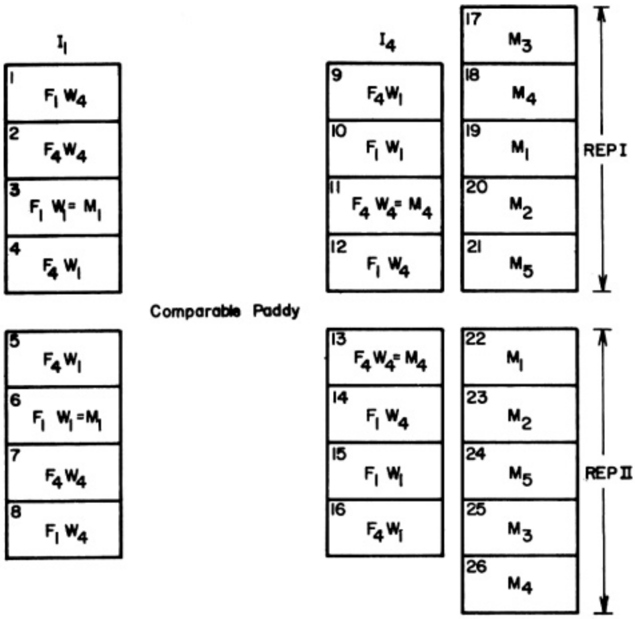

Fig. 4. Typical plot layout used in experiments studying yield constraints on farmer's fields, Philippines.

Analysis. The yield gap was obtained as the yield difference between the plots with all inputs at the high level, and the plots with all inputs at the farmers' level. The yield contribution of each individual input was determined by comparing the average yield of all treatments with the factor at the high level. Statistical analysis of the factorial component was conducted to determine whether interactions were present.

Simulating the farmers' input level. The farmers' level of each factor was defined as the level actually used by each farmer on whose fields the experiments were conducted. To accurately simulate the farmers' practices, we designated one of his paddys near the experiment as the "comparable paddy." Every operation by the farmers on the comparable paddy was noted by the researchers and duplicated on the appropriate experimental plot as soon as possible. The process was facilitated by having the farmer change a visual signal in the comparable paddy whenever he had worked there.

Table 7. High levels and average farmers' levels of inputs in yield constraints experiments on farmers' fields, three locations, Philippines, 1974—1976.

Input level	Area	Sites (no.)	Fertilizer- (kg/ha) N	P	K	Weed control[a] (kg/ha) M	C	Insect control[b] (av. no.) F	G
			1974 wet season						
Farmers'	Laguna	10	36	2	0	1.7	0.1	0.5	0
High	Laguna	10	90	30	0	2.0	1.0	4.0	2.0
Farmers'	Nueva Ecija	10	31	21	0	0.3	0.3	1.1	0.4
High	Nueva Ecija	10	130	60	60	1.0	1.0	5.0	3.0
			1975 wet season						
Farmers'	Laguna	20	74	3	2	2.4	0.3	2.3	0.4
High	Laguna	20	80	30	0	1.0	1.0	5.0	4.0
Farmers'	Nueva Ecija	11	79	22	2	0.3	0.4	0.9	0.4
High	Nueva Ecija	11	100	40	30	1.0	1.0	5.0	4.0
Farmers'	Camarines Sur	6	28	15	8	0.4	1.0	3.3	0.0
High	Camarines Sur	6	100	40	30	1.0	1.0	5.0	4.0
			1975 dry season						
Farmers'	Laguna	9	63	5	1	1.9	0.0	2.3	0.2
High	Laguna	9	100	30	0	1.0	1.0	5.0	3.0
Farmers'	Nueva Ecija	3	118	52	0	0.7	0.3	1.0	1.0
High	Nueva Ecija	3	160	40	40	1.0	1.0	5.0	3.0
Farmers'	Camarines Sur	3	36	16	16	0.6	0.3	1.7	0.0
High	Camarines Sur	3	160	40	40	1.0	1.0	5.0	3.0
			1976 dry season						
Farmers'	Laguna	12	92	21	8	1.2	0.1	3.3	0.1
High	Laguna	12	120	0	0	2.6	1.0	2.0	5.1
Farmers'	Nueva Ecija	9	79	38	1	0.9	0.3	1.3	0.2
High	Nueva Ecija	9	150	40	30	1.0	1.0	1.0	4.0
Farmers'	Camarines Sur	5	40	18	7	0.6	0.8	3.0	0.2
High	Camarines Sur	5	150	40	30	1.0	1.0	1.0	4.0

[a]M = mechanized weeding, either by hand or rotary weeder, C = chemical weed control.

[b]F = foliar spray, Hytox, and Azodrin, G = granular control, spread on the paddy water, Lindane and Furadan; no. of treatments refers to treatments to the main field crop. In some cases seedbeds were also treated.

The validity of the approach depended on the success of the simulation of farmers' practices. The yields on the simulated farmers' plots and the comparable paddy were compared in 1973 experiments in Laguna (Gomez, 1974). Those results suggested that no systematic bias occurred using the comparable paddy technique. However, they did suggest that a more accurage measure of the yield effect of insect control could be obtained if high insecticide plots were physically separated from low insecticide plots. Hence, insect control levels were blocked and where possible, separated from each other in the present trials.

Identifying socioeconomic constraints

Socioeconomic constraints can explain why farmers act as they do. Economic considerations are a major force conditioning farmers' behavior. Thus, a primary analytical tool is the calculation of costs and returns of alternatives tested in the experiments.

Other factors such as the availability of inputs when and where they are required, the ability of farmers to buy the inputs either with cash or credit, the farmers' knowledge of technical aspects of agriculture and farmers' subjective feelings about the use of technology are important in understanding farmers' behavior. Several samples of farmers were surveyed to gather data on these variables.

Survey design. Although the experiments were necessarily confined to a rather small sample of farmers in each season and location, because they were expensive and complicated to carry out, a much larger number of farmers were included in the surveys. This helps determine how similar the farmers within experiments were to a larger sample of farmers.

In 1974—75, we selected samples of 60 farmers in each of three widely separated areas in Central Luzon (Fig. 2). All farms were located on silt—loam soils within the same rainfall classification. Selection was by randomly sampling among all farmers in barrios purposely selected near the experimental sites and classified as fully irrigated, partly irrigated and rainfed.

In 1975—76, we continued studying one subsample of Nueva Ecija farmers from the first survey and, in addition, selected samples of 40 farmers in Laguna and 40 farmers in Camarines Sur for a more restricted interview study. The farmers were randomly selected from among all farmers in the barrios where experiments were located.

Cost and returns analysis. A partial budgeting analysis of the costs and returns associated with each package of inputs tested in the management package component of the experiment was carried out. For this analysis, only the experimental factors that were varied were included in the cost calculation, so the criteria for economic benefits was the comparison of the profitability of the farmers' input package with the alternative input packages.

Labor inputs associated with the use of higher rates of inputs were assumed to come from the farm family, so costs of labor were not included in the packages costs. Under this procedure, the added benefits from the tested alternative is the return to family labor and land, not profit. Prices paid and received by farmers were recorded in the farm interviews and used in the cost and returns analysis.

Representativeness of experimental farms. We attempted to choose "typical" farmers' fields for the experiments. However, farmer's willingness, field location and similar practical considerations also affected the choice. To determine how similar the experimental farms were to a larger sample of farms, we compared yields and practices of the experimental farm to those of our randomly selected survey farms in the same and nearby barrios (Table 8). Reported yields and input use of experimental farm were somewhat above those of other farms in the dry seasons but quite similar in the wet.

Regression analysis of input use. To determine the relative importance of factors explaining why some farmers use high levels of inputs and others low, we used a multiple regression analysis on the 1974—75 Central Luzon data.

Input use was measured by two alternative variables: number of improved practices, and expenditure per hectare on purchased inputs (fertilizer, herbicide and insecticide). These measures of input use were regressed on variables reflecting input availability, technical knowledge, traditional beliefs, alternative earnings, credit use, tenure, water control and other variables hypothesized to be important in explaining why some farmers used high levels of technology while other farmers use low levels.

To quantify independent variables, we asked farmers their opinions about the availability of fertilizer, insecticides, and herbicides on a 1 to 5 scale ranging from always available to never available. We devised and administered a test of technical rice production knowledge which included 10 questions, each scored correct or incorrect. Farmers were asked whether they agreed or disagreed with a series of traditions or folk beliefs related to rice production. Answers were scored on a five—point scale from strongly agree (1) to strongly disagree (5). The total score on 14 such questions forms the traditional beliefs variable.

Alternative employment opportunities were measured by nonfarm earnings, calculated as the product of days worked off the farm times wage rate received. Farms were classified as irrigated and rainfed. Tenure was categorized as share tenure or nonshare tenure because other forms all involve fixed costs for land. Farmers were asked to rate the overall value of their extension technicians on a scale of 1 to 5 ranging from very helpful to not helpful.

Tabular analysis of input use constraints. In 1975—76, we expanded survey coverage to all three areas and at the same time narrowed the scope of the survey to focus more sharply on the use of only those inputs included in the experiments. We used tabular analysis to summarize the results of those surveys.

Farmers identifying certain constraints were contrasted with those not mentioning such constraints. Relatively high reliance was placed on the subjective interpretation of constraints by farmers. Where the identified constraints were physical or biological in nature, the farmers' evaluations were compared with experimental results. For social or economic constraints, the perception itself may be as important as the "objective" existence or absence of a constraint. For example, if a farmer believes credit is difficult to obtain, he may not even try to get it, or if he doesn't recognize that insects attacked his rice he may not try to protect it.

Table 8. Comparison of yields and inputs of farms with constraints experiments and a random sample of farmers in the same areas, three locations, Philippines, 1975—76.

Unit	Number	Yield (t/ha)	Fertilizer (kg/ha) N	P	Weed control (₱/ha)	Insect control (₱/ha)
			Laguna, 1975 wet season			
Farms with experiments	10	2.5	62	2	95	74
Farms without experiments	30	2.5	44	4	58	70
			Laguna, 1976 dry season			
Farms with experiments	17	3.7	78	11	137	122
Farms without experiments	26	2.4	57	10	58	57
			Camarines Sur, 1975 wet season			
Farms with experiments	5[a]	2.7	30	15	64	92
Farms without experiments	35	2.2	19	6	42	50
			Camarines Sur, 1976 dry season			
Farms with experiments	7	2.6	44	18	79	79
Farms without experiments	33	1.5	20	7	52	39
			Nueva Ecija, 1975 wet season			
Farms with experiments	11	2.4	48	19	14	60
Farms without experiments	60	.2.2	36	17	28	66
			Nueva Ecija, 1976 dry season			
Farms with experiments	4	4.1	79	45	119	63
Farms without experiments	57	2.6	60	29	19	42

[a] Not all farmers with experiments were interviewed.

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Components of the yield gap. Table 9 shows the average yield gap and the contribution of the tested factors to the yield gap from the three locations during four seasons. The gap between yields with farmers' inputs and with high inputs ranged from 0.4 t/ha to 2.6 t/ha. In Laguna, the gap was between 1.7 and 2.6 t/ha in all seasons. In Nueva Ecija, the gap was 0.4 and 0.7 t/ha in the two wet seasons but increased to 0.9 and 2.0 t/ha in the two dry seasons. In Camarines Sur, the gap was 1.1 t/ha in the 1975 wet season and about 0.5 t/ha greater during the dry seasons.

It seemed that in Laguna, where the gap was consistently largest, the level of farmers' yields was also highest. Similarly in Nueva Ecija, in the 1976 dry season when the yield gap was the highest observed, farmers yields were nearly the highest observed.

Fertilizer and insect control were of about equal importance in all locations in the wet season but fertilizer was more important than insect control in the dry season contributing up to 1.3 t/ha additional yield. Weed control gave relatively small yield increases in all cases, ranging from 0.1 to 0.5 t/ha. The largest yield increase from weed control, 0.5 t/ha, was observed in the 1975 dry season crop in Nueva Ecija. These results seem to indicate that while relatively good weed control is being practiced by most farmers, better fertilization and insect control would increase yields.

One obvious exception to the general trend of the results were those for the 1974 wet season in Nueva Ecija. There the yield gap was 0.4 t/ha, and there was no contribution of fertilizer. This was explained by the unusual typhoons during the growing season that year.

Interfarm variability. Figure 5 illustrates the variability among farms for the Laguna and Nueva Ecija sites by showing each farm as one point. The graph shows the yields with farmers' inputs and high inputs on each farm. Points above the 45° line show sites where the yield gap was positive while points below the line represent farms where yields with farmers' practices were higher than with the high level of inputs. In Laguna, all sites in both seasons showed a positive yield gap. Even where farmers' yields were 4 to 5 t/ha or more, the high level of inputs raised yields by a substantial amount in nearly every case.

The gap tends to be larger in the dry season. In Nueva Ecija, the wet season gap appears to be smaller than in Laguna, and the results are much more variable. During the wet season of 1974, yields with high inputs clustered around 2 t/ha, while in wet 1975 many were close to 4.5 t/ha. Nueva Ecija dry season yields and yield gap showed wide variability with high maximum yields.

Comparisons between locations and seasons suggests that these Laguna farmers in general produced 1.5 - 2.0 t/ha below maximum possible yields in both seasons. Farmers in Nueva Ecija seem to be slightly below the maximum possible yield in the wet season and somewhat more below the maximum yield

Table 9. Contribution of separate inputs toward improving rice yields over farmers' levels in yield constraints experiments in farmers' fields, three locations, Philippines, 1974—1976.

Area	Sites (no.)		Yield (t/ha)			Contribution[a] (t/ha) of			
	rain-fed	irri-gated	Farmers' inputs	High inputs	Differ-ence	Ferti-lizer	Weed control	Insect control	Resi-dual
				1974 wet season					
Laguna	2	8	3.6	5.6	2.0	1.1	0.3	0.8	—0.2
Nueva Ecija[b]	3	7	1.9	2.3	0.4	—0.1	0.2	0.4	-3.1
				1975 wet season					
Laguna	0	20	3.6	5.3	1.7	0.7	0.3	0.7	0.0
Nueva Ecija[b]	5	6	3.2	3.9	0.7	0.3	0.1	0.2	0.1
Camarines Sur	2	4	3.6	4.6	1.0	0.4	0.1	0.6	—0.1
				1975 dry season					
Laguna	0	9	4.2	6.8	2.6	1.3	0.2	1.0	0.1
Nueva Ecija	0	3	4.3	5.2	0.9	0.2	0.5	0.2	0.0
Camarines Sur	0	3	3.9	5.6	1.7	1.1	0.1	0.4	0.1
				1976 dry season					
Laguna	0	12	4.4	6.1	1.7	1.0	0.2	0.6	—0.1
Nueva Ecija	0	8	4.2	6.2	2.0	1.3	0.3	0.6	—0.2
Camarines Sur	0	5	3.3	4.8	1.5	1.3	0.1	0.2	—0.1

[a]Measured as the yield increase from the high level of each input compared to the farmers' level of each input, averaged over all levels of other inputs.

[b]Land preparation was included in these experiments but had no significant effect on yield.

in the dry season. But there was much greater variability in Nueva Ecija than in Laguna. Also, there seemed to be a wet—season yield limit of 4.5 t/ha in Nueva Ecija, while in Laguna yields often exceeded 6.5 t/ha. In the 1976 dry season, high input yields were the same in Laguna and Nueva Ecija.

Input packages. The input—packages component of the experiment provided a basis for judging the economic attractiveness of input levels intermediate between the farmers' and the maximum yield level. In most wet—season cases except Laguna, the farmers' yield level (Ml) was lowest, with yields increasing to a maximum at M4 or M5 (Table 10). By contrast, during the dry season farmers' yields and inputs exceeded the M2 level in most cases.

Table 10. Grain yields of farmers' varieties grown with five input management packages and farmers' cultural practices on farmers' fields, three locations, Philippines, 1974-1976.

Year	Area	Sites (no.)	Yield (t/ha)				
			M1[a]	M2	M3	M4	M5[a]
		Wet seasons					
1974	Nueva Ecija	10	1.7	1.9	2.1	2.4	2.2
1974	Laguna	10	3.7	3.8	4.2	5.0	5.2
1975	Nueva Ecija	11	3.2	3.4	3.7	3.8	4.4
1975	Laguna	5	4.0	3.0	2.7	4.6	5.3
1975	Camarines Sur	2	3.5	3.9	4.7	4.3	4.1
		Dry seasons					
1975	Nueva Ecija	3	4.5	3.6	4.2	5.5	6.6
1975	Laguna	9	4.2	3.5	4.1	5.5	5.7
1975	Camarines Sur	3	4.0	3.5	4.8	5.5	6.0
1976	Nueva Ecija	9	4.2	b	4.6	6.3	6.5
1976	Laguna	7	4.3	b	4.8	5.2	6.4
1976	Camarines Sur	5	3.3	b	3.7	4.3	4.8

[a]M1 stands for the farmers' level and M5 stands for the high level of inputs. M1 and M5 yields in this table are slightly different from corresponding yields in Table 9 because not all components of both experiments were conducted at all sites and because the two components of the experiments gave slightly different yields.

[b]Four packages were tested here in 1976 dry season.

In the dry season, the highest level of inputs generally resulted in the highest yield, with steady increases from M2 to M5, while the results are less consistent in the wet. Yield response from M2 to M5 averaged only about 1.0 t/ha in the wet season. The impact of the typhoons in the 1974 Nueva Ecija wet season is especially evident, but even in the 1975 wet season, the M5 package increased yields over M2 by only 0.9 t/ha in Nueva Ecija and 0.2 t/ha in Camarines Sur. In the dry season, by contrast, the highest package increased yields by at least 2 t/ha above the M2 level in all locations. Thus, the benefits of high inputs are much more certain in the dry season (where irrigation is available, as it was in our experiments).

Varieties and cultural practices. During the 1974 wet season an experiment comparing the latest released variety, IR26, with the farmers' varieties was conducted on three of the same farms in Nueva Ecija where the constraints experiments were conducted. Treatments consisted of the five input management packages, but with seedling age, plant spacing, method of planting, and seedlings per hill controlled at the recommended level. Subsequently, the high level of those cultural practices were included in all Nueva Ecija experiments. Table 11 compares the yields obtained at the farmers' level and at the high level.

In the 1974 wet season, the high cultural practices gave an increased yield at all levels of input on the three farms with experiments. In the 1975 wet season, and in both dry seasons, there was no yield increase from high cultural practices. The difference between the wet season 1974 results, and the subsequent results suggests that perhaps the unusual weather or pest problems of 1974 interacted with the cultural practices to give a favorable yield effect from high cultural practices.

Table 11. Yields with cultural practices at a high level compared to the farmers' level for input packages in experiments on farmers' fields, Nueva Ecija, Philippines.

Level of cultural practices[a]	No. of farms	Yield (t/ha)					
		M1	M2	M3	M4	M5	Average
		1974 wet season					
Farmers'	3	2.3	2.0	2.4	2.7	2.8	2.4
High	3	2.4	2.5	3.1	3.4	3.5	3.0
		1975 wet season					
Farmers'	11	3.2	3.4	3.7	3.8	4.4	3.7
High	11	3.2	3.1	3.2	3.3	4.3	3.4
		1975 dry season					
Farmers'	3	4.5	3.6	4.2	5.5	6.7	4.9
High	3	4.4	3.8	4.0	5.6	7.0	5.0
		1976 dry season					
Farmers'	9	4.2	h	4.6	6.3	6.5	5.4
High	9	4.0	h	4.5	b	6.3	4.9

[a]Cultural practices include spacing, method of transplanting, age of seedlings, and number of seedlings per hill. High level of each is: 25 x 25 cm during the wet and 20 x 20 cm during the dry seasons; straight row trsnsplanting; and 21 day—oldseelings. Farmers generally plant more closely at random and use 30—50 day old seedlings.

[b]These levels were not included in the test of cultural practices.

The comparison of farmers' and test varieties shows similar results to that of cultural practices. During 1974 wet season, the test variety gave a somewhat higher yield at all input levels tested (Table 12). During the other three seasons, either the reverse or no difference was usually observed. This is explained by noting that in the 1974 wet season, farmers were growing IR20, which was somewhat damaged by the brown planthopper attacks. IR26, the test variety that season, is resistant to the brown planthopper and so gave a higher yield. In subsequent seasons, farmers were growing resistant varieties so the test variety contributed nothing to their yield. In this case, as for cultural practices, the interaction of environmental conditions with experimental factors resulted in significant differences between years.

Table 12. Yields of farmers' compared to test varieties for input packages grown with a high level of cultural practices, Nueva Ecija, Philippines.

Variety	No. of farms	Yield (t/ha)					
		M1	M2	M3	M4	M5	Average
		1974 wet season					
Farmers' (IR20)	3	2.4	2.5	3.1	3.4	3.8	3.0
Test (IR26)	3	3.3	2.9	3.7	4.4	4.3	3.7
		1975 wet season					
Farmers'[a]	4	3.5	3.2	3.9	3.9	4.5	3.8
Test (IR30)	4	2.8	3.2	3.2	3.3	3.8	3.3
		1975 dry season					
Farmers'[b]	3	4.5	3.3	3.9	5.5	7.2	4.9
Test[b]	3	4.2	3.1	3.4	4.7	6.8	4.4
		1976 dry season					
Farmers'[d]	9	4.0	c	4.5	c	6.3	4.9
Test[d]	9	4.1	c	5.0	c	6.3	5.1

[a]Farmers grew IR20, IR26, and IR1561.

[b]Farmers grew IR1561, and IR26. The test variety on the farm growing IR1561 was IR26, on the other farms it was IR30.

[c]These levels were not included in 1976 dry season.

[d]Farmers grew IR1561, IR30, IR26. The test variety was IR36.

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Costs and returns analysis

Maximum yields are of interest to researchers but farmers are more motivated by profits. The experimental results suggest that yield increases could have been obtained if farmers had used higher levels of inputs. This section examines the profitability of those higher input levels.

Prices. The prices paid by farmers in Nueva Ecija for the inputs tested are given in Table 13. Prices in the other two regions differed only slightly from those in Nueva Ecija. We included only those chemicals commonly used by the farmers. Between the 1974 wet season and the 1975 wet season, fertilizer prices increased from 10 to 30% and insecticide prices increased as much as 35%. During the same period, the rice price remained constant at ₱1.00/kg (US$ = ₱7.35), then it increased to ₱1.18/kg in the 1976 dry season.

Table 13. Prices used in calculating costs of experimental and farmers' input packages, Nueva Ecija, Philippines.

Input	Unit	Price (₱)			
		Wet season 1974	Dry season 1975	Wet season 1975	Dry season 1976
Fertilizers					
Urea (45% N)	50 kg	70.00	82.70	90.50	90.00
14—14—14	50 kg	61.90	60.20	67.50	66.00
16—10—0	50 kg	63.00	64.95	72.35	72.00
Insecticides					
Furadan 3G	16.7 kg	85.00	89.50	91.10	86.50
Hytox	0.5 kg	25.45	25.45	30.00	-
Lindane 6G	25.0 kg	76.00	90.00	103.00	81.00
Weed control					
Hand weeding	1 ha	87.50	87.50	87.50	87.50
Rotary weeding	1 ha (1 way)	30.00	30.00	30.00	30.00
24—D(G)IPE	25 kg	64.50	64.50	61.00	61.00
Saturn D	15 kg	67.80	67.80	63.50	65.00
Agroxone	btl.	27.00	-	30.70	30.70
Palay	1 kg	1.00	1.00	1.00	1.18

The costs of the input packages for each of the seasons are in Tables 14 and 15. Despite the higher prices of inputs, the costs of input packages M2 through M5 were lower in later years than in 1974. That was because the levels of inputs tested were reduced after the first year (see Table 7). The data also illustrates the high cost of M3, M4, and M5 relative to the amounts farmers are spending. That is largely due to the high costs associated with the insect control practices of the higher—level packages.

Management packages. Table 16 gives the economic evaluations of the four input packages compared to the farmer's inputs in Nueva Ecija. In the 1974 wet season M2 was more profitable than the farmers' inputs. The other packages were all less profitable, on average, than the farmers' inputs even though they gave higher yields. In the 1975 wet season, M2 and M3 were both somewhat more profitable, while the higher input packages were less profitable than the farmers' practices. In both years, on a substantial proportion of farms, profits were lower with the high inputs than with the low.

Table 14. Average cost (₱/ha) of inputs used by farmers (M1) and in the tested input management packages in experiments on farmers' fields, Nueva Ecija.

Input package level	Ferti— lizer	Weed control	Insect control	Total	Ferti— lizer	Weed control	Insect control	Total
	Wet season, 1974				Dry season, 1975			
M1	205	32	74	484[a]	619	70	70	1057
M2	94	88	222	515	183	88	88	635
M3	301	65	560	1125	393	65	65	1236
M4	538	113	1008	1951	589	113	113	1771
M5	717	201	1668	2938	784	200	200	2809
	Wet season, 1975				Dry season, 1976			
M1	287	29	95	411	480	81	208	769
M2	141	88	181	410	a	-	-	-
M3	297	61	361	719	294	149	178	621
M4	453	106	620	1188	548	149	526	1223
M5	611	193	990	1794	799	149	526	1473

[a]During wet 1974 in Nueva Ecija and dry 1975 in Nueva Ecija and Camarines Sur land preparation was included as a factor in the experiment, hence the difference between the sum of the other three factors and the total is the cost of land preparation.

Table 15. Average cost (₱/ha) of inputs used by farmers (M1) and in the tested input management packages in experiments on farmers' fields, Laguna and Camarines Sur.

Input package level	Ferti- lizer	Weed control	Insect control	Total	Ferti- lizer	Weed control	Insect control	Total
	Laguna, dry season 1975				Camarines Sur, dry season 1975			
M1	247	108	19	374	244	106	180	640
M2	74	88	204	366	224	88	216	668
M3	144	61	761	966	446	65	577	1288
M4	327	113	1318	1758	671	113	810	1854
M5	393	201	2079	2673	895	201	1372	2808
	Laguna, wet season 1975				Camarines Sur, wet season 1975			
M1	328	146	118	592	200	89	76	365
M2	99	88	240	427	144	88	128	360
M3	196	61	840	1097	306	65	471	842
M4	417	106	1441	1964	467	117	637	1221
M5	516	193	2281	2990	631	204	878	1713

Table 16. Economic comparisons of tested input management packages to average farmers' level of inputs, Nueva Ecija, Philippines.

Input package level	Comparison with farmers' level (M1)							
	Increased			% of sites with increased net benefits	Increased			% of sites with increased net benefits
	gross return (₱/ha)	input cost (₱/ha)	net benefits (₱/ha)		gross return (₱/ha)	input cost (₱/ha)	net benefits (₱/ha)	
	Wet season 1974				Dry season 1975			
M2	62	31	31	50	−908	−422	−486	0
M3	282	641	−358	20	−343	179	−522	33
M4	565	1667	−902	0	994	714	280	67
M5	401	2454	−2053	0	2109	1752	357	67
	Wet season 1975				Dry season 1976			
M2	204	-1	205	64	[a]	-	-	-
M3	454	308	146	64	673	−147	a20	70
M4	599	777	−178	45	2419	671	1748	77
M5	1127	1383	−256	27	2785	921	1864	65

[a]Only three alternative packages were tested this season.

The high packages, M4 and M5, increased profits during both dry seasons in Nueva Ecija. The increases were very substantial during 1975 and accrued on two—thirds of the farms.

The results in Laguna were surprising because none of the input packages gave an increase in net return (Table 17). In fact, M2 and M3 gave lower gross returns than the farmers' existing practices even though considerably more was spent on inputs for M3. That indicates that the Laguna farmers' wet season input use was more efficient than the tested packages; just the opposite of the Nueva Ecija situation.

In Camarines Sur, profitability was increased on all farms with experiments at the M4 level in the dry season and at the M3 level in the wet season. In both cases, yields, were increased by more than 1 t/ha with those packages. However, the highest package gave lower returns than the farmers' in both seasons.

Separate input effects. One gets some indication of the relative economic contribution of the separate inputs by analyzing the cost and returns in the factorial experiments. However, the high levels of inputs were chosen, without regard to cost, as the level needed for maximum yield, so one should not be surprised if they are not profitable. Still, the differences between returns to various inputs are striking.

Table 17. Economic comparisons of tested input management packages with farmers' levels of inputs, Laguna and Camarines Sur, Philippines

	Comparisons with farmers' level (M1.)							
	Laguna				Camarines Sur			
	Increased			% of	Increased			% of
Input package level	gross return (₱/ha)	input cost (₱/ha)	net benefits (₱/ha)	sites with higher net benefits	gross return (₱/ha)	input cost (₱/ha)	net benefits (₱/ha)	sites with higher net benefits
	Dry season 1975				Dry season 1975			
M2	−698	−8	−690	11	−508	28	−536	33
M3	−74	592	−666	0	825	648	177	67
M4	1319	1384	−65	44	1521	1214	307	100
M5	1531	2299	−768	0	1987	2168	−181	33
	Wet season 1975				Wet season 1975			
M2	−1006	−165	−841	0	376	−5	381	83
M3	−1246	505	−1751	0	1135	477	658	100
M4	110	1372	−1262	0	698	856	−158	50
M5	1342	2398	−1056	0	502	1348	−846	0

Table 18 shows the expenditure levels of farmers and the increase in costs and value of output incurred by raising the three tested inputs from the farmers' level to the high level. As already pointed out, the high level of fertilizer led to a decreased yield in Nueva Ecija in wet season 1974. But in all other cases high fertilizer gave an increased value of output twice as great as its cost. The high level of weed control added more to value than to cost in all cases but insect control showed the opposite result. In all but one case, the high level of insect control added more to cost than to value of output. These results suggest that maximum levels of insect control, while important for high yields, are not economically feasible with present technology.

We speculated that the uneconomic showing of insect control might have occurred if there were low levels of insect attack. In such a situation, the yield increase from insect control would be low while the cost would be high. To investigate this, we divided the wet season Nueva Ecija experimental sites into those with a high level of insect attack and those with a low level of insect attack (Table 19). Intensity of green leafhoppers and stemborers were scaled with 0 indicating no damage, and 5 indicating heavy infestation.

During 1974, the six experiments on farms with heavy attack gave an average yield increase of 0.8 t/ha from the high level of insect control, while those four farms with low levels of insects gave an increased of

Table 18. Farmers' cost, increased costs and increased value of output from high levels of three inputs compared with average farmers' levels, three areas in the Philippines, 1974—76.

Location	Year	Farms (no.)	Fertilizer (₱/ha) Farmers' cost	Increase to high cost	Increase to high value	Weed control (₱/ha) Farmers' cost	Increase to high cost	Increase to high value	Insect control (₱/ha) Farmers' cost	Increase to high cost	Increase to high value
					Wet seasons						
N. Ecija	1974	10	205	333	—84	32	81	152	74	934	440
N. Ecija	1975	11	287	166	324	29	77	124	95	534	200
C. Sur	1975	6	200	267	421	89	28	186	76	561	525
Laguna	1975	20	307	209	729	147	103	286	161	1331	653
					Dry seasons						
N. Ecija	1975	3	619	165	169	126	43	520	128	680	227
N. Ecija	1976	10	480	318	1509	81	68	401	208	534	776
C. Sur	1975	3	244	427	1121	106	7	25	180	630	395
C. Sur	1976	5	234	565	1522	58	91	165	125	618	224
Laguna	1975	9	247	146	1324	108	93	225	19	2060	968
Laguna	1976										

less than 0.2 t/ha. In 1975, the six farms with high insect attack levels got an increase of 0.5 t/ha from the high level of insect control, while the five farms with low insect attack levels showed a decreased of 0.1 t/ha from the high level of insect control inputs. The results confirm our hypothesis that the high level of insect control results in a greater yield increased when insect intensity is high than when it is low. Still, the increased value of crop output attributable to high insect control did not exceed the cost of control even for the high insect intensity groups.

Table 19. Farmers' costs, increased cost and increased value of output from high levels of three inputs compared with average of farmers with high insect intensity and low insect intensity. Nueva Ecija, Philippines, 1974—75.

Farms (no.)	Insect intensity[a]	Insect control (₱/ha) Farmers' cost	Increase to high Cost	Increase to high Value
		1974 wet season		
6	2.5	121	887	842
4	1.0	39	969	172
		1975 wet season		
6	2.3	104	525	493
5	0.7	84	545	—83

[a] Based on a scale of 0 = no infestation to 5 = very heavy infestation. The absolute levels may not indicate seasonal differences because different researchers made the observations during the two seasons.

Farmers' views on the use of inputs

The foregoing analysis suggests that farmers may be able to make modest improvements in average profits by using the M2 or M3 level of inputs during the wet season. Farmers who are averse to risk may avoid M3 because under poor weather conditions it gives a lower profit than their M2 practices, even though on the average M3 may give higher profit. During the dry season, there is more scope for profitably increasing yields; M4 and in some cases M5 levels are more profitable than existing practices for many farmers, although risk—averse individuals may not be willing to use these practices because they result in reduced profit one—thirdof the time and cost from two to four times as much as farmers normally spend for cash inputs (M2). Higher fertilizer rates can increase profits even where insect control is maintained at modest levels. Weed control generally seems to give a rather small added return. Given the economic incentives, why are farmers not taking advantage of the potential profitability that apparently can be exploited by selectively using higher levels of certain inputs?

Awareness and attitudes. Farmers in the surveys were generally aware of the practices and inputs associated with modern fertilizer, weed control, and insect control practices. In fact, they scored somewhat higher on tests of their technical knowledge than expected. Among the 1974—75, Central Luzon sample, nearly 90% used semidwarf varieties, fertilizer, insecticide, and some form of weed control (Table 20). However, there was a clear tendency for a smaller proportion to use the newer forms of inputs that were heavily used in the experiments such as granular herbicides and insecticides.

Table 20. Proportion of 180 sample farmers with three types of water control who used and who believed that specified components of modern technology increased yields. Bulacan, Nueva Ecija and Pangasinan in Central Luzon, Philippines, 1974 wet season.

Input or practice	Used during wet season 1974 (%)			Believe use increased yield(%)		
	Irri-gated	Mixed	Rain-fed	Irri-gated	Mixed	Rain-fed
Fertilizer related						
Chemical fertilizer	90	98	92	99	100	98
Basal fertilizer	36	30	17	86	83	79
Split fertilizer	58	60	51	99	98	85
Weed control related						
Hand weeding	90	85	94	98	96	92
Sprayable herbicides	25	36	36	88	80	81
Granular herbicides	41	49	26	86	85	77
Straight—row transplanting	29	19	17	74	65	70
Rotary weeding	10	11	4	77	67	55
Insect control related						
Spray insecticides	84	83	81	96	96	94
Granular insecticides	49	62	45	91	87	83
Seedling insecticide soak	28	28	11	75	74	66
Cultural practices						
Semidwarf varieties	87	93	89	96	96	98
21 day—old seedlings	6	4	4	70	65	62

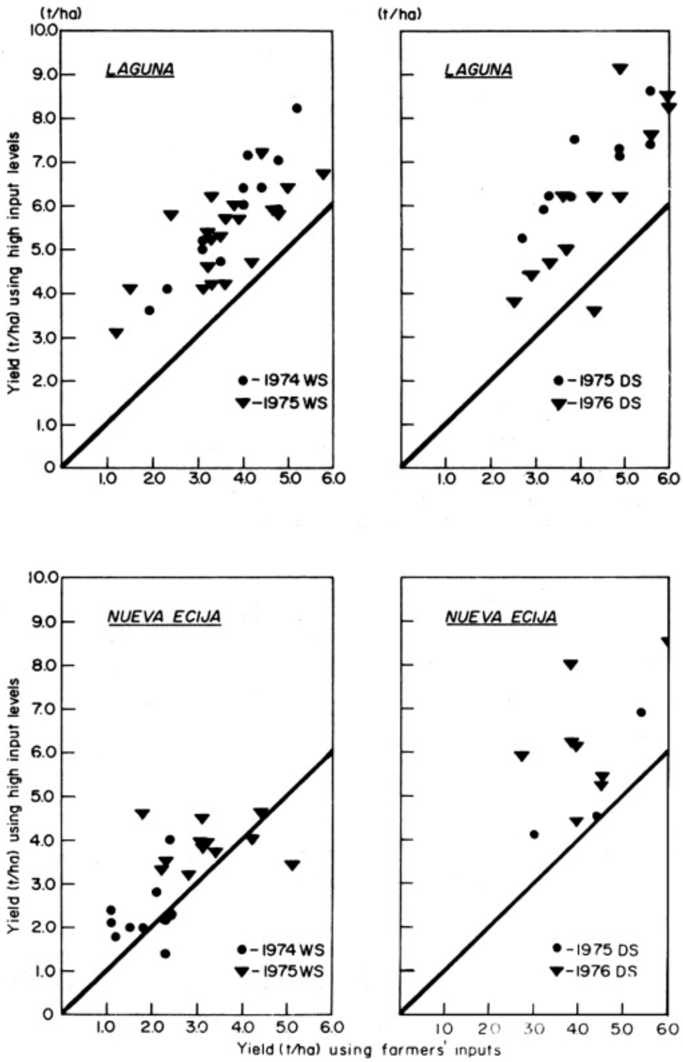

Fig. 5. Farmers. and high input yields in experiments on farmers' fields, Laguna and Nueva Ecija, Philippines, 1974–1975 and 1975–1976.

Most cultural practices that agronomists believe are important for high yields seem to have found little acceptance by farmers in Central Luzon. Less than 20% of the farmers transplanted their rice in straight rows and even fewer used rotary weeding (which requires straight row transplanting). Only a few farmers transplanted at the recommended 21 days or younger. Basal and split application, techniques to improve the efficiency of fertilizer utilization were used by some farmers, but the proportion was not high.

We asked farmers whether they believed that the various inputs and practices increased yields. All the inputs and practices were perceived as increasing yields by a relatively high proportion of farmers, but a much smaller proportion used many of the practices and inputs. Their reasons are shown in Figure 6. The most common reason given was that they were "too expensive." We interpret this to mean that while farmers think the practices would increase yield, the value of the additional yield would not exceed the cost of the additional inputs. The second most frequent reason for not using inputs was that they were either ineffective or not needed -- essentially the same reason as "too expensive."

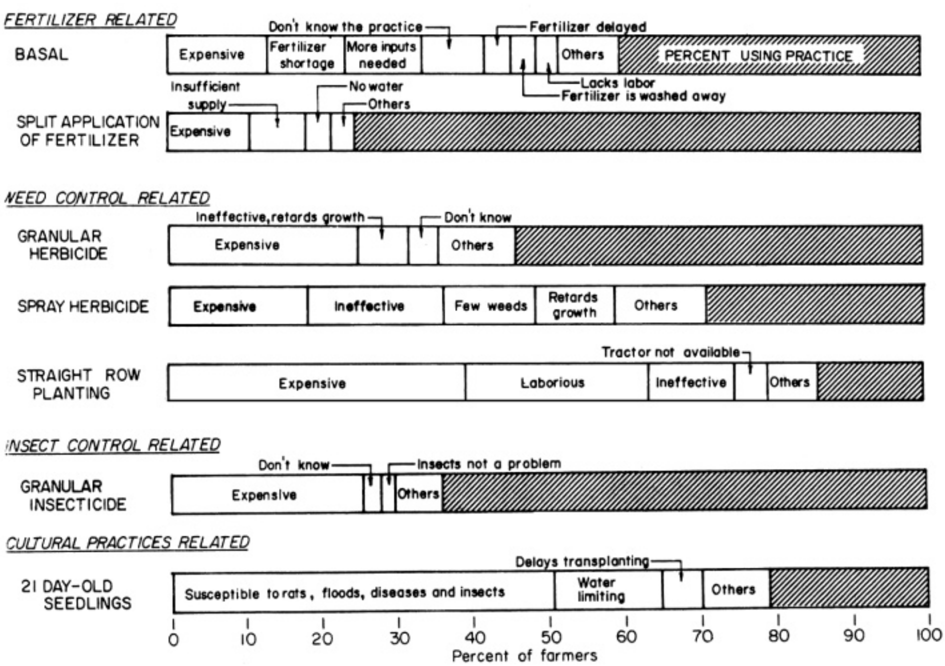

Fig. 6. Percent of farmers using selected recommendations and relative importance of reasons given for non-use by those not using the practices or inputs, 180 farmers in three Provinces of Central Luzon, wet season, 1974.

The experimental results seem to confirm farmers' reasons for not using 21 day—old seedlings and straight row planting. These practices were tested in the "high cultural practices" plots in the experiments. Even without taking into account the extra cost of straight row transplanting, or if replanting dead hills, these practices are not generally worthwhile in Nueva Ecija because they gave no consistently higher yield (Table 11).

Farmers seem to misunderstand the concept of basal and split application of fertilizer because of their claim that these are more expensive than a single application. The only cost difference is in the labor used for applying the fertilizer, which is small. Agronomic evidence from experiment stations suggests that some nitrogen and all phosphorus should be applied before transplanting, and the rest of the nitrogen applied at panicle initiation. Where this was done in the M2 package experiments, yields and profits were most often higher than farmers' levels with the same use of inputs. Most farmers applied fertilizer in several split doses beginning shortly after transplanting and spread over the first 60—80 days of plant growth.

Because most farmers were using the basic practices of fertilizer, insect control and weed control although perhaps at low levels, the reasons for non—use of these inputs reflect the opinions of relatively few individuals. In the survey conducted during the second study year, more emphasis was placed on determining why farmers used the levels of these basic practices that they did.

Fertilizer use 1975-76 Table 21 describes the use of fertilizer by farmers in the three study locations. Fertilizer use was universal in Laguna province, with the average rates exceeding the recommended level

Table 21. Use of fertilizer by 150 sample farmers, three areas of the Philippines, 1975—76.

Fertilizer	Wet season 1975			Dry season 1976		
	Nueva Ecija	Laguna	Camarines Sur	Nueva Ecija	Laguna	Camarines Sur
	% of sample applying					
Nitrogen	a7	100	58	100	97	37
Phosphorus	80	20	43	96	47	29
Potash	22	7	40	26	28	21
	Average rate by those applying (kg/ha)					
Nitrogen	50	70	33	66	78	38
Phosphorus	26	23	14	31	16	22
Potash	15	12	14	17	12	15

for the wet season and approaching it during the dry season. In Nueva Ecija, the proportion of farmers using fertilizer and the rates of application were slightly lower in the wet season than in Laguna. In Camarines Sur, fertilizer use was much lower than in Laguna, both in terms of rates and in terms of proportion of users.

Farmers who used no fertilizer were asked why, and users were asked why they did not use higher rates. Their answers are summarized in Table 22. Half the wet—season, Laguna respondents and up to one—fourth of the other respondents believed they had applied "enough" fertilizer. Lack of water was identified as the factor keeping some farmers in Laguna and Camarines Sur from applying as much fertilizer as they might have. About two—thirds of the Nueva Ecija farmers said they were constrained by a lack of capital funds, but lack of water was not mentioned in Nueva Ecija, perhaps because of the overriding problem with capital in 1975—76.

Nueva Ecija and Laguna farmers who reported using enough fertilizer were, in fact, using about the levels recommended for the wet and dry seasons (Table 23). The few Camarines Sur farmers reporting they used enough were applying two—thirds the rate of their counterparts in the other provinces, but required about the same yield. Except for the wet—season Laguna group, farmers who thought they applied "enough" were using substantially more than the other farmers in the same province and season. Yields of those who used enough were at least 1 t/ha higher than other farmers in Nueva Ecija and Camarines Sur, but only slightly higher in Laguna, closely reflecting relative fertilizer levels.

In all three areas, farmers who thought they had applied enough were using rates somewhat below the high rates tested in the experiments. Those high fertilizer rates were generally more profitable than farmers' levels.

Table 22. Proportion of sample farmers citing given reasons for not using or not applying higher rates of fertilizer, 150 farmers, three areas of the Philippines, 1975—76 (%).

	Applied "enough"	Lack of capital	Lack of water	Other	No response
		Wet season			
Nueva Ecija	16	64	0	10	10
Laguna	50	18	15	10	7
Camarines Sur	13	60	18	5	4
		Dry season			
Nueva Ecija	26	73	0	0	1
Laguna	21	24	0	8	47
Camarines Sur	13	21	11	8	47

Table 23. Fertilizer application rates and yields reported by farmers who claimed to have "applied enough" fertilizer and by other farmers, three areas of the Philippines, 1975—76.

Areas	N—P—K applied by farmers (kg/ha)		Yield reported by farmers (t/ha)	
	who believed they used enough fertilizer	who gave other reasons for fertilizer level	who believed they used enough fertilizer	who gave other reasons for fertilizer level
	Wet season 1975			
Nueva Ecija	69—28—5	36—19—3	2.9	1.9
Laguna	69—6—2	72—4—0	2.8	2.7
Camarines Sur	40—11—1	18—6—5	3.1	2.1
	Dry season 1976			
Nueva Ecija	89—42—4	58—26—4	3.5	2.1
Laguna	85—13—6	73—5—2	3.1	2.5
Camarines Sur	49—22—12	9—4—2	3.1	1.7

Insects and weeds. Eighty—eight percent of all sample farmers reported significant insect attacks in the wet season and 64% reported them in the dry season (Table 24). Eighty—eight percent of the farmers who perceived insect damage during the wet season attemped control measures, and 72% attempted control during the dry season. Of those who reported damage and attempted control, all the Laguna farmers and 70% of the others believed they had achieved control over the insects.

Table 24. Number of farmers reporting insect and other pest damage, attempted control, and reported yields, with and without insect attack, three areas of the Philippines, 1975—76.

	Wet season 1975			Dry season 1976		
	Nueva Ecija	Laguna	Camarines Sur	Nueva Ecija	Laguna	Camarines Sur
Total sample	70	40	40	66	36	38
Farms reporting insect damage	56	35	35	48	12	29
Farms with damage attempting control	47	31	33	45	11	8
Farms with successful control[a]	34	12	25	34	11	7

[a]Of those attempting control.

These data suggest that insects are not perceived as a major yield constraint by farmers. Farmers appear confident of their ability to deal effectively with insect problems, a view somewhat at variance with the results of the experiments, which suggests that farmers are losing a substantial proportion of yield to insects. The difference may be that farmers' opinions reflect their confidence that they have done what could economically be justified, while the experiments measure the total yield lost to insects.

About 75% of the Nueva Ecija farmers reported they thought their yields had been reduced because of weed infestation (Table 25). The proportion reporting reduced yields was lower in Laguna and Camarines Sur. In general, one—half to two—thirds of the farmers who perceived a yield reduction due to weeds had used some weed control measures, except that in the wet season in Camarines Sur all farmers with weed problems used some control.

Table 25. Number of farmers reporting yield reduction from weeds and their weed control practices, three areas of the Philippines, 1975—76.

	Wet season 1975			Dry season 1976		
	Nueva Ecija	Laguna	Camarines Sur	Nueva Ecija	Laguna	Camarines Sur
Total sample	70	40	40	66	36	38
Farms reporting reduced yields from weeds	51	16	21	52	24	18
Farms using hand weeding only[a]	11	6	2	16	6	6
Farms using herbicides only[a]	12	1	8	8	1	9
Farms using both[a]	6	2	11	7	6	1

[a]Of those who perceived yield reductions.

Those results are fairly consistent with the experiments, which showed a greater constraint from weeds in Nueva Ecija than in the other areas. What is not clear is why farmers in Nueva Ecija do not make a greater effort to control weeds. In Laguna and Camarines Sur, farmers appear to be practicing adequate weed control.

Perceived constraints. When asked to identify the main factors keeping their yields low in the wet season of 1975, Nueva Ecija farmers mentioned diseases most frequently (Table 26). Rats and excessive wind, rain and flood were the two most frequently mentioned wet—season factors in Laguna. In Camarines Sur, lack of water was more important in the dry season than the wet season in all three locations, but excessive water was also a problem in the dry season in Nueva Ecija, where unexpected typhoons occurred near the end of the dry season. Use of too little fertilizer was recognized as a yield constraint by a substantial proportion of farmers in Nueva Ecija and Camarines Sur.

Practical control of diseases can only be achieved through the use of resistant varieties. To a large extent, farmers who suffered from disease losses chose to use varieties that were not resistant to tungro, the major disease present in the wet season of 1975.

Table 26. Yield constraints perceived by 150 surveyed farmers in three areas of the Philippines, 1975—1976.

	Percentage of total					
	Wet season 1975			Dry season 1976		
Reported constraint	Nueva Ecija	Laguna	Camarines Sur	Nueva Ecija	Laguna	Camarines Sur
Lack of water	7.5	1.9	29.8	19.1	26.6	45.1
Excessive wind, rain, flood (typhoon)	16.8	27.4	13.4	36.7	5.0	8.0
Too little fertilizer	17.6	0.0	20.8	13.9	5.0	16.1
Insects	11.7	15.6	8.9	4.4	3.3	17.7
Diseases	25.2	7.8	17.9	5.8	8.3	1.6
Rats	7.5	27.4	0.0	7.3	21.6	3.2
Weeds	1.7	0.0	0.0	5.1	10.0	4.8
Others	12.0	19.9	9.2	7.7	20.2	3.5

In total, water—related constraints in the 1976 dry season were mentioned by 30% of the Laguna farmers, 50% of Camarines Sur farmers and 55% of dry season Nueva Ecija farmers. Effective correction of these constraints lies beyond the individual farmers' ability. Control of rats also requires community action, but many other constraints can be relieved by individual farmers' using modern technology.

Other constraints. The result of a regression analysis to determine whether personal or social circumstances of farmers constrained their use of inputs is presented in Table 27. The first equation explains only 27% of the observed variability in expenditures on fertilizer, insect control and weed control, with three variables significant. The dummy variable measuring irrigation, indicates that farmers who irrigated spent about ₱ 180 more per hectare on inputs than nonirrigating farmers. The amount of credit used was significantly related to expenditures on inputs, indicating that at least some of the credit was being used for its intended purpose. Farmers with higher scores on our test of technical knowledge spent significantly more on inputs.

The equation fitted to explain variation in the number of components of modern technology used by farmers gave similar results. Twenty—one components were included. Credit used and technical knowledge were positively related to the number of technologies used. Unlike the equations explaining expenditures on inputs, irrigation is not related to the number of new technologies used. As in the equation explaining input expenditures, the variables reflecting input availability, traditional beliefs, alternative earnings and tenure were not significant in explaining the number of modern rice production practices used.

Table 27. Estimated coefficients and standard errors in equations explaining the use of modern rice technology by 60 Nueva Ecija farmers, wet season 1974.

Independent	Nueva Ecija: P/ha spent on inputs[a] as dependent variable	Number of practices as dependent variable[b]
Technical knowledge	27.71** (12.26)	0.260** (.052)
Credit used	0.172** (.039)	0.0003* (.0001)
Input availability	26.53 (24.5)	—0.103 (.105)
Traditional beliefs	—3.238 (3.92)	—0.007 (.017)
Alternative earnings	0.079 (.155)	-.0009 (.0007)
Irrigation dummy	179.9** (76.8)	—0.402 (.329)
Technician's value	—5.208 (4.79)	0.022 (.020)
Share tenure dummy	29.97 (115.7)	—0.060 (.496)
R^2	.27	.35

SUMMARY AND CONCLUSIONS

The experimental results for two years show that using modern varieties and practices, and maximum yield—level inputs, wet—season yields averaged about 5.4 t/ha in Laguna and 4.5 t/ha in Camarines Sur and Nueva Ecija (Tables 9 and 12). Actual farmers' wet—season yields were 1.7 t/ha below the maximum in Laguna, 1 to 2 t/ha lower in Nueva Ecija and about 1 t/ha below the maximum in Camarines Sur. In the dry seasons, maximum yields were higher than during the wet seasons in all areas -- 7.5 t/ha in Laguna, 6.5 t/ha in Nueva Ecija and 6.0 t/ha in Camarines Sur. Actual farmers' dry season yields were about 2 t/ha below these maximums in all three areas. Thus, the physical "yield gap" between average farmers' yields and average maximum attainable yields under farmers' conditions with presently available technology in the Philippines ranges from 1 to 2 t/ha in the wet season and more nearly averages 2 t/ha in the dry season.

About half of the yield gap could he attributed to farmers' fertilizer practices -- both inadequate rates of application and the timing of fertilizer application. Still, farmers who were able to apply the level of fertilizer they considered "high enough" reported yields more than one ton per hectare higher than farmers constrained by lack of capital, water problems, or other external factors. Cost and returns analysis of the experiments showed that, in general, higher rates of fertilizer than presently used by most farmers were economically attractive. The yield variability associated with high rates of fertilizer in the typhoon—prone wet season may be a factor keeping farmers from using higher rates of fertilizer. Another factor may be the reported lack of capital to purchase fertilizer. It appears that half the yield "gap" could be closed if all farmers applied higher rates of fertilizer.

Insect damage was the second most important components of the yield gap, accounting for 30 to 50% of the difference between the potential and the actual yield. Most sample farmers responded to observed insect attacks by spraying their crop and believed they were successful in getting control. However, the experiments indicate that despite the efforts of farmers to protect their crops from insects, considerable losses to insects still occurred, most likely because farmers used much lower rates of application than researchers. It is unlikely that farmers would ever use the maximum insect protection levels tested in the experiments because they cost more than the value of output they protect. Lower—cost, effective insect control techniques are badly needed if farmers are to be able to recover the rice lost to insects.

Farmers' weed control practices cannot generally be improved upon. Only in Nueva Ecija did inadequate weed control account for up to 0.5 t/ha of yield in the dry season. Many farmers in that area recognize they suffer some yield losses from weeds, but do not take adequate counter measures. This may be a result of their inadequate water control which makes the result of chemical weed control highly variable.

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GIRITALE, SRI LANKA, 1975—76

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ABSTRACT

During the wet season a yield gap of over 1 t/ha was measured on 4 complex experiments while 8 simpler experiments showed an average gap of 0.6 t/ha. Insect control was the primary factor contributing to the gap. In the dry season, results were very erratic due to poor water control. None of the three major factors tested, fertilizer, weed control, or insect control stood out as most important. The wet season economic analysis showed that M_2 was most profitable, on the average, altough M_5 gave a higher yield. Weed control practices were more expensive than their return while fertilizer and insect control added to profit. In both seasons the researchers' fertilizer treatment ressulted in a higher yield than the farmers' although farmers used higher rates, apparently indicating inefficient fertilizer use by farmers.

RICE IN THE ECONOMY OF SRI LANKA

Rice accounts for about 45% of the per capita calories and 40% of per capita protein in the average Sri Lanka diet. It is the single most important crop under production, occupying 33% of total cultivated area. Domestic production is not sufficient to meet rice requirements and Sri Lanka has continued to be dependent on sizeable imports. But rapid increases in domestic production over the last two decades have led to a decline in the relative importance of rice imports (Table 1).

Rice production increased from 490,000 tons in 1948—52 to over 1.5 million tons in 1974 registering an average annual compound rate of growth of 6%. Apparent rice consumption, defined as the total of domestic rice production and imports, increased from about 1.0 million tons to about 1.9 million tons, an average annual rate of growth of 3%. Wheat flour, the other major cereal component of the diet and entirely imported, increased from 187,000 tons to 380,000 tons, reflecting an average annual increase of 3.6% during this period. During the period the average annual rate of growth of population was around 2.5%. Per capita real incomes in the period 1961—71 are estimated to have increased at 2.3% per annum.

Table 1. Area, production and imports of rice and imports of wheat flour, annual average, Sri Lanka, 1948—74.

Period	Production ('000 t)	Area planted ('000 ha)	Yield (t/ha)	Rice imports (Paddy equi— valent) ('000 t)	Wheat flour imports ('000 t)
1948—56	533	450	1.4	604	203
1957—59	725	522	1.7	709	216
1960—64	976	615	1.9	711	194
1965—70	1199	660	2.0	577	362
1971	1396	726	2.4	424	323
1972	1312	726	2.4	430	306
1973	1312	725	2.3	490	402
1974	1602	825	2.3	428	409

Source: Department of Census and Statistics, Government of Sri Lanka.

Rice production in Sri Lanka is strongly influenced by topography and climate, factors that cause considerable regional variations. Sri Lanka comes under the influence of the southwest monsoon from May to September and the northeast monsoon from November to January. The location of the central highlands in the path of the rain bearing winds dictate the pattern of rainfall. The southwest quadrant of the island receives a mean annual rainfall ranging from 100 to over 200 inches. It is well distributed and because of the absence of any pronounced dry season, this area is customarily referred to as the wet zone. The remaining three quarters of the island receives a mean annual rainfall of less than 75 inches, mainly during the three months of the northeast monsoon. In this area, there is a pronounced dry season from about April to September and hence it is called the dry zone.

The area and production of rice in the major climatic regions are shown in Table 2. The dry zone accounts for 62% of the area under rice. About 32% of the total area is served by major irrigation schemes, of which nearly 90% is in the dry zone. Minor irrigation schemes account for 28% and rainfed areas for 40% of the total area. The dry zone has nearly 70% of the area under minor schemes and 56% of the rainfed. The dry zone contributed a little over 60% of production, but its share of the total purchases under the government purchase scheme is somewhat higher.

Two seasons of rice production based on the pattern of rainfall distribution are recognized. The Maha or major season coincides with the northeast monsoon from October to February and production is spread over the entire country. The Yala or minor season coincides with the southwest monsoon and production is mainly confined to the wet zone and the major irrigation schemes in the dry zone. In the dry zone the main season Maha crop is similar to wet season crops in other countries of Asia, while the Yala crop is more like dry season crops elsewhere. The Maha crop accounts for 65% of the total sown extent and contributes about as much to total production.

Rice production in the wet zone is almost entirely dependent on rainfed cultivation. But because of its better rainfall distribution, in the wet zone Yala cultivation is almost as important as Maha.

Table 2. National and regional rice statistics. Sri Lanka, 1969—71 average.

	Dry zone	Wet zone		Sri Lanka
		Low country	Hill country	
Area planted (ha)	450842	145284	128991	725390
% of national total	62	20	18	100
% of area under Maha crop	44	11	11	65
Sources of water supply:				
Major schemes (ha)	158448	6366	12126	177540
Minor schemes (ha)	106572	10690	40336	161644
Rainfed (ha)	128528	73900	27172	229600
Total production ('000 t)	931	197	330	1462
% of national production	63	14	23	100
Govt. purchases				
% of national production	26	1	5	32

Increases in the domestic production of rice have come about equally from increases in area and increases in yields (1). The area under major irrigation schemes increased by 40,470 ha over the period 1960—74, compared to an increase of 31,970 ha under minor schemes and 40,065 ha under rainfed cultivation.

In addition to the expansion in area, there has also been an increase in the use of fertilizers, disbursement of credit and area under new varieties of rice. Table 3 presents information on fertilizer use, credit availability and the area under the new varieties. Except for a brief period in 1975 when consumption fell drastically, fertilizer prices have been subsidized. Credit schemes have also been reorganized from time to time in order to ensure greater availability of credit to peasant farmers. In addition, the government has maintained a rice price for producers well above world market levels. During the 1960's, the government purchase price averaged Rs0.60/kg while imported rice cost Rs0.30/kg and during the 1970's, the government price increased to Rs0.96/kg while imported rice increased to Rs0.88/kg. Perhaps, most important of all is the success of government's efforts to develop and ensure the widespread diffusion of modern varieties of rice. Since 1970, the modern varieties have covered more than 65% of the total rice area.

National yields, however, do not appear to reflect the widespread adoption of the new varieties. Average yield levels are far below the potentials of the new varieties as reported from experimental stations. The coordinated rice varietal trials conducted by the Government Department of Agriculture indicate that the potential of the new varieties is about double that of the traditional varieties. But, average yield levels of the new varieties

Table 3. Fertilizer use and credit disbursements for rice, and area under new rice varieties, annual average. Sri Lanka, 1959—75.

Period	Fertilizer use (t)	kg/ha	Credit Total ('000 Rs)	Credit Rs/ha	Improved varieties Area ('000 ha)	Improved varieties % sown extent
1959—64	37,289	61	16,937	28	-	-
1965—69	62,127	93	43,276	64	na	na
1970	86,739	114	51,710	68	492	65
1971	91,432	126	29,280	40	478	66
1972	81,791	113	30,630	42	489	67
1973	98,384	136	28,260	39	500	69
1974	122,616	148	109,100	132	646	78
1975	43,800	63	77,250	111	519	75

Source: Department of Agriculture, Government of Sri Lanka and Central Bank of Sri Lanka.

under farm conditions have been disappointingly low, hardly approaching 2.5 t/ha. Adoption of the new varieties is not the reason because adoption has been rapid. The reasons for the relatively low levels of yields must be sought elsewhere.

Research objectives

The objective of this research project is to help understand the factors that explain the difference or "yield gap" between the yields farmers actually get and the potential yield of the new varieties under their conditions. Since experimental station conditions cannot be duplicated on farmers' field, it is not expected that experimental station yield levels can be achieved on farmers' fields. The "potential yield" is defined as the highest yield that can be obtained on farmers' fields when three or four of the most critical inputs or practices are maintained at high levels with other inputs at farmers' levels. The difference between the actual and potential yield is the focus of this study. Since environmental conditions vary widely, it is necessary to measure the yield gap in farmers' fields in a well defined homogenous area. The difference can be explained as being due to biophysical constraints such as water, fertility, weed control, insect control, and cultural practices. Socioeconomic constraints such as limitations in institutions, input availabilities, credit and other factors explain why farmers are not following the recommended management practices or using the recommended levels of inputs.

General methodology

We combined experiments with socioeconomic surveys. A representative area was selected and from this area a few representative farmers were chosen.

Experiments were placed on farmers' fields to compare yields obtained using farmers' practices with those obtained with recommended inputs and practices. The farmers' practices on a "comparable paddy" were continuously observed and simulated on the farmers' level plots in the experiment.

Twelve sites were selected for the experiment. Three inputs considered to be the most important constraints in the area, namely fertilizer, weed control and insect control were selected for study. These were compared at the farmers' level and the recommended level using a complete factorial design. Depth of planting and spacing were also studied in the same experiment in a partial factorial combination. Yields at farmers' level and recommended level of the selected factors were compared and the yield gap apportioned among the components. A second part of the experiment tested different management packages which were economically evaluated.

A farm record keeping project and a socioeconomic survey were associated with the experiments. These were designed to determine the level of input use and management practices, and to explain the constraints that prevent farmers from following the recommendations.

The study area

Because of its importance in the national rice production system, the dry zone was selected for the study. Giritale Special Project, a major irrigation scheme, was chosen as the specific location. The original intention was to select a rainfed area in close proximity, but this was not possible because of the continued failure of the seasonal rains.

Polonnaruwa district, in which Giritale is located, is a major rice production area, accounting for about 6% of the national rice area and for about 10% of total national production. About 12% of the total area under major irrigation schemes is located in this district. Giritale is considered to be representative of the major irrigation schemes and it was selected because of the availability of background information from a previous survey of the ease of access. Rice is the most important crop under cultivation, accounting for about 80% of average gross farm incomes.

QUANTIFICATION OF YIELD CONSTRAINTS

The research project started in November 1975. Giritale Special Project area was one of the few major irrigation schemes where cultivation for the Maha (main season) had not started. Detailed background information on this area was available to the authors. Reported yields showed that over 60% of the farmers obtained yields varying from 2.5 to 3.0 t/ha while few farmers obtained over 5.0 t/ha. The potential for increased yield and production seemed to exist in Giritale.

The Giritale Special Project area is fed by the Giritale tank. Being a colonization scheme and a special project, the entire rice fields here are well traversed by irrigation channels thus ensuring water supply to all fields. Hence, all the sites selected for experiments received irrigation water. The sites selected were distributed among four of the six extension technicians regions of this project area.

Methods of measuring biological yield constraints

Subsequent to the presurvey and after discussions with the Agriculture Department Extension staff, three inputs were identified as the probable major yield constraints -- fertilizer, weed control and insect control. In addition, the Agricultural Extension staff strongly recommended the inclusion of depth of planting. Following from the discussion on the depth of planting, it was observed that almost all farmers do random transplanting and the resulting plant density at farmers' fields were often twice as much as the recommended level. Deep planting may complement such close spacing because tillering will be reduced. Therefore, depth and spacing were selected as two additional variable factors.

Experimental design

The field experiments had two components: a two—level factorial and a five—level management package. In the factorial, the selected factors were included at two levels, farmers' level and recommended level. Because a complete factorial design with 5 factors at 2 levels would involved 32 combinations, which was too large a number to handle, the factors selected were grouped as shown in Table 4. By testing depth and spacing with either the high or low level of all three of the other test factors, only 14 treatments were used. When the 14 are grouped as shown in Table 4, they can be considered as two complete factorial designs, inputs factorial and practices factorial.

A series of management packages with combinations of increasing levels of the three inputs were tested. Five levels of input combinations were used, including the farmers' level (M_1) and recommended level (M_4). In addition a higher level, M_5, was tested and another combination, M_5H was also tested where depth (D) and spacing (S) were at the recommended level. In all management packages other than M_5H, D and S were at the respective farmer's level.

The levels of the three inputs are shown in Table 5. The low level of each factor in the factorial was the farmers' level and the high level was M_4. All P and K and 5 kg N/ha were applied basally. Input levels were the same in both seasons.

Layout of experiments

Two types of layout were adopted. At 4 sites, a "large experiment" was used consisting of the 14 treatments of the factorial and the 6 treatments of the management package (Figure 1). A split plot design with insect control as the main plot was used. Treatments were replicated twice.

In eight sites, a small experiment consisting of treatments 1, 2, 3, 8, 11, 14 (see Table 4) was used. The treatments were unreplicated and randomized completely. Plot size was 15 m^2.

Table 4. Treatments in the two factorial components, Giritale, Sri Lanka, 1975—76.

No.	Treatment details	Inputs factorial design		Practices factorial design	
1	F_f W_f I_f D_f S_f	1	F_f W_f I_f	1	Y_f D_f S_f
2	F_R W_f I_f D_f S_f	2	F_R W_f I_f		
3	F_f W_R I_f D_f S_f	3	F_f W_R I_f		
4	F_R W_R I_f D_f S_f	4	F_R W_R I_f		
5	F_f W_f I_f D_f S_R			5	Y_f D_f S_R
6	F_f W_f I_f D_R S_f			6	Y_f D_R S_f
7	F_f W_f I_f D_R S_f			7	Y_f D_R S_R
a	F_R W_R I_R D_f S_f	8	F_R W_R I_R	8	Y_R D_f S_f
9	F_f W_R I_R D_f S_f	9	F_f W_R I_R		
10	F_R W_f I_R D_f S_f	10	F_R W_f I_R		
11	F_f W_f I_R D_f S_f	11	F_f W_f I_R		
12	F_R W_R I_R D_f S_R			12	Y_R D_f S_R
13	F_R W_R I_R D_R S_f			13	Y_R D_R S_f
14	F_R W_R I_R D_R S_R			14	Y_R D_R S_R

F = fertilizer use
W = weed control
I = insect control
R = recommended level

Y = input use
D = depth control
S = spacing control
f = farmer's level

Results of experiments, wet season

The yield gap measured in the experiments is shown individually in Figure 2 for the large and the small experiments. The yield gap is measured in a similar way for both types, but fewer plots are available from each small experiment.

Table 6 shows the yield gap and contribution of the three inputs. On one large experiment, the gap was negative, and on one it reached 2 t/ha. In the small experiments, it averaged 3.6 t/ha. Lack of insect control was the major factor causing yield constraints, while fertilizer and weed control were less important.

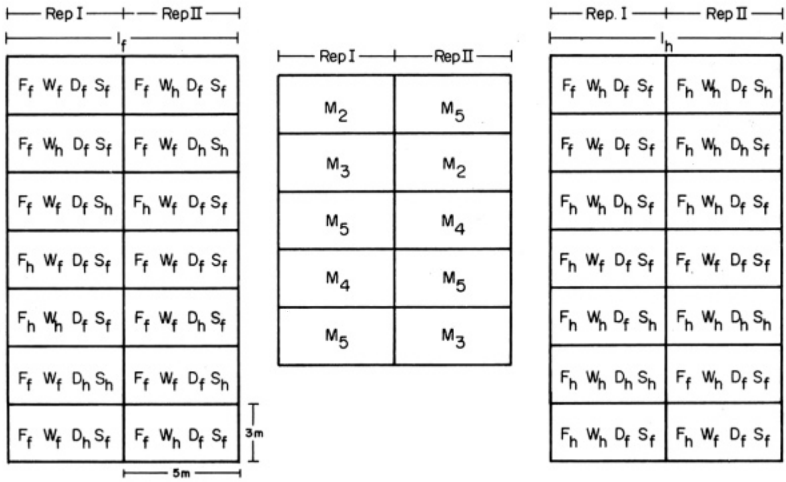

Fig. 1. Layout of the large experiment, Giritali, Sri Lanka 1975–76.

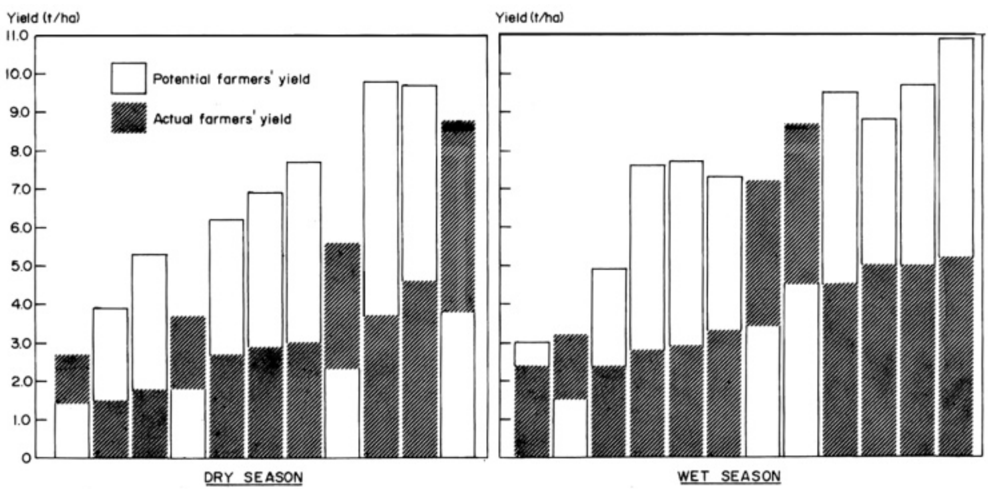

Fig. 2. Actual and potential farm yield from constraints experiments in farmers' fields, Giritali, Sri Lanka, 1975/76.

Table 5. Input levels in experiments. Giritale, Sri Lanka, 1975—76.

	M_1[a]	M_2	M_3	M_4	M_5
Fertilizer (kg/ha)					
N	166	57.8	48.4	77.3 (106.2)[b]	91.8 (120.7)[b]
P_2O_5	29	0	17.22	34.44	57.66
K_2O	29	0	8.07	16.14	24.2
Weed control	0.7 Hw	Hand weeding (35 DAT)	M.C.P.A. (21 DAT)	Saturn G (4 DAT)	Saturn G (4 DAT)
					Hand weeding (35 to 42 DAT)
Insect control	1 foliar	2 foliars[c]	Furadan G	Furadan G	2 Furadan G
	0.7 granular	(30 DAT & P. I.)	(10 to 14 DAT)	(10 to 14 DAT)	(10 to 14 DAT & 60 DAT)
		1 Foliar	1 Foliar	2 Foliars	3 Foliars
			(P. I.)	(30 DAT & P.I.)	(30 DAT, 60 DAT & 70 DAT)

[a]Average for four large experiments, level in eight small was very similar.
[b]For 4—4—1/2 months. New improved varieties (e. g. B. G. 11.11).
[c]Foliar sprays were Fenitrothion.

Fertilizer. High fertilizer gave a positive response in three of four farms while its effect was negative in the fourth farm. The farmer's levels of N application was far in excess of the recommended level (Table 7), K was well over the recommendation and P was slightly below the recommended level. Hence, it appears that farmers applied an adequate level of fertilizer.

All plots summarized in Table 6 were planted at the farmers' spacing and consequently the initial plant population was very much higher than the recommended level. As the plants grow, those in the center die due to competition thereby reducing the plant density. Therefore, it is likely that interplant competition is the highest during the early stages of growth at farmers spacing. Yield differences recorded could be due to incorrect timing of fertilizer application in the farmers' management. In this context, therefore, further examination of the timing of fertilizer application, particularly the first top dressing seemed relevant (Table 8).

Table 6. Contribution of three inputs towards improving yields in experiments on farmers' fields. Giritale, Sri Lanka, wet season, 1975—76.

Site	Yield (t/ha)			Contribution (t/ha) of			
	Farmers' inputs & practices	High inputs & farmers' practices	Difference	Fertilizer	Weed control	Insect control	Residual
1	3.3	4.0	0.7	0.1	0.5	0.3	-0.2
4	0.6	2.4	1.8	0.5	0.1	1.2	0.0
7	5.0	4.7	-0.3	-0.4	0.0	0.1	0.0
10	2.8	4.8	2.0	0.4	0.1	1.5	0.0
Average	2.9	4.0	1.1	0.2	0.2	0.8	-0.1
Small[a]	3.3	3.9	0.6	-0.1	0.1	0.6	0.0

[a]Average of eight sites.

Table 7. Fertilizer rate used by farmers (M_1) at experimental sites. Giritale, Sri Lanka, wet season, 1975—76.

Fertilizer	Site				Recommended level	
	1	4	7	10	3—3—1/2 months	4—4—1/2 months
N (kg/ha)	171	146	204	142	77	106
P_2O_5 (kg/ha)	26	35	30	26	34	34
K_2O (kg/ha)	26	35	30	26	16	16

Table 8. Timing of application of top dressings (DAT) at farm level. Giritale, Sri Lanka, wet season, 1975—76.

T/D	Site				Recommended level	
	1	4	7	10	3—3—1/2 months	4—4—1/2 months
First	18	16	13	21	14	14
Second	25	37	20	47	42	28
Third	46	-	36	-	-	56

All farmers and research plots received P and K basally at similar rates. The plots with recommended fertilizer level received the first top dressing of N at 14 days after transplanting (DAT) whereas in farms 10 and 1, the first top dressing were at 21 DAT and 18 DAT, respectively. Correspondingly, farm no. 10 showed a 0.4 t/ha effect due to fertilizer while farm no. 1 showed an effect of 0.1 t/ha. In farm no. 7, yield

was high where the first top dressing was at 13 DAT. These results suggest the necessity for early application of fertilizer to overcome the interplant competition at farmers' spacing.

Weed control. The average effect of weed control was positive but small. The average weed control at farmers' level was extremely low compared to the high level.

In farm 1, no weed control was practiced at the farmers' level and the high level gave an increase of 0.5 t/ha. On the other hand, farm no. 7 also received no weed control at the farmers' level and showed no increase in yield at the high level. A probable explanation is that irrigation gave adequate weed control due to submergence in farm no. 7 thereby making any other method of weed control unnecessary.

Insect control. An average positive effect of 0.7 t/ha with 1.2 and 1.5 t/ha on two farms, points out the consistent effect of insect control (Table 6). A similar result was observed on the small experiments. Surprisingly, in the regular field inspections for pests, hardly any difference was observed between the farmers and high insect control plots in both pest population and observable pest damages. It may be that there were insects, identified as minor pests, or even unidentified which caused considerable yield loss, but which were not counted as pests because they did not cause any visible or obvious damage to the standing crop.

Depth and spacing. The effect of depth and spacing is shown in Table 9. In three of the four large experiments, the high practices gave a slight yield increase over the yield with high inputs and farmers' practices. In the fourth experiment, the contribution was negative. The individual effects of depth and spacing were very inconsistent, indicating that it is unlikely that farmers practices with regard to these items can be much improved upon.

Management packages. The physical yields obtained at the different management levels in the four farms tested is given in Table 10. The average figures show a gradual yield increase with increases in the input levels, M_1 being the lowest. However, the averages conceal substantial individual differences.

Farm 7 had the highest yield at the M_1 level. This may be explained by the fact that this farm, apart from being fortunate in having no serious insect or weed problems also received a very high level of fertilizers at M_1, an amount costing almost twice as much as the high level. In farm 1 the yield at M_1 was higher than at M_2 and M_3, but M_4 and M_5 packages gave a yield increase over the M_1 level.

Table 9. Contribution of inputs, depth and spacing toward improving rice yields. Giritale, Sri Lanka, wet season, 1975—76.

Site	Yield (t/ha)					Contribution (t/ha) of		
	Farmer's inputs and practices	High inputs, farmers' practices	Difference due to inputs	High inputs, high practices	Difference due to practices	Depth	Spacing	Residual
1	3.3	4.0	0.7	4.1	0.1	-0.2	-0.4	0.7
4	0.6	2.4	1.8	2.5	0.1	0.3	0.0	—0.2
7	5.0	4.7	-0.3	4.9	0.2	0.1	0.2	—0.1
10	2.8	4.8	2.0	4.3	-0.5	0.4	0.3	—1.2
Average	2.9	4.0	1.1	4.0	0.0	0.2	0.0	—0.1

Table 10. Rice yield (t/ha) from the management packages. Giritale, Sri Lanka, wet season 1975—76.

Package	Yield at site no.				Average
	1	4	7	10	
M_1	3.3	0.6	5.0	2.8	2.9
M_2	2.6	1.7	4.6	4.6	3.4
M_3	2.8	1.9	4.7	4.3	3.4
M_4	3.5	1.8	4.6	4.6	3.6
M_5	3.7	2.9	4.9	4.7	4.1
M_5H	3.6	2.7	4.7	5.2	4.1

The other two farms with low M_1 yields had progressively higher yields as the input packages increased from M_2 to M_5. The addition of high cultural practices (M_5H) gave a response on only one farm.

Results of experiments, dry season

Table 11 shows the results of the dry season experiments. In the dry season, many farmers in Giritale broadcasted their paddy because water from the canal was delivered late, and they did not want their crop to be delayed further. Three large experiments were installed, two broadcast, along with eight small ones, two of which were broadcast.

There was quite a range in both the farmers' yields and the high yields as shown in Figure 2. The yield gap averaged 0.6 t/ha. It was negative on three farms and reached as high as 2.4 t/ha on one farm. None of the three inputs -- fertilizer, weed control, or insect control gave consistent yield increases. As evident from the large residual, results were quite inconclusive.

Table 11. Contribution of three inputs toward improving yields in experiments on farmers' fields. Giritale, Sri Lanka, dry season, 1975—76.

Site	Planting method[a]	Yield (t/ha) Farmer's inputs and practices	High inputs, farmers' practices	Difference	Contribution (t/ha) of Fertilizer	Weed control	Insect control	Residual
3	TP	5.0	3.8	—1.2	—1.7	—0.6	—0.6	1.7
5	BC	1.9	1.8	—0.1	—0.2	0.2	0.1	-0.2
8	BC	1.5	2.4	0.9	0.4	0.1	0.2	0.2
Small	TP[b]	2.8	3.5	0.7	0.1	—0.2	0.2	0.6
Small	BC[b]	2.5	4.8	2.3	1.1	—0.5	0.1	1.6
Average	-	2.9	3.5	0.6	0.2	—0.2	0.1	0.5

[a] TP = transplanted, BC = broadcasted.
[b] Six of the small experiments were transplanted; two were broadcast.

The water available in the experimental fields was the basic cause of the lack of definitive results. Some farms had adequate water, but most suffered from drought at some stage of the crop. Under those circumstances the fertilizer and weed control inputs were not effective in raising yields. Insect control had little effect because of the lack of insects in most cases.

Because the crop was broadcast on four sites, the transplanting depth and spacing could not be tested there. The results on the other sites are shown in Table 12. As in the wet season, depth and spacing appeared to add very little to rice yields. Even when high inputs were used yields with farmers depth and spacing were higher. As with the input responses, a great deal of variability in response was observed.

Table 12. Contribution of inputs, depth and spacing, toward improving rice yields. Giritale, Sri Lanka, dry season 1976.

Site	Yield (t/ha) Farmers inputs and practices	High inputs, farmers practices	Difference due to inputs	High inputs, high practices	Difference due to practices	Contribution (t/ha) of Depth	Spacing	Residual
3	5.0	3.8	—1.2	3.6	—0.2	0	—0.4	0.2
Small[a]	2.8	3.5	0.7	3.0	—0.5	b	—0.2	—0.3

[a] Average of six sites.
[b] In the small experiment, only one plot with recommended depth and spacing was planted so the effect cannot be separated, and is shown under spacing.

Management packages. Table 13 shows the yields obtained in the management package component on the three farms where they were conducted in the dry season. The yield obtained by the farmer on the comparable paddy, as determined by crop cutting is also shown.

It is evident that the M_1 level did not simulate the farmer's level very effectively. On farm 5, the yield of M_1 was 1.4 t/ha higher than on the comparable paddy, while on farms 5 and 8, the M_1 yield was 0.6 to 0.9 t/ha less than the comparable paddy.

Table 13. Rice yield (t/ha) in management package experiments on three farmer's fields. Giritale, Sri Lanka, dry season 1976.

Package	Yield at site				Average for broadcast
	3	5	8	Av.	
Comparable paddy	3.6	2.9	2.1	3.9	2.5
M_1	5.0	2.0	1.5	2.8	1.8
M_2	4.2	1.9	1.4	2.5	1.7
M_3	3.3	2.0	1.7	2.3	1.9
M_4	4.4	2.5	2.1	3.0	2.3
M_5	4.5	2.9	2.8	3.4	3.9
M_5H	4.7	-	-	4.7	-

Little consistent yield increase was observed as inputs increased from M_2 through M_5. Yields on the two broadcast experiments were about 2 t/ha lower than on the transplanted experiment, much of the difference being traceable to water differences. As with the factorial experiment, lack of water on many plots prevents one from interpreting the results as being caused by input differences.

Costs and returns

Table 14 shows the average costs of the M_1 levels used by farmers and the corresponding costs of the higher packages. The farmers spent much more on fertilizer than on any other inputs, and in fact had a higher level of fertilizer than was used for the high package. In the dry season, farmers levels of inputs fell drastically because of the lack of water in the canals and the uncertainty associated with that.

Table 15 shows the costs and returns for the management package component of the large experiments. In the wet season, M_2 had the highest average net benefits because it entailed considerably lower cost than M_1. However, M_3 and M_4 were more profitable than M_1 on 3 of the 4 farms where tested.

In the dry season, only one farm showed an increase in net returns. On that farm, the increase, Rs800/ha, was nearly the same for all packages. This

Table 14. Average cost (Rs/ha) of inputs used by farmers (M_1) and in the tested input management packages. Giritale, Sri Lanka, 1975—76.

Package	Materials costs[a]			Materials plus application			
	Fertilizer	Weed control	Insect control	Fert—ilizer	Weed control	Insect control	Total
M_1 (wet season)				1278	46	138	1462
M_1 (dry season)	442	96	0				
M_2	342	118	136	362	118	180	661
M_3	418	81	297	438	103	330	871
M_4	721	449	365	886[b]	459	420	1765
M_5	938	449	662	1106[b]	577	749	2433

[a]Prices were: Urea, Rs2,771/t; Triple Superphosphate, Rs2,798/t; Carbofuran, Rs62/lb; Fenitrothion Rs44/lb; MCPA, Rs17.5/lb; Saturn, Rs8.3/lb.

[b]The Cost for 3 months varieties is about Rs200 less per ha.

Table 15. Economic comparison of tested input management packages to farmers' level of inputs in large experiments. Giritale, Sri Lanka, 1975—76.

Input package level	Comparison with farmers' level (M_1)							
	Wet season[a]				Dry season			
	Increased (Rs/ha)			% of sites with increased net benefits	Increased (Rs/ha)			% of sites with increased net benefit
	Cross return	Input cost	Net benefits		Gross return	Input cost	Net benefits	
M_2	727	—801	1528	50	—539	—17	—522	33
M_3	808	—591	1399	75	—836	193	—643	33
M_4	1132	303	829	75	210	951	—741	33
M_5	1827	972	855	50	916	1755	—839	33
M_5H	1827	784	1043	50	—583	1978	—2561	33

[a]Four experiments.

result is not surprising in view of the dry season yields obtained in the experiment (Table 12).

Insect control, which in the wet season gave the biggest contribution to the yield gap, increased value of output by more than cost on 3 of the 4 large experiments (Table 16). On the other farm, no. 7, yields were quite high with no insect control, so apparently there was no insect pressure.

In the wet season, the farmers used nearly Rs400/ha more value of fertilizer than used in the high level in the experiment. Despite this in three out of four cases, the "high" treatment (which was actually less fertilizer) gave

Table 16. Farmers' costs, increased costs and increased value of output from high levels of three inputs compared with average farmers' levels. Giritale, Sri Lanka, wet season 1975—76.

Site	Fertilizer (Rs/ha)			Weed control (Rs/ha)			Insect control (Rs/ha)		
	Farmer's cost	Increase to high		Farmer's cost	Increase to high		Farmer's cost	Increase to high	
		Cost	Value		Cost	Value		Cost	Value
1	1285	—354	31	0	459	728	137	283	404
4	1207	—276	728	64	359	81	350	69	1940
7	1516	—585	—647	0	459	0	0	420	81
10	1103	—353	687	119	340	121	64	356	2385

a greater profit than the farmers'. Obviously, something other than quantity of fertilizer used caused this increased profit. It is not clear what the source was, however.

The high level or weed control was uneconomical, although in farm 1 it gave an increased income of Rs270/ha. Its effect on physical yield was small, and the cost of the high level, Rs410/ha, was about 10 times what farmers were spending for weed control. It may be desirable to design a lower cost method of weed control in order to economically capture the gains of effective weed control.

IDENTIFICATION OF SOCIOECONOMIC CONSTRAINTS

A socioeconomic survey together with a farm record keeping project was undertaken at Giritale in order to determine the level of cultural practices and inputs used on a wider basis and to identify the factors which prevented farmers from following the recommended management practices or using the high levels of inputs required by the new varieties.

Giritale is one of the many settlement schemes undertaken by the government. Farmers hold uniform land allotments under a long lease and problems of variability in size of farms and tenurial conditions are not normally expected. While an earlier survey indicated that a certain amount of subdivision of holdings and renting of land was occurring, this had not assumed major proportions as in some of the other settlement schemes. As a special project area, infrastructural facilities were widely available to all farmers.

Sampling. Giritale is under the direction of a project manager with two agricultural instructors directly under him, each in charge of a region. The two regions are further divided into six division, each under a farm level extension official. There were in all about 1,350 settlers under the scheme. For purposes of the survey and record keeping project, two divisions were selected from each of the agricultural instructor's regions, and 10 farmers randomly selected from each division. Of these 10 farmers within each division, three farmers were selected for locating the experiments. All 40 farmers were included in the record keeping project. On completion of the harvest, a more comprehensive followup survey was undertaken. It covered 80 farmers, including the 40 farmers participating in the record keeping project. Its main purpose was to identify the reasons why farmers did not adopt the recommended practices and levels of inputs.

Inputs. The data on input use derived from the record books is shown in Table 17. These data show that, in general, farmers appear to be using more nitrogen than recommended. Expenditures on insect control and weed control measures are far below recommendations.

Table 17. Average levels of input use by 40 record keeping farmers, Giritale, Sri Lanka, wet season 1975-76.

Input	Levels reported		Recommended levels	
	Users (%)	Amount/farm reporting	3-3-1/2 month varieties	4-4-1/2 month varieties
Fertilizer				
N (kg/ha)	90	129	77	106
P_2O_5 (kg/ha)	50	26	34	34
K_2O (kg/ha)	50	26	16	16
Insecticides (Rs/ha)	75	71	420	420
Weed control (Rs/ha)	20	88	460	460

Reasons for not using new technology

The data from the survey presented in Table 18 show that almost all farmers used the new improved varieties. There were, however, wide variations in the types of new varieties grown. BG 11-11 was the preferred variety and is recommended for the wet season. Delays in the canal water forced many farmers into growing shorter duration varieties. Small areas were also given over to the traditional varieties.

Practices. Farmers were generally aware of the recommended cultural practices, but not all used them. Thus, while all farmers were aware of the advantages of row transplanting, only 10% reported practicing it. About 75% of the farmers practiced random transplanting, while another 15% broadcast the seed. The major reasons for not following the recommendations was that the methods followed were cheaper and easier.

Table 18. Cultural practices followed and major reasons for not following recommended practices by 80 survey farmers. Giritale, Sri Lanka, wet season 1975–76.

Cultural practices	Users (%)	Major reason for not following recommendation
New varieties	99	Not applicable
Used own seed	95	Own seed reliable
Random transplanting	75	Cheaper and easier than straight row
Fertilizer use		
Basal		
More	25)	Did not know recommended rate
Less	35)	Financial problems
Same	31)	Given amount thought adequate
Top dressing		
More	4)	Did not know recommended rate
Less	60)	Financial problems
Same	31)	Given amount thought adequate
Urea		
More	40)	Did not know recommended rate
Less	37)	Recommended rate low
Same	10)	Financial problems
Insect control		
Use recommended rate	5	Did not know recommended rate
Not used or not used recommended rate	88	No insect damage
Weed control		
Hand weeding	58	Hand weeding most effective
Chemical weeding	28	Rotary weeding breaks up soil
Rotary weeding	17	Plants damaged

Inputs. Almost all farmers reported using chemical fertilizers, but there were wide variations in the techniques of application. Farmers did not appear to be quite conversant with the need for split applications. Nearly 40% reported using more than the recommended rate of use, the reason given being that they were either not aware of the recommended rate or thought that the recommended rate was too low.

Farmers were closely questioned on the practice of insect control and, weed control measures. Nearly 80% did not appear to be familiar with the measures recommended for insect control. About 40% indicated that there was no insect damage, while among those who used control measures, nearly 90% did not follow recommendations. Farmers also appeared to prefer hand weeding because, in their opinion, it was a better way of weeding.

Problems. Survey farmers reported yields averaging over 4.0 t/ha, but only 23% of the farmers indicated that they were satisfied with the yields.

Over 70% indicated that yields were less than expected, due primarily to water problems (see Table 19). Other reasons given, in order of importance, were insect damage, fertilizer shortage, delayed planting and rat and bird damage.

Table 19. Farmers' reasons for lower than expected yields. Giritale, Sri Lanka, wet season 1975—76.

Reasons	Percent of farmers reporting
Water problems	77.5
Insect damage	34.0
Fertilizer shortage	31.0
Delayed planting	15.0
Rat and bird damage	10.0
Inadequate credit	7.5
Weeds	6.5
Poor land preparation	5.0

SUMMARY AND CONCLUSIONS

There has been a rapid diffusion of the new varieties of rice in Sri Lanka, but national yield levels are still below what is thought to be the potential. A series of experiments were conducted in farmers' fields in the wet season 1975—76. They were located at Giritale in the Polonnaruwa district. Whereas experimental station yields were estimated at about 7.5 t/ha, experiments on farmers' fields utilizing high levels of inputs averaged 4 t/ha and actual farmers' yields averaged 2.9 t/ha. Thus, there appears to be a "yield gap" of about 1.1 t/ha on farmers' fields.

Fertilizers, insect control, and weed control were the factors tested in the experiments and insect control appears to contribute to most of the yield difference. There was, however, considerable variation between farms. In the wet season, analysis indicated that management package (M_2) would prove most economical, although the highest management package (M_5) outyielded all others, even the recommended package (M_4). Results were too erratic in the dry season to draw conclusions.

Data from a wider segment of the farm population collected by means of record books and farm surveys indicate that farmers are not utilizing recommended practices and inputs.

The experiments, consisting of four large and eight small designs and comprising 190 plots, were found to be unwieldly and for the dry season certain modifications were made. Highly unreliable water supply in the dry season contributed to extreme variability in dry season yields. No reliable conclusions could be obtained from the dry season data, except the observation that the high level of inputs could not overcome the lack of water.

In general, the results from the large and small experiments tallied and it is now proposed to considerably modify the experimental design and cover a larger number of farms. We feel that this is important because wide variations between farmers in a small sample may not accurately reflect farm level conditions. In pursuance of this, for 1976—77 experiments being located in a different area, it has been decided to locate experiments on 35 farmers' fields using a simpler design with only eight treatments per experiment.

TAIWAN, SECOND CROP 1975, FIRST CROP 1976

Yi—Chung Kuo, Carson Wu and Cheng Chang Li

ABSTRACT

Experiment yields on three farmers fields ranged from 5.0 to 7.2 t/ha with farmers' inputs. The yield gap was 0.8 t/ha with fertilizer contributing about 60% of the gap in both seasons. The researchers believed their M_1 fertilizer level, set according to the presurvey information actually was less than the rate being applied by farmers. Economic interpretation was therefore conducted assuming M_3 as the "farmers' level" of inputs. M_3 was the optimal economic level during the first season but M_5 gave higher returns in the second seasons. Fertilizer input, technician's value and number of modern rice practices used were associated with yield. Input levels were associated with knowledge of fertilization practices and with alternative earnings.

RICE PRODUCTION IN TAIWAN'S AGRICULTURE

Rice is one of the most important agricultural products in Taiwan's economy, earning much of the foreign exchange needed for the past two decades of economic development. Rice has been and will continue to be the main staple food in the Chinese diet. The stability of rice production and rice prices is viewed as one of the stabilizing forces on the general price level and on national security. Hence, the increase of rice production has been a national agricultural and economic policy. The present role of rice in the economy -- and for the near future -- is the assurance of self—sufficiency of a basic food.

Measures to increase the yield of rice changed from production subsidies to price incentives (parity prices) for rice production (Wu and Mao, 1975). The pressure on producing more rice is always present however, due to the ever increasing population and the limited land area of Formosa Island.

The total production of rice increased about 30% from 1960 to 1975, but at a decreasing rate. Rice production increased at an annual rate of 3% for the period of 1953—64, but slowed to 0.9% annually for 1965—1974, which was less than the population growth rate. Yields per hectare increased from 2.50 t/ha in 1960 to 3.16 t/ha in 1975 (Table 1), but also at a decreasing rate. Despite an increase in both production and yield, two unfavorable factors, the high rate of population growth and the relative low international rice price, led to a sharp decrease of Taiwan's rice export in recent years.

Table 1. Production, area, yield, and export of paddy, Taiwan, 1960—1975.

Period	Total production (t)	Planted area (ha)			Yield (kg/ha)	Export (t)
		Total	First crop	Second crop		
1960—64	2,079,369	771,460	332,186	439,274	2,696	77,823
1965—69	2,396,246	785,029	337,754	447,275	3,052	118,618
1970	2,462,643	776,139	341,224	434,915	3,173	4,892
1971	2,313,802	753,451	333,621	419,830	3,071	33,790
1972	2,440,329	741,570	329,610	411,960	3,291	16,183
1973	2,254,730	724,164	324,331	399,833	3,114	25,709
1974	2,452,417	777,849	345,275	432,574	3,153	101
1975	2,494,183	790,248	358,087	432,161	3,156	10

Source: Taiwan Statistical Data Book - 1975

The total area of paddy fields is about 517,000 ha, which constitutes 56% of total cultivated area. Of the paddy field, 66% is double cropped, and the rest is single cropped.

The planted area of the second season crop (fall rice) is about 30% more than that of the first season (spring rice). That is because of the uneven distribution of rainfall and the shortage of irrigation water in the first season. However, due to favorable weather and the longer growing season in the first crop, the average yield of the first crop is about 32% higher than that of the second crop. Under the policy of increasing rice production in Taiwan, increasing the yield of second crop is a target to be achieved in the near future.

A characteristic of rice production in Taiwan is the application of fertilizer in large amounts. The rice fertilizers used by farmers are distributed by the Food Bureau through farmers associations. The fertilizer quantities and the frequency of application are regulated by region and by rice areas to be planted. The average amount of fertilizer applied on rice in terms of plant nutrients was 156 kg/ha in 1960 and 210 kg/ha in 1974 (Table 2). The fluctuation in different years was mainly due to the total supply of fertilizers and the relative price of fertilizer to rice.

The production of rice is concentrated in the south and the central parts of Taiwan. Areas and production of rice in different regions are shown in Tables 3 and 4. Taichung (the center of Taiwan) and Tainan (mid—south) regions constitute half of the total rice area. Distribution of rainfall and irrigation facilities are the two factors that make the difference in production area between the first and second season among the regions. A higher yield of the first rice crop than that of the second rice crop is shown in all regions (Table 4) but the difference in yield between the two seasons is more significant in the southern region (Kaohsiung area).

Table 2. Use of chemical fertilizer for rice, Taiwan 1960—1975.

Year	Chemical fertilizer applied (t)	Planted area (ha)	Average applied (kg/ha)	Nutrients (kg/ha)			
				N	P_2O_5	K_2O	Total
1960—64	586,245	771,460	761	114	37	32	183
1965—69	682,153	785,029	869	151	33	35	218
1970	360,342	776,139	464	79	17	16	112
1971	503,606	753,451	668	107	23	25	155
1972	392,435	741,570	529	88	19	20	127
1973	622,568	724,164	858	139	35	42	216
1974	604,446	777,849	777	134	34	42	210
1975	566,415	778,500	719	na	na	na	na

Source: Taiwan Provincial Food Bureau

Table 3. Rice area planted for different regions, Taiwan 1975

Region	Planted area					
	Total		First crop		Second crop	
	(ha)	%	(ha)	%	(ha)	%
Taipei	79,250	10.03	41,516	11.59	37,734	8.73
Sinchu	149,275	18.89	76,752	21.43	72,523	16.78
Taichung	202,092	25.57	100,011	27.93	102,081	23.62
Tainan	189,259	23.95	59,453	16.60	129,806	30.04
Kaohsiung	126,463	16.00	58,484	16.33	67,979	15.73
Taitung	43,909	5.56	21,871	6.11	22,038	5.10
Total	790,248	100.00	358,087	100.00	432,161	100.00

Source: Department of Agriculture and Forestry, Provincial Government of Taiwan.

Two main rices are cultivated in Taiwan: Japonica and Indica. The rice varieties used by Taiwan's farmers is shown in Table 5. Japonica varieties constitute more than 85% of total rice production in Taiwan.

Table 4. Rice production by region, Taiwan 1975.

Region	Total production (1,000 t)	%	Yield (kg/ha)	First crop (1,000 t)	%	Yield (kg/ha)	Second crop (1,000 t)	%	Yield (kg/ha)
Taipei	225,493	9.04	2,845	128,906	9.75	3,105	96,587	8.24	2,560
Sinchu	420,611	16.86	2,818	238,067	18.00	3,102	182,544	15.58	2,517
Taichung	713,490	28.61	3,531	393,029	29.72	3,930	320,461	27.35	3,139
Tainan	555,390	22.27	2,935	215,358	16.28	3,622	340,032	29.02	3,331
Kaohsiung	452,992	18.16	3,582	274,540	20.76	4,694	178,452	15.23	2,625
Taitung	126,207	5.06	2,874	72,702	5.50	3,324	53,505	4.57	2,428
Total	2,494,183	100.00	3,156	1,322,602	100.00	3,694	1,171,581	100.00	2,711

Source: Department of Agriculture and Forestry, Provincial Government of Taiwan.

Table 5. The percentage of planted area by varieties, Taiwan, 1974.

Variety	1974 first crop (%)	1974 second crop (%)
Tainan No. 5	60.2	67.1
Sinchu No. 56	8.2	5.1
Kaohsiung No. 1	4.7	6.8
CHIA NAN No. 8	4.3	4.1
Taipei No. 309	2.7	2.0
Taichung No. 178	2.1	1.8
Other	17.4	12.7

Source: Department of Agriculture and Forestry, Taiwan Provincial Government.

Taiwanese farmers acquire water from three sources: rainfall, irrigation and ground water. Most of the paddy land is irrigated through channels of irrigation associations (Table 6). Farmers use ground water from pumps of their own to supplement the canal irrigation whenever there is shortage of water in the fields.

Table 6. Area irrigated by irrigation associations, Taiwan, 1975.

Region	Paddy area (ha)	Irrigated area (ha)	% of paddy area irrigated
Taipei	46,279	32,578	70
Sinchu	82,635	65,720	79
Taichung	110,620	101,020	91
Tainan	179,962	153,970	86
Kaohsiung	72,454	54,229	75
Tung—Tai	23,902	20,788	87
Total	515,852	428,305	83

Source: Department of Agriculture and Forestry, Taiwan Provincial Government.

Research objectives

With the economic development that has occurred the farmers in Taiwan are becoming more price responsive and earning more income from off—farm sources. It is believed that it is more important than ever to consider the present and future incentives and opportunity costs of increasing rice yields. The constraints project was designed to examine whether or not there is any further scope for farmers to profitably increase rice yields. The specific objectives of the research include.

1. Identification of production techniques giving higher yields than farmers now get in given physical environments.

2. Determination of how much each technical factor (i.e., cash input or cultural practice) contributes to the gap between actual and potential yield.

3. Determination of the extent to which use of each technical factor can profitably increase yields.

4. Determination of what social and institutional factors prevent farmers from using technology that gives profitable high yields.

METHODOLOGY

To achieve the objectives, we follow closely the methodology developed by the International Rice Research Institute, and used in the International Rice Agro—Economic Network for measuring constraints to higher rice yields --

agronomic experiments on farmers' fields and socioeconomic research among the same farmers and other farmers in the same region.

The agronomic experiment measures the yield gap on farmers' fields, and quantifies the inputs and practice that constrain the yield. A two—level multi—factorexperiment is designed for that purpose. In addition, the experiment includes a series of levels of multi—factor input packages including the farmers' level of inputs. The results are analyzed by a simple budgeting method to determine the profitability of each package.

At the same time, data on socioeconomic factors are collected by interviewing farmers in the same region and multiple regression analysis is used to understand the farmers' behavior.

The study area

Because this research is the pilot study for the agroeconomic network in Taiwan, the Taichung area was chosen as the study area. It is where the university is located and one of the most important rice production regions in Taiwan. Farm income in the area comes mainly from rice production and constitutes about 60% of farm family income.

To select the experimental farm sites we consulted the agricultural improvement station at Taichung and Tah—yia village was selected (Fig. 1) where the conditions of rice production serve as representative of the region. The village is about 20 km northwest of the university.

A sample of 60 farmers were interviewed in the same village for the socioeconomic studies. The physical and social conditions of those 60 farmers were representative of similar farmers in the region and were compared to those of the farmers with experiments.

Measuring biological yield constraints

Most of the lowland rice grown in Taiwan depends entirely on irrigation water. The study areas selected are representative of Taichung (middle part of Taiwan) rice growing conditions. A large proportion of the rural population depends on rice production as a major income source. Although farms with an area less than 0.5 ha constitute more than 30% of total farm households in Taiwan, we consider that the group will be reduced through modernization of the agricultural sector. In fact, that group of farmers earn their income largely from nonfarm sources. Hence, the group of farms selected for our study were at least 1 ha in size, because that size of farm will be our major concern in the future. As a result, three sites were chosen, representing low, medium and high yielding farms. The area around Tah—Yia mainly consists of loam soils. The characteristics of the soils of the farmer—cooperators in the experiment are shown in Table 7.

Growing conditions. During July 1975 to July 1976 there was 1,677 mm of rainfall, compared with the 5—year average of 1,796 mm. Most of the rainfall was in July and August in 1975 and June in 1976 whereas in the past rainfall was from May to September with more widespread distribution.

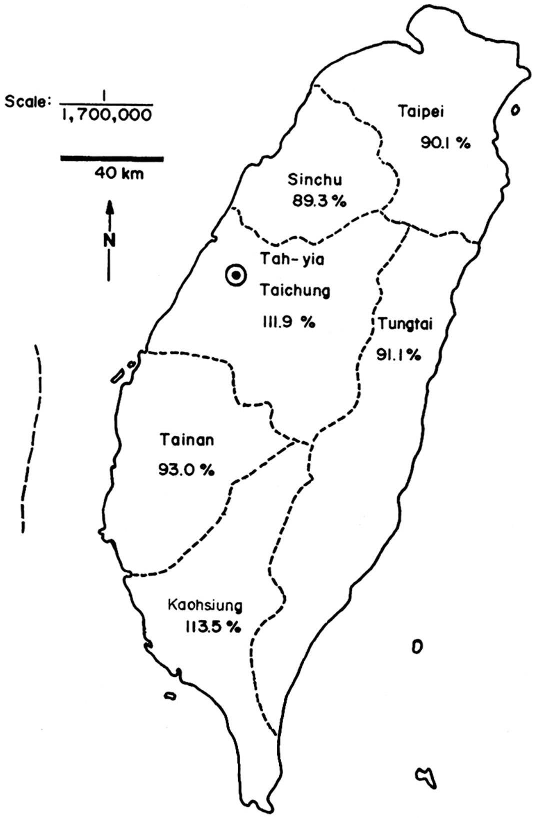

Fig. 1. Study area and relative rice yield among regions (% of total average), Taiwan, 1975.

High solar radiation occurred in the two crop seasons, except for the early stage of the second crop 1975 and the late—maturing first crop in 1976. The heavy rain in June, 1976, caused slight damage to maturing first crop rice that was close to harvest. In addition, typhoons hit the area several times in September and October during the late stages of the second crop growth. Nevertheless, there was not much crop damage compared with past years.

Experimental design and experimental factors. To investigate the yield gap between high potential yield and the farmer's yield, we used replicated two—level factorial component combined with a replicated five—level management package component. The factors included fertilizer (F), weed control (W) and insect control (I) at the farmer's level (f) and at the high level (M_4) and in the management package at a series of levels. Table 8 shows the levels of inputs used in the experiments and Figure 2 shows typical plot layouts. The levels of management package were:

Table 7. Physical and chemical characteristics of soil at three experimental sites, Taichung, Taiwan, 1976.

Characteristics	Farmer No. 1	Farmer No. 2	Farmer No. 3
Mechanical composition:			
Sand (%)	34	23	34
Silt (%)	39	40	39
Clay (%)	27	37	27
Texture	Loam	Clay loam	Loam
Chemical characteristics:			
Organic matter	2.83	2.96	2.83
Available P_20_5	75.1	53.5	51.4
Exchangeable K_20	54	91	53
pH	5.7	6.5	5.1
C. E. E. (me/100 g)	6.86	8.44	7.01

M_1 = farmer's practice
M_2 = maximization of input efficiency (economic optimum, based on input level of fertilizer obtained from Taiwan Provincial Food Bureau)
M_3 = agronomic optimum with greatest economic return (agronomist's point of view)
M_4 = high yield (high yield farmer practice level)
M_5 = maximum yield (flexible practice as needed to attain higher than experiment station practices), no economic consideration.

The farmers' level of each factor, determined by the comparable paddy technique, was the level actually used by each farmer on whose fields the experiments were conducted. M_4 was used as the high level of inputs in the factorial component in both seasons. The local improved variety of Tainan 5 was used. The two components of the experiment were replicated twice.

Analysis. The yield gap was measured by the difference between the plots with all inputs at the high level (plots 11, 13, 18, and 24) and the plots with all inputs at the farmers' level (plots 3 and 6) (Fig. 2). The contribution of each individual input to the increase of yield was determined by comparing the average yield of all treatments with the factor at the farmers' level and at the high level. Statistical analysis of the factorial component was conducted to determine whether significant effects of each individual input and interactions were present. In addition, the magnitude of interactions were determined by comparing the yield gap with the total effects of the individual factors.

Table 8. Average level of inputs used by farmers and input levels of four input management packages in experiments on farmers' field, Taichung,Taiwan.

Input package level	Fertilizer (kg/ha)			Weed control (no.)		Insect control (no.)[a]			
						Seedbed		Field	
	N	P_2O_5	K_2O	HW	CW	F	G	F	G
	1975 second crop season, three farms								
M_1[b]	97	48	44	0	1	1.2	0	2.3	1.2
M_2	90	30	50	2	0	0	0	2	1
M_3	100	60	60	0	1	2	0	2	1
M_4	120	60	60	0	1	2	0	3	1
M_5[c]	150	80	70	2	1	0	2	5	0
	1976 first crop season, three farms								
M_1	107	58	50	0	1	1.4	0	3.4	1.9
M_2	100	30	50	2	0	0	0	3	0
M_3	120	60	60	0	1	1	0	3	1
M_4[d]	150	60	60	0	1	1	0	3	1
M_5	180	60	70	2	1	0	2	3	2

[a]F indicates a foliar spray, G a granular material.
[b]M_1 is designated as the "farmers' level" of inputs. The data shown are the average for each season.
[c]All P_2O_5 in M_2 through M_5 was applied as a basal. The N was split into four (basal, 15, 30, PI for first crop season; basal, 10, 20, PI for second crop season). The K_2O was split into three (i.e. basal, 15 and 30 DT for first crop season; basal, 10 and 20 DT for second crop season).
[d]M_4 was used as the "high level" of inputs in the factorial component in both seasons of the experiments.

Identification of socioeconomic constaints

Analysis of the socioeconomic constraints to rice yield, requires data from more sample farms than the three experimental farms. We assumed that the difference in cropping patterns and technological factors for farms in the region were not large. To get homogeneous physical conditions between farms with and without experiment, we drew the sample farms from the same village where the experimental farms were located. Sixty farmers were selected in Tah—yia village, and interviewed twice. Because the three experimental farms were selected to represent farms of high, medium and low yields, the 60 farmers were selected accordingly. First, we chose

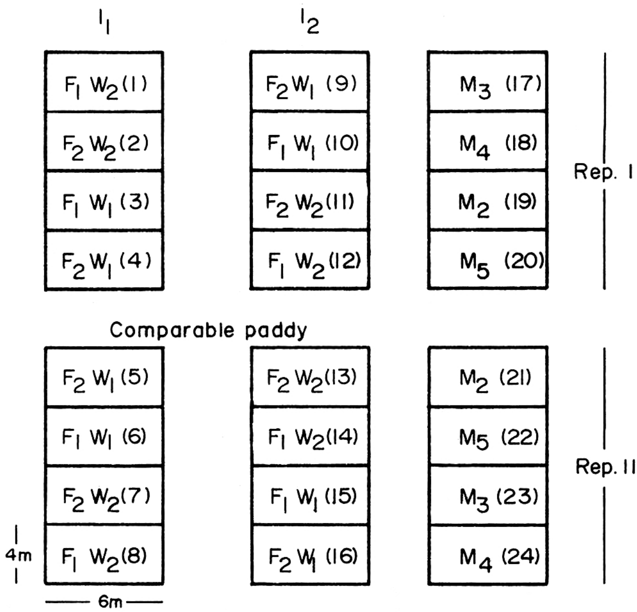

Fig. 2. Typical plot layouts used in experiments studying yield constraints on farmer's fields, Taichung, Taiwan.

six sub—villages from the eight sub—villages. Based on consultation with extension workers, the six sub—villages were divided into three levels concerning the physical conditions of rice production. Each level contained two sub—villages. Within each sub—village, 10 farmers were randomly selected.

Design. The survey schedule was designed as a general type of survey, but emphasized rice production. Items included the use of land and labor, cropping system, inputs and output of rice production, evaluations of production technologies, and attitude of farmers toward technologies.

A comparison of the general features of farms in the constraints experiments and farms in the random sample is shown in Table 9. Income from rice production constitutes 60% of farm family income for the farms with experiments and 52% for the sample farms, and the remaining sources of income are mainly from off—farm source rather than from other crops on the farms. Based on the data on costs and yields of rice production, the farms with experiments appear on the average to be relatively more efficient than the random sample farms.

The rice yields and input levels of various management packages on farms with experiments and farms of the random sample are compared in Table 10.

Table 9. Comparison of general features of farms with experiments and a random sample of farms in the same areas, Taichung, Taiwan 1975—76.

Item	Unit	Average of farms with experiment	Average of farms without experiment
Number of farms	Farms	3	60
Average farm size	ha	1.35	1.11
Family workers per farm	person	4.00	4.10
% of rice area of total cultivated area	%	100	96
% of rice income of total income	%	60	52
Rice yields: second season	kg/ha	5,298	4,658
first season	kg/ha	4,268	4,872
Costs of rice production:[a]			
second season	NT$/ha	28,226	33,394
first season	NT$/ha	28,313	37,205

[a] Costs including labor fees and fixed costs.

The average yield and input levels between farms with and without experiments matched fairly closely. The average input level on the sample farmers fields were between M_3 and M_4. With respect to yield, the data show that the average yields at different levels of management packages were higher than those of the sample farms in the survey which implies that factors other than the inputs chosen in the experiment affected rice yields.

Use of technology by farmers

We believe that farmers in Taiwan are, relatively speaking, sensitive and responsive to price changes, and adaptive of new rice technology. This is partly because of the well developed communication and extension systems in Taiwan. In the interviews, 81% of the sample farmers said that they receive instructions or advice from time to time either from the Farmers' Association or other sources. And 95% of the farmers said that they usually get technological and market information from audiovisual communication sources. Therefore, the rice production practices are more or less homogeneous among the sample farms. In fact, not much of the modern rice technology which agronomists can list is new to the farmers in Taiwan.

We asked the farmers whether they used specific rice production practices and whether they believe those technologies would increase yield if applied. The data concerning the answers is shown in Table 11.

Table 10. Comparison of yields and inputs of farms with constraints experiments and a random sample of farms in Taichung, Taiwan.

Observation unit	Number	Yield t/ha	Fertilizer applied[a] kg/ha N	P_2O_5	K_2O	Total	Weed control NT$/ha	Insect control NT$/ha
			1975 second crop season					
Comparable paddy M_1	3	5.8	97	48	44	189	978	3,266
M_2	3	5.3	90	30	50	170	-	2,525
M_3	3	6.0	100	60	60	220	1,100	3,160
M_4	3	6.5	120	60	60	240	1,000	3,245
M_5	3	6.5	150	80	70	300	1,000	1,639
Farms with experiments	3	5.3	132	66	62	260	978	3,266
Farms without experiments	60	4.6	133	44	67	244	970	3,100
			1976 first crop season					
Comparable paddy M_1	3	6.7	107	58	so	215	811	2,987
M_2	3	6.7	100	30	50	180	-	3,579
M_3	3	7.0	120	60	60	240	1,100	3,919
M_4	3	7.0	150	60	60	270	1,000	4,570
M_5	3	7.2	180	60	70	310	1,000	6,185
Farms with experiments	3	4.3	128	42	76	246	811	2,987
Farms without experiments	60	4.9	133	52	97	282	959	3,393

[a] Fertilizer applied is shown in nutrients.

All farmers in the sample used the same variety of rice (Tainan No. 5) and all of them believed that it was the best variety. Chemical fertilizer, herbicides and insecticides were applied by 100% of the farmers. Rodenticide is distributed by the government free of charge. It is interesting to note that the proportion of farmers who believe that chemical inputs will increase the rice yield is low. A large proportion of the farmers think that the level of chemical fertilizer they applied was at the optimum.

In addition to the feeling on chemical fertilizer, 70% of the farmers believed that manure will increase the yield, but only about 50% of the farmers apply natural manure (compost) on their field. Hence, we raised the question why they were not using it? The reason they gave is lack of labor to make it.

Table 11. Proportion of sample farmers (%) who used and who believed that specified components of modern rice production technology increased yield, Taichung, Taiwan, second crop, 1975.

Inputor practice	Used	Believed use increased yield
Technologies		
New variety	100	100
Direct seeding method	3	0
Natural manure application	54	71
Hand weeding	20	25
Chemical technologies		
Chemical fertilizer	100	27
Herbicides	100	24
Insecticides	100	62
Rodenticides	97	34
Mechanical technologies		
Water pump	62	58
Seeding machine	5	0
Combine	6	0
Dryer	16	0
Land preparation with tiller	97	0

Twenty percent of the farmers used hand weeding as complementary to herbicides. Most of the farmers were satisfied with the herbicides they apply.

Land tillers are popular in preparation of the rice fields, but none of the farmers believed that the use of land tiller increased yield. The same is true for the use of the seeding machine, the combine harvester and the grain dryer.

The answers to the mechanization of rice cultivation seem to be contradictory to our usual understanding. The answers suggest that machines are used to substitute for labor.

BIOLOGICAL CONSTRAINTS

The analysis of variance of the experiments for both crop seasons are shown in Tables 12 and 13. The effect of the management packages was significant in three cases, there is however, no evidence to show that the intensive management is better than the farmers' practice if disease and insect control, or weed control, are the only factor added (Table 12). Only fertilizer was significant. Furthermore, the interaction among three factorial treatments was not significant.

Table 12. Analysis of variance of three farmers of the International Rice Agro—EconomicNetwork, Taichung, Taiwan, second crop 1975 and first crop 1976.

S. V.	D.F.	Mean squares					
		Farmer No. 1		Farmer No. 2		Farmer No. 3	
		1975	1976	1975	1976	1975	1976
Block	1	0.002	0.014	0.158	2.781	0.047	0.551
Insect control (I)	1	0.240	0.232	0.094	0.394	0.955	0.228
Error (a)	1	0.256	0.292	0.444	10.643	0.027	0.613
Fertilizer (F)	1	6.326*	0.710	2.520	5.371	13.487**	5.748**
IXF	1.	0.048	0.003	0.034	0.228	0.001	0.104
Weed control (W)	1	0.416	0.268	0.278	1.410	0.052	0.233
IXW	1	0.002	0.008	0.003	0.158	0.019	0.028
FXW	1	0.005	0.009	0.025	0.025	0.439	0.059
IXWXF	1	0.151	0.018	0.018	0.004	0.080	0.223
Error (b)	6	0.474	0.149	0.656	3.600	0.160	0.341
Total	15	0.686	0.163	0.501	2.844	1.071	0.656

a/ Significance level: ** = 5%, * = 10%.

Table 13. Analysis of variance for management package, Taichung, Taiwan second crop 1975 and first crop 1976.

S. V.	D.F.	Mean squares					
		Farmer No.1		Farmer No.2		Farmer No. 3	
		1975	1976	1975	1976	1975	1976
Block	1	0.100	0.009	0.177	1.680	0.010	0.008
Treatment	4	1.441*	0.215	1.377	3.765	3.241**	1.524*
Error	4	0.174	0.220	0.526	1.327	0.144	0.197
Total	9	0.729	0.194	0.865	2.450	1.505	0.766

a/ Significance level: ** = 5%, * = 10%.

The average grain yield of main effect and interaction effect are shown in Table 14. The yield of the second rice crop with farmers inputs in 1975 ranged from 5.04 t/ha to 6.18 t/ha and averaged 5.64 t/ha (Table 15). The yield gap was small, ranging from 0.68 to 1.08 t/ha with an average gap of 0.89 t/ha. The average contribution of each factor to yield gap reveals that fertilizer contributes 66%, weed control 23% and insect control 11% of the yield gap.

Table 14. Grain yield in constraints experiments, Taichung, Taiwan, 1975—76.

Treatment	Yield by farm, first season 1976 (t/ha)				Yield by farm, second season 1975 (t/ha)			
	1	2	3	Ave.	1	2	3	Ave.
$F_fW_fI_f$	6.4	5.7	5.3	5.8	7.4	6.7	5.9	6.7
$F_fW_mI_f$	6.3	5.9	5.4	5.8	7.3	6.1	5.8	6.4
$F_mW_fI_f$	6.7	6.1	6.2	6.3	7.4	6.4	6.3	6.7
$F_mW_mI_f$	6.9	6.2	6.1	6.4	7.5	6.8	6.4	6.9
$F_fW_fI_m$	6.2	5.8	5.4	5.8	7.2	6.1	5.9	6.4
$F_fW_mI_m$	6.4	5.9	5.5	6.0	7.5	6.3	5.8	6.6
$F_mW_fI_m$	7.0	6.2	6.4	6.5	7.5	6.6	6.3	6.8
$F_mW_mI_m$	7.0	6.3	6.3	6.6	7.6	6.7	6.5	7.0

The potential improvement from ordinary management is estimated by the ratio of yield with intensive management using improved varieties and the yield with farmers' present cultivation method. The value of the ratios ($F_mW_mI_m/F_fW_fI_f$) at 1.13 and 1.10 for farmers No. 1 and 2 indicates that a slight improvement in management can be expected. The potentiality of using intensive management expressed by $F_mW_mI_m/F_fW_fI_f$ for farmer No. 3 is larger (1.21) indicates an expected large improvement from management for farmers with poor cultivation practices. Such an improvement is mainly from the effect of the application of fertilizers at different levels and times.

The average yield of the 1976 first crop was more than 0.5 t higher than that of the previous season. The yield ranged from 5.58 t/ha to 7.20 t/ha and averaged 6.16 t/ha (Table 15). In three factorial treatments, the difference was not significant for farmers No. 1 and No. 2, but significant for farmer No. 3 in the application of fertilizers (Table 12). However, the contribution of the factors to the yield gap was quite similar to the previous season. Fertilizer application contributed the largest portion (60%), weed control 23%, and insect control 17% to the 1976 yield gap.

Table 15. Contribution of four inputs towards improving rice yields (t/ha) in yield constraints experiments in farmers' fields, Taichung, Taiwan, 1975—76.

Farm	Yield (t/ha)			Contribution (t/ha) of			
	Farmers' inputs	High inputs	Difference	Fertilizer	Insect control	Weed control	Residual
				1975 second crop season			
1	6.2	7.1	0.9	0.6	0.2	0.3	-0.2
2	5.7	6.4	0.7	0.4	0.1	0.1	0.1
3	5.0	6.1	1.1	0.9	0.1	0.2	-0.1
Ave.	5.6	6.5	0.9	0.7	0.1	0.2	-0.1
				1976 first crop season			
1	7.2	7.6	0.4	0.2	0.1	0.1	-0.1
2	5.7	6.9	1.2	0.6	0.2	0.3	0.1
3	5.6	6.5	0.9	0.6	0.1	0.1	0.1
Ave.	6.2	7.0	0.8	0.5	0.1	0.2	0.1

Input packages

From the management package experiment in both seasons, grain yields tended to increase as the level of inputs increased (Table 16). Statistical analysis for grain yield indicates that there was a significant difference between management treatments for farmers No. 1 and 3 in 1975 and for farmer No. 3 in 1976. However, no significant difference in yield was observed for farmer No. 2 in either season (Table 13).

Table 16 shows that in 1975, maximum yield obtained with M_5 was almost the same as for the high input of M_4. The average yield increase from M_1 to M_4 was 0.82 t/ha and from M_1 to M_5 was 0.85 t/ha. The yield gap between farmers' practice (M_1) and high yield—potential treatment (M_4) was 12%. In 1976, the level of inputs and the cost of M_4 increased as compared to 1975, but the yield increased only 0.57 t/ha. The average yield increase from M_1 to M_4 was 0.85 t/ha and from M_1 to M_5 was 0.98 t/ha. The average yield gap between M_1 and M_4 was 12%, the same as for the second crop of 1975.

Table 16. Yield with farmers' inputs and with four input packages in experiments on farmers' fields, Taichung, Taiwan, 1975–76.

Farm	Yield (t/ha) at package level				
	M_1	M_2	M_3	M_4	M_5
			1975 second crop season		
1	6.2	6.0	6.8	7.1	6.9
2	5.7	5.4	6.2	6.4	6.2
3	5.0	4.8	5.2	5.9	6.3
Ave.	5.6	5.4	6.1	6.5	6.5
			1976 first crop season		
1	7.2	7.4	7.6	7.6	7.5
2	5.7	6.4	7.0	7.0	7.3
3	5.6	6.2	6.4	6.5	6.7
Ave.	6.2	6.7	7.0	7.0	7.2

Economic analysis of experimental results

The experimental results show that rice yield for both seasons significantly increased as higher levels of inputs were used, and among these inputs, fertilizer contributed more than others.

The results we obtained, however, were contradictory to our expectation for farmers in Taiwan. Apparently, an economic scope existed for yield increase through the use of more inputs (especially fertilizers) between M_1 and M_3, but it seemed that the farmers did not take advantage of that situation. Hence they operated at a far from satisfactory level and it seemed that the farmers were not profit maximizers.

After several checks and rechecks, we found that the fertilizer levels used in M_1 were lower than the level of fertilizers actually used by farmers. We carefully examined the input levels of the original experiments and compared the input levels in the management packages with the average levels of farms from the survey data, and realized that the actual level of farmers' fertilizer input was about equivalent to the level between M_3 and M_4 in our experiments. The difference in the amount of fertilizer was mainly due to differences in the level of nitrogen used.

The possible explanation of the underestimation of the farmers' level was that false information was provided by farmers in the presurvey before the experiments were designed. To obtain a rational explanation in the economic analysis of the experimental results, we adjusted the farmers' level to a higher level by designating M_3 as the farmers' level, and M_5 as the "high level." Consequently, we cannot evaluate the increased return by separate factors because the original design consisted of two levels only. However, costs and returns of different input package levels can be analyzed as originally designed. The results from the above adjustments turn out quite reasonable and meaningful. We start our analysis from the original setting (M_1 as farmers' level), and adjust the farmers' level to M_3 in comparison with high level M_5.

Prices and inputs costs. The prices paid by farmers for some of the inputs used in the experiments are given in Table 17. The same prices were used in calculating input costs of experimental management packages for both seasons. In the same period, the government—supported price of paddy also remained at NT$ 11.50/kg for Pon—lai paddy, and NT$ 10.50/kg for Tsai—lai (native) paddy.

Table 17. Prices used in calculating costs of experimental and farmers' input packages, Taichung, Taiwan, second season 1975, first season 1976.

Input	Unit	Prices (NT$)[a]
Fertilizers		
Urea	1 kg	6.08
Ammonium sulphate	1 kg	3.79
Insecticides		
Sumithion	11	240.00
Furadan	1 kg	55.00
Benlate	1 kg	1,200.00
Herbicides		
Machete	3 kg	100.00
Saturn	3 kg	110.00
Saturn M	2.5 kg	100.00
Hand weeding	1 ha (2 times)	5,000.00

[a] 1US$ = 38 NT$

The costs of input packages for the two seasons are shown in Table 18. The small differences between the two seasons were due to small changes in both quantities and kinds of inputs. In general, the first crop rice requires more fertilizer than the second rice crop because of a longer growing season. Labor costs, which constituted more than 70% of the total costs, are separated from the material inputs such as fertilizer and herbicide. The higher cost of M_2 relative to M_1 was mainly due to the high cost of weed control, which was completely hand weeding. For M_5, about 6 man—days/ha of hand weeding was used besides herbicides. The data also shows that the cost of fertilizer as well as that of insecticide was higher at M_3 - M_5 to that of M_1.

Table 18. Average cost of inputs used in the input management package experiments on farmers' fields, Taichung, Taiwan, 1975—76.

Input package level[a]	Cost (NT$/ha)				
	Fertilizer	Herbicide	Insecticide	Wage	Total
		1975 second season, three farms			
M_1	2,786	978	3,266	17,926	24,956
M_2	2,452	0	2,525	22,926	27,903
M_3	3,158	1,100	3,160	17,926	25,344
M_4	3,518	1,000	3,245	18,176	25,939
M_5	4,438	1,000	1,639	19,426	26,503
		1976 first season, three farms			
M_1	2,786	811	2,987	17,941	24,525
M_2	2,630	0	3,579	22,941	29,150
M_3	3,518	1,100	3,919	17,941	26,478
M_4	4,060	1,000	4,570	18,191	27,821
M_5	4,678	1,000	6,185	19,441	31,304

[a]M_1 as farmers' level.

Comparison of management packages

The economic evaluations of the four input packages compared to M_3 are shown in Table 19. In 1975, M_4 and M_5 were relatively more profitable than M_3 on all three farms. In 1976, M_3 was most profitable on average on all three farms, while M_5 offered moderately higher profits than M_3 on one of the three farms.

Because the prices of all the inputs and rice were quite stable in both seasons, the differences in income between the two seasons can be attributed to the differences in yields.

Table 19. Economic comparisons of different management package on three farms[a].

Input package level	Average difference from M_3			No. of sites with net returns	
	Gross return (NT$/ha)	Input cost (NT$/ha)	Net above input cost (NT$/ha)	Higher than M_3	Lower than M_3
	1975 second crop season				
M_1	−2829	−388	−2441	0	3
M_2	−7624	2559	−10183	0	3
M_4	5221	595	4626	3	0
M_5	5152	1159	3993	1	2
	1976 first crop season				
M_1	−3668	−1953	−1715	0	3
M_2	−3910	2672	−6582	0	3
M_4	173	1343	−1170	0	3
M_5	2576	4826	−2250	1	2

[a] This table is compiled from Table 18 by using M_3 as the farmers' level and recalculating the results.

Separate input effects

For the evaluation of the relative costs and benefits of separate inputs, the contribution in terms of yields and costs combined for each input is shown in Table 20. Table 20 shows the expenditure level of farmers, the increase in cost and the value of output by raising the three tested inputs from M_1 to the high level (M_4). Among all inputs in both seasons, except insect control in 1976, the higher level of inputs resulted in more increase in value of output than in increase of costs. The cost of insect control at high level in 1975 was lower than the farmers' level due to the good quality of the insecticde, and the small quantity needed. On the other hand, high level led to an increase in the value of output.

In comparing the investment returns of high−level inputs between the two seasons, the data show that all the high−level inputs led to more return in the second season of 1975 than in the first season 1976 of rice crop. That suggests that it is more profitable to invest in high−level inputs in the second season than it is in the first season.

The high level of fertilizer brought more profit than the other two factors in both seasons. The results of economic analysis coincide with the results of the yield experiment, which revealed the dominant contribution of fertilizer to yield increase.

Table 20. Farmers' (M_1) costs, increased cost and increased value of output from high levels (M_4) of three inputs compared with average farmers' levels (M_1) yield constraints experiments on farmers' field, Taichung, Taiwan, 1975—76.

Crop season	Fertilizer (NT$/ha)			Weed control (NT$/ha)			Insect control (NT$/ha)		
	M_1 cost	Increase to high		M_1 cost	Increase to high		M_1 cost	Increase to high	
		Cost	Value		Cost	Value		Cost	Value
Second 1975	2786	732	6825	978	22	2415	3266	—21	1155
First 1976	2786	1274	4830	811	189	1890	2987	1583	1365

SOCIOECONOMIC CONSTRAINTS

Based on the results of the experiments, the biological constraints of rice production were analyzed in the preceding section. We now examine some socioeconomic factors that were not included in the experiments. From the economic analysis we know that in the first season, it is uneconomical for the farmers to increase rice yield by increasing input level. However, in the second season, there is still some economic incentive for farmers to increase rice yields. This analysis will, therefore, concentrate on the second season's rice production.

To determine the factors associated with variation in yields among farms and levels of inputs used by farmers, regression was used. Two regressions, one with yield and the other with the level of inputs as the dependent variable, were calculated using explanatory variables reflecting socioeconomic factors. It is difficult to identify and measure these factors, and so some qualitative factors are represented by dummy variables.

Factors affecting rice yield

In searching for the factors affecting rice yield, we tried many forms of regression and many combinations of variables. After excluding those factors that had the opposite sign of what was expected and at the same time were statistically insignificant, five factors are left to explain the variations of the yield.

Fertilizer input. Our hypothesis is that the intensifications of the application of fertilizers is positively related to the rice yield in the second season of rice. The monetary expenditures per hectare were used as the measurement of this intensity.

Labor availability. In the survey, we asked the farmers how serious the shortage of labor was during rice production. About 70% of farmers acknowledged a labor shortage. However, when the question whether the shortage of labor affected the proper timing of cultivation was asked, no one gave a positive answer. Most of the farmers solve their labor problem by exchanging worker with neighbors or hiring the cultivation service team as needed.

Net return from rice. The average net return from rice production on the sample farms is NT$21,583/ha for the second season crop. This variable is selected to reflect the economic incentive to increase rice yields. By comparing the net return from the second season crop with that from the first season, we found that the former is about 45% higher than the latter. In fact, on the average, only NT$14,899/ha is earned from the first season rice. That finding coincides with the results of economic evaluation from the experimental data.

Technician's value. The farmers were asked to evaluate the overall value of their extension technician based on receiving no advice, poor service and good service.

Use of technology. The practices listed in Table 11 were used as indicators for the kind of technology adopted by the farmers. However, we exclude those practices which were adopted by 100% of the farmers in our analysis. Seven practices were left. They were the application of natural manure, complementary hand weeding, complementary irrigation, and the use of different farm machines, such as land tiller, seeding machine, combine harvester, and dryer. Among those practices, the first three were expected to have a positive relation with high yields of rice.

In addition, we asked the farmers about the availabilities of inputs and credit services. Farmers' responded that those are always available when needed.

Results. The results of the regression analysis are shown in Table 21. The equation fitted to explain variation in yields, explained about 50% of the observed variability. Net return, representing economic incentive is the most significant factor affecting the yield of rice although the effect is not large. The level of fertilizer input is positively related and significant at the 5% level. The coefficient shows that yield can be increased 0.3 kg/ha by an increase of NT$1 of fertilizer input. Both the technician's value and the number of practices had positive effects on the yield and are significant at the 10% level. These results seem to indicate that more extension services are needed in the production of rice. They also indicate that natural manure, complementary irrigation and hand weeding have positive effects on rice yield.

Factors affecting input levels

The question of why some farmers used higher level of inputs was analyzed through regression. Expenditures on inputs per hectare (fertilizer,

Table 21. Estimated coefficients and standard errors of equations explaining yield and expenditures on inputs. Second rice crop, Taichung, Taiwan, 1975.

Independent variable	Equation explaining	
	Yield (kg/ha)	Expenditures (NT$/ha)
Intercept	2,165 (677)	34,912 (4,242)
Fertilizerinput	0.2978** (0.1417)	-
Laboravailability	147.01 (188.80)	0.0052 (3.5624)
Net return	0.0380*** (0.0063)	-
Technician'svalue	143.93* (99.18)	-
Number of practice	106.87* (86.79)	2,354.93** (1,383.50)
Alternativeearning	-	−0.0962*** (0.0383)
Knowledge of fertilizer application	-	−1,306.68 (1,951.80)
R^2	0.51	0.14

Significance level: *** = 1%; ** = 5%; * = 10%.

weeding control and insecticide control) were treated as the dependent variable. Again, after excluding those factors with opposite sign and statistical insignificance, four factors were left. They were labor availability, use of technologies, knowledge of fertilizer application, and alternative earning. Measurement of the first two factors was the same as for the first regression, and the latter two follow.

Knowledge of fertilizer application. Because fertilizer is one of the key factors affecting the yield of rice, the knowledge of farmers on application of fertilizer is viewed as an indicator to show the farmers' level of technological knowledge. Among the techniques of fertilizer application, we considered the timing of application as the most important. Although the question as to whether farmers apply fertilizer, at the proper time was asked of them, we believe that this measurement was rough and lacked objective criteria. To understand better, we consulted the agronomist at the Taichung Experiment Stat ion on the "standard" timing, of fertilizer application. Then we compared the farmers' actual timing with the "standard" timing, and counted the difference between these two timings as the number of times that are treated as "improper." Furthermore, we considered that the existence of deviations among individual farms map be related to the soil conditions. We set "proper time" into a range such as one week instead of one day. With those considerations, this indicator is negatively related to the level of knowledge that farmers have. The average "improper time" of fertilizer application on the sample farms is 1.6 times out of 4 times in the second season.

Alternative earnings. On the average, about 45% of farmers' income is from sources other than rice production, which includes income from other crops, from livestock and from off—farm sources. With respect to other earnings, we expect that the largest proportion of alternative income is from off—farm income. Although we do not have such data from our 60 sample farms, some secondary data show that off—farm income on the average, constitutes more than 40% of the total farm family income in the whole country. In Taiwan, it has been argued that increasing the proportion of off—farm income may affect the efficiency of agricultural production. We thus hypothesize that the alternative earnings of a farmer is negatively related to the levels of input used.

Results. Only 15% of the variation in the level of inputs were explained by the equation. Nevertheless, two factors among the four were significantly different from zero. Alternative earning is highly significant (1%) and is negatively related to the input levels. This result supports the argument that agricultural efficiency is reduced as more farmers become part—time workers in the field. The result also implies that farmers' are maximizing the total family income instead of maximizing agricultural income only. This phenomenon should be taken into consideration by agricultural policy makers, Number of practice as an indicator for the technology level also has a significant effect and is positively related to the level of input.

Although labor availability had a positive relationship to input levels, it was not significantly different from zero. We suspect that labor availability is somehow negatively related to alternative earning, and hence, the insignificance of labor availability in the equation can be ignored.

SUMMARY AND CONCLUSIONS

Our analysis of rice production in Taiwan was carried out using two components -- agronomic and socioeconomic. The basic data for analysis came from experiments on three farmers' fields where farmers cultivated rice following the instructions of researchers, and from a survey of 60 sample farms. Physical constraints on rice production were analyzed based on the data from experimental fields on three farms, and socioeconomic constraints of rice production are analyzed based on data both from the experiments and the survey.

We draw three conclusions.

1. Rice yields are significantly and positively related to the level of fertilizers applied. The application of fertilizer has reached the level of the most profitable amount in the first rice crop, but there is still room for further increase of yield in the second rice crop under current technology and economic conditions.

2. Management of water resources is prerequisite for the improvement of rice production, especially through intensive management. When compared with other regions, the percentage of irrigated paddy in Taichung is the highest (91%) among all regions in Taiwan. Though the yield of the first crop is higher than that of the second crop, economic constraints limit both intensification and expansion of the first crop in Taichung. The planted area in first crop limited by water shortage in central and southern Taiwan is smaller than that for the second crop.

3. Rice yield in Taiwan has almost reached the optimum level both from the physical and the socioeconomic point of view. As a result of agricultural and economic development in Taiwan, rice production as well as agricultural production is affected not only by agricultural operations, but also by the continuous prosperity of the non—farm sectors. Net return from rice production and alternative earnings are two significant factors. The former is related positively to yield increase and the latter is related negatively to the level of input used. The farmers in Taiwan seem to operate their farms in seeking maximization of whole family income.

Rice production in Taiwan is in the second stage of agricultural development. The first stage can be viewed as the stage when increase of production was the major concern. In the second stage, farmers are responsive to price incentives of products and consequently to choice of enterprises. In other words, market mechanism and concept of opportunity costs are the key factors to be considered. Rice production in Taiwan, with the technology now available, is mainly constrained by economic factors.

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SUPHAN BURI, THAILAND, 1974 and 1975*

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ABSTRACT

Experiments were conducted on three sites in the 1974 wet season and on six sites in the 1975 wet and dry seasons. Inadequate fertilizer was the dominant constraint all three seasons, responsible for a gap of about 0.5 t/ha during the wet and 1.5 t/ha during the dry season. Insects and weeds reduced yields between 0.1 and 0.3 t/ha. Combinations of inputs higher than the farmers were using profitably increased yields by 0.3 to 1.0 t/ha, and farmers' net returns were increased by ฿500 to ฿800/ha for added costs of ฿700 to ฿2,000/ha. Farmers in the area near the experiments who reported that the prevailing depth of water in their fields exceeded 10 cm applied less fertilizer and insect control inputs than those with shallower water in the wet season. Tenure, credit and membership in farmers' associations were independent of input use.

RICE PRODUCTION AND DEVELOPMENT IN THAILAND

Rice is the most important commodity in the Thai economy. About 31% of the gross domestic product originates from the agricultural sector, and rice provides 32% of that. Rice farming occupies 65% of the total cultivated land. About 79% of the population is engaged in farming, and 84% of those farming are rice growers. Almost all rice produced is domestically consumed, with 10% exported in recent years.

Thai rice production increased by about 2.1%/year during 1960—1974. That increase was largely due to the expansion of the cultivated area

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and to an increase in the labor force. For the period 1960—64, average yields of rice were about 1.7 t/ha, which increased to 1.8 t/ha for 1970—74. If rice yields cannot be further increased, Thailand faces a shortage of rice for export and eventually for domestic consumption.

Rice is grown in all regions of Thailand (Table 1). However, the most important region for producing rice commercially is the Central Plain. That region occupies about 30% of the total rice area of Thailand and produces about 33% of the total output. In the Central Plain, two crops of rice a year are grown where water is available.

Table 1. Area, production and yield of rice by regions, Thailand, 1969—70 to 1974—75.

Region	1969—70	1970—71	1971—72	1972—73	1973—74	1974—75
			Area ('000 ha)			
Northern	1604	1596	1472	1515	1839	1662
North—eastern	3238	3273	3435	1958	3551	3309
Central	2145	2086	2107	2298	2479	2396
Southern	595	537	511	617	493	613
			Production ('000 t)			
Northern	3840	4070	3557	2710	3984	3872
North—eastern	4580	4920	5434	4198	4638	3795
Central	4010	3720	3895	4483	5451	4829
Southern	980	860	858	1022	825	890
			Yield (t/ha)			
Northern	2.4	2.6	2.4	1.8	2.2	2.4
North—eastern	1.4	1.5	1.6	2.1	1.3	1.1
Central	1.9	1.8	1.8	2.0	2.2	2.0
Southern	1.6	1.6	1.7	1.7	1.7	1.5

Source: Division of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Wet season rice depends largely on rainfall, and is planted from May through August and harvested in November through February. Local improved varieties are mostly grown in that season because they are suited to the rather deep water level. In wet season 1972—73, about 5% of the nations' total rice area was planted to modern varieties. However, in places such as the Chanasutr Project of Sing Buri, where land consolidation has been completed and the irrigation system is good, modern varieties are more widely grown.

Dry season rice is planted from December through May, and harvested from April through August. The beginning and end of the dry season varies depending on the harvesting of the wet season rice and availability of irrigation water in each irrigation zone. Modern varieties are mostly grown in the dry season in irrigated areas.

The increases in rice production arises not only from land expansion and adoption of modern varieties but also from increasing use of modern inputs such as fertilizer, insecticides and herbicides. Use of fertilizer increased almost 15%/year since 1962 (Table 2). During the early 1970's, about 60% of total fertilizer demanded was for rice production (Division of Agricultural Economics, 1975). In 1970, about 1 kg N/ha was applied for local improved varieties, and about 3 kg/ha for modern varieties. However, on the average, farmers in our study area used about 6 kg N/ha for local improved varieties, and about 15 kg N/ha for modern varieties in the wet season (Chungtes and Burton, 1972).

Table 2. Fertilizer and irrigation in Thailand's agricultural sector, 1962—1971.

	Fertilizer nutrients (tons)			Irrigated area ('000 ha)			
	N	P	K	State projects	Tank projects	Pumps	Total
1962	13,126	6,795	1,955	1477	10	68	1555
1962—71	31,232	22,782	12,212	na	na	na	na
1972	57,242	41,053	35,657	21.97	0.83	2.15	24.96
1972—74	41,242	37,038	34,121	na	na	na	na

na = not available.
Source: Division of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Farm machinery, especially farm tractors, have been rapidly adopted by Thai farmers. Farm tractors were introduced in 1951 and by 1967 there were about 17,500 four—wheel farm tractors, and about 2,000 two-wheel farm tractors in Thailand. About 52% of large—size tractors were used in upland crop farming, and 48% in land preparation for broadcast rice farming (Royal Thai Government 1969). The large—size tractors were imported, expensive and mostly owned by local merchants who rendered custom services to farmers. Because of the unsuitability of large-size tractors in the lowland rice area, especially for transplanted rice, the power tiller was developed locally and has been used in areas growing transplanted rice since 1955. At present, local, privately-owned assembling plants produced 3-25 hp tillers at a much lower price than imported tillers. The local power tiller has been popularly adopted by farmers growing modern varieties in the dry season. There are about

56,000 power tillers used in rice farming, of which 802 were assembled in Thailand.

In addition to the input factors outlined above, irrigation is critical for rice production. The irrigated area in Thailand, however, is small compared to the total cultivated area. During 1962—72, irrigation expanded by nearly 60% (Table 2) to cover about 161 of the total cultivated area. This irrigated area is mostly in the Central Plain. However, the Irrigation Department's policy is to increase the irrigated area by 64,000 ha/yr.

The Thai government has recognized the importance of rice as a source of employment and foreign exchange earnings for more than 100 years. The policies concerning rice in the Fourth Development Plan (1977—1981) are summarized as

1. Increase rice yield on the land best suited for rice.

2. Implement land reform and land consolidation urgently.

3. Expand the sale of good quality seed through the Farmers' Market Organization.

4. Provide more supervised production credit through the Bank for Agriculture and Cooperatives.

5. Continue the rice premium (rice export tax).

6. Maintain a price support at a limited scale to increase paddy prices at a somewhat faster rate than the general price level.

7. Encourage more farmers' associations.

8. Establish a rice buffer stock and marketing board.

POTENTIAL RICE TECHNOLOGY

In Thailand, rice research efforts intensified after the release of the modern varieties RD 1, RD 2, and RD 3 in 1969. Before that the maximum yields obtained from a simple demonstration program with available varieties in three regions were 3 to 5 t/ha, about 60% above farmers' yield levels (Lussanandana et al., 1967).

After the release of modern varieties, a program of Field Tests on Rice Yield Improvement was conducted throughout Thailand. Yield trials of modern varieties and promising lines resulted in maximum yields of 4 to 5 t/ha in most regions except the Northeast where soil fertility is extremely poor and rainfall distribution is uneven (Tongsang, 1970). Interstation yield trials conducted by experimental stations throughout the country between 1971 and 1974 resulted in average maximum yields of 3.7 t/ha in the wet season and 4.4 t/ha in the dry season (Table 3).

Suphan Buri Station ranked first with a maximum yield of 5.3 t/ha (Rice Division, 1974). With presently recommended varieties, experiments on the effect of nitrogen fertilization gave maximum yields over 5 t/ha with RD7 at Suphan Buri in the wet season (Table 4).

This shows that much progress has been made in developing new rice technology, and that potential yields on experiment stations are at least 5 t/ha. But actual yields obtained by farmers, average less than 2 t/ha nationally. That indicates a yield gap of about 3 t/ha, brought about by various physical, economical, and social factors, or combinations of the three. The constraints, if identified, should explain the yield gap, tell us what the farmers' needs are, and ultimately lead to an increase in yields.

Table 3. Yields of experimental rice lines in the interstation, photoperiod nonsensitive yield trials. Thailand, 1971—74.

Region	Stations (no.)	Yield (t/ha)				
		1971	1972	1973	1974	Average
		Dry season				
Central	8	4.9	4.0	4.3	4.7	4.6
North	3	3.8	4.8	4.3	4.1	4.3
Northeast	6	5.0	4.3	5.0	5.1	4.9
South	3	3.8	3.6	4.7	2.8	3.7
All	20	4.4	4.4	4.6	4.2	4.4
		Wet season				
Central	8	4.5	3.9	3.9	3.5	4.0
North	3	4.1	2.9	2.8	3.9	3.2
Northeast	6	4.0	3.6	4.1	4.1	4.0
South	3	3.9	3.9	2.8	2.4	3.3
All	20	4.1	3.6	3.4	3.5	3.7

Source: Rice Division, Ministry of Agriculture and Cooperatives.

OBJECTIVES AND METHODOLOGY OF THE STUDY

To determine why the yield gap exists, we carried out a research project to

1. Identify production techniques that give higher yields than selected representative farmers can get in their physical environments.

Table 4. Effect of nitrogen rates on the grain yields of recommended varieties and promising lines. Suphan Buri Experiment Station, 1974—75.

	Grain yield (t/ha) at nitrogen, rates (kg/ha)[a]							
	Wet season, 1974				Wet season, 1975			
Variety	0	37.5	75.0	112.5	0	37.5	75.0	112.5
RD 1	2.7	3.5	4.5	4.1	2.4	3.3	4.4	4.9
RD 4	3.4	3.8	4.2	3.9	2.1	3.4	3.9	4.I
RD 5	3.7	4.1	4.7	3.8	2.6	3.6	4.9	5.5
RD 7	3.2	4.1	4.3	5.1	2.7	3.8	4.6	5.4
RD 9	3.2	3.8	4.0	4.4	2.8	3.7	4.2	4.9
WP 153	2.8	3.6	4.4	4.8	2.2	3.3	4.2	4.1
WP 252—1	2.9	3.5	4.3	4.2	2.2	3.1	4.0	4.4
PMT 6624—257—1	3.7	4.5	4.9	4.9	2.7	3.0	3.6	4.6
Average	3.2	3.5	4.5	4.4	2.4	3.4	4.2	4.7

[a]In addition, 75 kg/ha of P_2O_5 and 37.5 kg/ha of K_2O were applied.
Source: Rice Division, Ministry of Agriculture and Cooperatives.

2. Determine the relative contribution of several technical factors (inputs or cultural practices) to the yield gap between actual and potential yield,

3. Determine the extent to which use of technical factors can be profitably increased.

4. Determine what social and economic factors prevent farmers from using technology that gives higher yields.

Both experimental and survey techniques were used. For 1 and 2 above agronomic experiments were conducted on farmers' fields. In the same villages a larger sample of farms were surveyed to obtain the data required for 3 and 4.

The study area

The study area was at Suphan Buri Province, about 170 kms northwest of Bangkok (Figure 1). Suphan Buri is one of the leading rice producing provinces in the country, and was chosen because

1. A large proportion of the rural populaton in the province is dependent on rice.

2. The area has relatively good water control.

3. It is a double-cropping rice area (wet and dry seasons) where many farmers were growing modern varieties.

4. The researchers were familier with the area.

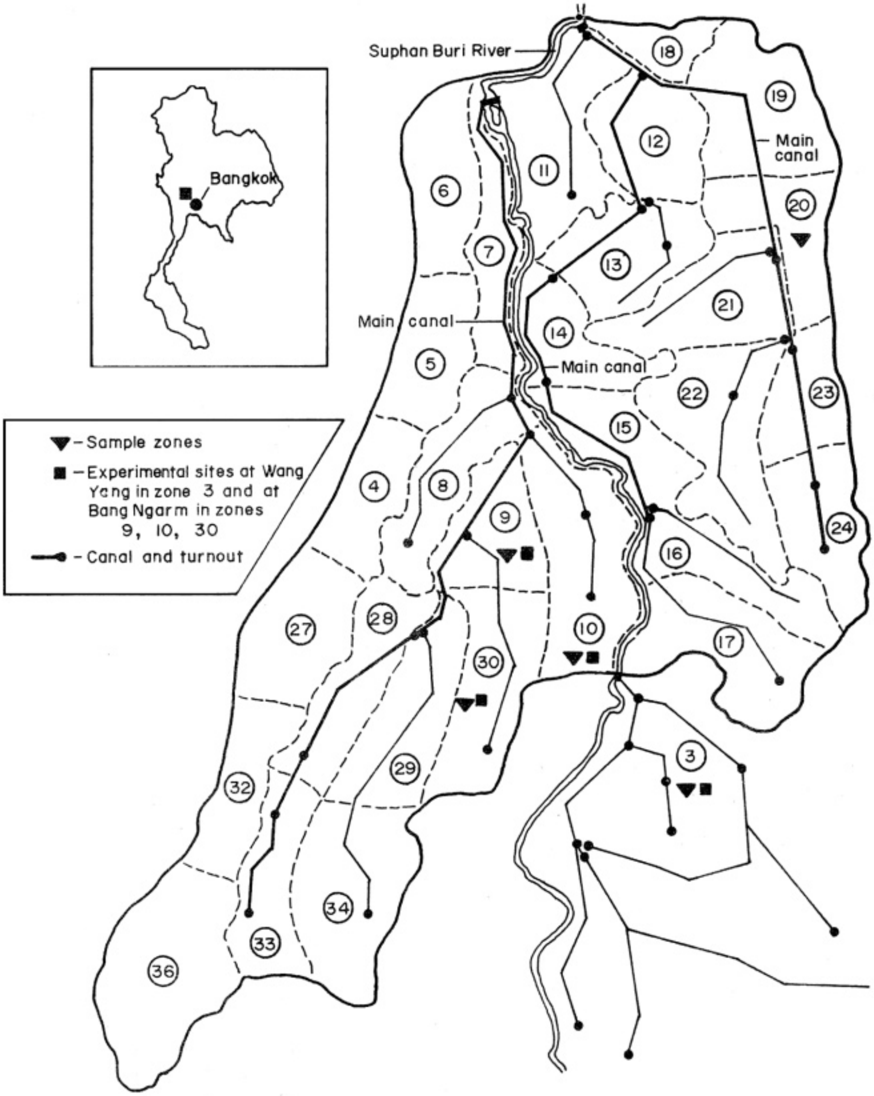

Fig. 1. Zone map of Samchook Irrigation Project and Zone 3 of Pho Phya Irrigation Project, Thailand, showing sample zones and experimental sites.

In Suphan Buri, there are eight amphoe or districts, 88 *tambon* or communes and 620 villages. The arable land area is 262,633 ha. There are about 64,000 households, and the average area per farm is 4 ha. Suphan Buri had an average annual temperature of 28°C for the period 1970 to 1975. The highest average monthly temperatures occurred in April (30.6°C), and the lowest in December (24.7°C). The average annual rainfall for Suphan Buri Province measured at Suphan Buri Synoptic Station was 1,326 mm. for the period 1970—1975. The highest average monthly rainfall was in September (304 mm), and the lowest in February (0.6 mm).

The study area for 1974 wet season was zone 3 in the Pho Phraya Irrigation Project of Suphan Buri. This area was chosen because it has relatively good water control, and is a double cropping area with a high proportion of modern varieties. In the 1975 dry season, an additional study area with similar characteristics was selected from the Samchook Irrigation Project of Suphan Buri. The two projects cover about 126,880 ha of irrigable land and are within Amphoe Sri Prachan and Amphoe Muang. Sample farms were chosen from the two districts (Figure 1). For convenience, the study area is referred to both as Suphan Buri and Sri Prachan.

Almost all of the farmers in the area use the transplanting method of rice cultivation. Most sample farms used tractors for their land preparation and over half used mechanized threshing. In the wet season of 1974, 25% of the sample farmers grew modern rices like RD 1, RD 5, C4—63 and WP 153 (IR 661 x khao Dok Mali 105), while the rest grew local or traditional non—floating varieties. In the dry season of 1975, all sample farmers grew modern varieties including RD 5, RD 7, C4—63, WP 153, WP 16 (IR 661 x RD 1 No. 16). WP 18 (IR 661 x RD 1 No. 18), and WP 20 (IR 661 x RD 1 No. 20). Planting of the wet season crop started in July or August with harvest in November or December; the dry season planting was in March or April and harvest in June or July.

The average rice area planted per farm in this study area was 4 ha in 1974 wet season, and 3 ha in 1975 dry season. The average farm family size was six. Of the six, 63% was between 14—60 years of age, 32% were less than 13 years of age, and 5% were 60 year of age or more. The average farm family labor available was three persons.

The majority of farmers in the study area had a primary education. Seventy—two percent had finished four years of primary education, 5% finished 3 years, another 5% completed more than 4 years of education, and 12% never went to school. Fifty percent of the sample farmers were full owners, 20% full tenants, and 30% part—owners.

Representativeness of study area. Water control was accepted as the most important yield constraint. Experimental work could be done well only in the good or rather good water control areas, thus Samchook Irrigation Project, and a part of Pho Phraya Irrigation Project were chosen. This study area does not represent all rice producing areas of the country because of the difference of water control condition and comparisons cannot be made. However, because the Central Plain of Thailand is the rice bowl, within which Suphan Buri has a fairly large area irrigated, we can say that the study area represents the irrigated rice growing area of the Central Plain.

Section of experiment sites. Experiments were conducted in irrigated, double—cropping areas of Sri Prachan, Suphan Buri, during the 1974 wet season, and the 1975 dry and wet seasons. In the 1974 wet season, three sites were selected at Tambon Wang Yang, representing areas of low, medium and high farm yields. After the experiments were underway, water control in the sites was observed to be poor, moderate and good (Table 5).

Table 5. Soil and farm characteristics of agronomic experimental sites, Sri Prachan, Suphan Buri, Thailand, 1974—75.

Site	Characteristics					
	Soil[a] series	Soil type	Soil fertility	Water control	Yield in previous 2 years[b]	Major problems encountered
Wang Yang						
1	Pimai	clay	moderate	moderate	2.4	*M. quadrifolia*
2 (U)[c]	Sara Buri	clay	low	poor	2.0	poor drainage
2 (L)	Sara Buri	clay	low	poor	3.0	poor drainage
3	Sara Buri	clay loam	high	good	3.0	*Cyperus sp.*
Bang Ngarm						
1	Nakorn Pathom	clay loam	low	good	na	*Cyperus sp.*
2	Pimai	clay	low	moderate	na	moderate water
3	Pimai	clay	low	poor	na	deep water

[a]Pimai constitutes 11.2% of the area of Sri Prachan; Sara Buri 51.4%, and Nakorn Pathom 21.8%.
[b]Based on interview with farmer prior to planting experiment, t/ha.
[c]This site was noticeably higher than the others, but located on the same farm as 2 (L).

The results of the 1974 wet season appeared as not truly representative of the particular farm. The average farmers' yields were obtained from the whole farm whereas experimental results were from a single paddy. Evidently, it was farm characteristics such as chemical and physical properties of soil, water control, and cultural practices by farmers that directly affected the yield reported by farmers.

In the 1975 dry season, three more sites were selected at Tambon Bang Ngarm. They were located on clay and clay loam soils in two prominent soil series of Sri Prachan with different water control presumed to be representative of main soil types and water management of the area. In each location, experiments were repeated for the subsequent seasons, 1975 dry and wet.

During the experiment, the farmers' levels of inputs were directly observed from the practices used by farmers on the comparable paddy. Details are in Table 6.

Table 6. Famers' levels of inputs used in management package experiments at two locations in farmers' fields. Suphan Buri, Thailand, 1974—75.

Site	Fertilizer (kg/ha)[a]		Insect control[b]		Weed control[b]	
	N	P	Foliar[c]	Granular[d]	Hand weeding	Chemical[e]
			1974 wet season			
Wang Yang						
1	8	10	0	0	0	1
2	8	10	0	0	0	0
3	10	12.5	1	1	0	2
			1975 wet season			
Wang Yang						
1	12	15	0	0	0	0
2	20	25	0	0	0	0
3	40	50	1	0	n	0
Bang Ngarm						
1	20	25	1	0	1	0
2	25	31.25	0	1	1	0
3	15	18.75	0	0	0	0
			1975 dry season			
Wang Yang						
1	30	37.5	1	0	0	1
2	28	35	1	0	0	1
3	28	35	2	1	0	1
Bang Ngarm						
1	12	15	0	0	0	0
2	25	31.25	0	0	0	0
3	10	12.5	0	0	0	0

[a] As ammonium phosphate (16—20—0) broadcast about 7—15 days after transplanting.
[b] Number of applications,
[c] Sevin 85 (W.P.) or F—3 mixed with Malathion or Endrin spray at presence of insects.
[d] g - BHC mixed with fertilizer and broadcast.
[e] 2,4—D (Sodium salt) mixed with fertilizer and broadcast.

Before the start of the experiment, soil analysis was done for each site (Table 7). The main texture classes were clays and clay loams. Soils were low in nitrogen and phosphorus but adequate in potassium. All soils were acidic, and relatively high in organic matter.

Table 7. Physical representativeness of the agronomic experimental sites. Sri Prachan, Suphan Buri, Thailand, 1974—75.

	Number of sites					Av. for all sites	Remarks
	Very high	High	Average	Low	Very low		
Nitrogen (%)	-[a]	-	-	-	-	0.122	
P_2O_5 (ppm)	0	0	0	2	5	6.78	Bray II
K_2O (ppm)	0	7	0	0	0	187.14	
pH	0	0	0	0		4.9	1:1 soil/water
C.E.C. (me/100 g)	0	2	4	1	0	18.4	
Organic matter (%)	1	5	1	0		2.5	

[a]Nitrogen levels were not classified.

During the crop seasons, the meteorological data observed at Suphan Buri Experiment Station and Observatory, were recorded as representative of experiment sites in term of weather. Weather during the seasons when research was conducted was not abnormal.

Experimental factors. Fertilizer, weed control and insect control were hypothesized as the main physical yield constraining factors. Moreover, results from an economic study on cost of rice production showed that of the different costs of production, the cost of management and protection, use of fertilizer, had the highest cost, followed by weed control and insect control, particularly for modern varieties in both seasons (Chungtes and Burton, 1972). Practices like land preparation, irrigation, and labor, which are also important for yields but difficult to handle, were excluded from the experiment. Variety was discarded as a factor because of incomparable degrees of response to fertilizer by modern and local varieties. Inclusion of variety as a factor in the experiment would have increased the number of plots and made the experiment difficult to manage under variable farm conditions.

Design. The experiments incorporated a multi—factor, two—level complete factorial component with farmers' level and high level, and a multi—level management package in a split plot design, and randomized complete block design, respectively in the same paddy, A total of 12 treatments with two levels of fertilizer, weed control, and insect control were tested. Details of the farmers' level treatment are in Table 6. The management package treatments are in Table 8. The high level in the factorial was set at the M5 level of each factor.

Table 8. Levels of inputs used in management package experiments in farmers' fields. Suphan Buri, Thailand, 1974 and 1975.

Management package	Fertilizer (kg/ha)[a]			Insect control[b] (no.of applications)				Weed control[c] (no. of treatments)	
				Seedbed		Field			
	N	P	K	F	G	F	G	HW	CW
				1974 wet season					
M_2	18.75	12.50	0	2	0	1	1	1	0
M_3	37.50	25.00	0	3	0	2	2	0	1
M_4	56.25	31.25	0	3	1	2	3	1	1
M_5	75.00	50.00	37.5	3	1	2	5	1	1
				1975 dry and wet seasons					
M_2	18.75	12.50	0	1	0	1	0	1	0
M_3	37.50	25.00	0	2	0	1	1	0	1
M_4	56.25	31.25	0	2	1	2	2	1	1
M_5	75.00	50.00	37.5	2	1	2	2	1	1

[a]P and some N was given as ammonium phosphate (16—20—0). N was split in two equal doses -- basal (broadcast and incorporated), and top dressing at PI as ammonium sulphate or urea, K_2O from potassium chloride.
[b]F = foliar of Sevin 85 (W.P.) + Malathion (E.C.); G = g - BHC (granular) or Furadan (granular).
[c]HW = hand weeding; CW = 2,4—D (G) @ 0.8 kg/ha a.i. 4 days after transplanting for M_3, M_4; CW = Saturn/2,4—D (G) for M_5, @ 1.0/0.5 kg/ha a.i. 4 days after transplanting.

Layout. The 12 treatments to be tested were divided into two groups. One consisted of four treatments receiving the farmers' level of insect control (I_1), and another group consisted of the rest of the eight treatments (Figure 2). Each group of treatments was assigned to plots located at different ends of the paddy -- eight plots on one side of the paddy, and 16 plots on the other side. The eight plots in the first side had four treatments of I_1, replicated twice. On the other side, the eight treatments were divided Into those receiving high level of insect control (I_2), and those of the four management packages. Randomization was done independently for each site while keeping the same groupings. Plot size was 3 x 6 sq m giving a net harvest area of 8 sq m after excluding border rows.

The inputs other than the three factors under study such as seedlings, time and method of planting and irrigation, followed as closely as possible the practices of the farmers. Extra plots of special high—level practices (M_5–H), and the farmer level of input management package (M_1) were added during the second seasons' research.

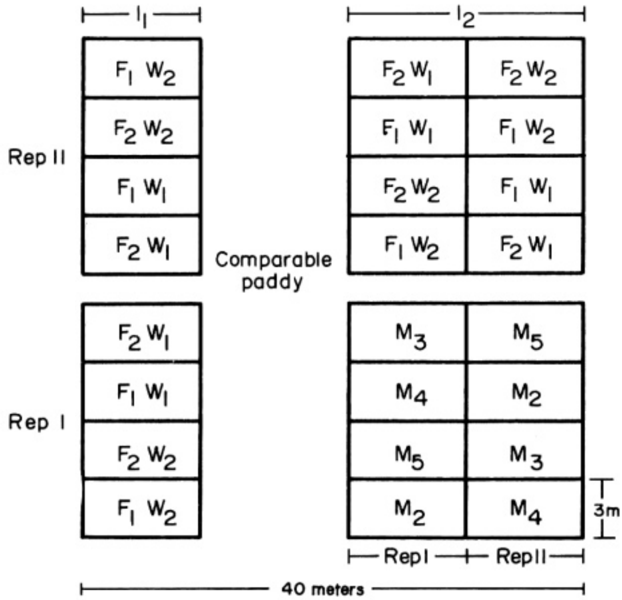

Fig. 2. Layout of agronomic experiment in farmers' fields, Suphan Buri, Thailand, 1974 wet season, 1975 dry and wet seasons.

Yield gap and its components

The data in Table 9 show an average yield gap of 1.3 t/ha in the 1974 wet season, 0.7 t/ha in the 1975 wet season and 2.2 t/ha in the dry season.

The data show that the contribution of fertilizer was consistent and significant for most farms. The effect averaged about 0.5 t/ha during the wet seasons, but it was distinctly larger and always significant during the dry season. That was partially because of the use of the more fertilizer—responsive varieties during the dry season.

The contribution of insect control to the yield gap during the 1974 wet season was larger than in the 1975 wet season. Insect infestation was lower during the 1975 dry season and two of the four farms in Wang Yang showed a negative response to insect control. In Bang Ngarm in the dry season, the contribution of insect control was substantially larger than in Wang Yang.

The increase in grain yield due to weed control was significant only on one farm during the 1974 wet season, and on two farms during the 1975 dry season, although there was an increase in grain yield due to weed control on most farms. The weed control effect was smallest of the three effects during the wet seasons but exceeded the effect of insect control during the dry season. Weed incidence was higher during the dry season because of a water shortage.

Table 9. Contribution of three inputs toward increasing rice yields in experiments on farmers' fields in Suphan Buri, Thailand, 1974—75.

Tambon	Farm	Variety	Grain yield (t/ha)			Increase (t/ha) due to			
			Farmers	High	Diff— erence	Ferti— lizer	Weed control	Insect control	Resi— dual
				1974 wet season					
Wang Yang	1	RD 5	3.7	5.5	1.8	0.7**	0.3	0.8	0.1
Wang Yang	2	RD 5	3.5	4.2	0.7	0.5*	0.1	0.0	0.1
Wang Yang	3	RD 5	3.9	5.5	1.6	1.0**	0.5*	0.1	0.0
	Av.		3.7	5.0	1.3	0.7	0.3	0.3	0.1
				1975 wet season					
Wang Yang	2[a]	RD 5	4.1	3.8	—0.3	—0.3	—0.1	0.1	0.0
Wang Yang	3	RD 7	4.1	4.9	0.8	0.9*	0.5	0.1	—0.7
Bang Ngarm	1	RD 7	3.6	5.2	1.6	0.5	0.3	0.7	-0.1
Bang Ngarm	2	RD 5	3.7	4.5	0.8	1.2*	—0.2	-0.1	—0.1
Bang Ngarm	3	RD5	4.0	4.7	0.7	0.4	—0.1	0.4	0.0
	Av.		3.9	4.6	0.7	0.5	0.1	0.2	—0.1
				1975 dry season					
Wang Yang	1	WP 153	6.0	8.0	2.0	1.9**	0.4	—0.2	0.1
Wang Yang	2 (U)	WP 153	5.0	6.6	1.6	1.0**	0.2	0.5	—0.1
Wang Yang	2 (L)	WP 153	3.8	6.0	2.2	2.1**	—0.1	0.2	—0.2
Wang Yang	3	WP 153	5.0	5.5	0.5	0.6*	0.4	-0.5	0.0
Bang Ngarm	1	C4—63	3.2	6.7	3.5	1.7**	0.7**	1.0*	0.1
Bang Ngarm	2	C4—163	3.9	6.5	2.6	1.0**	0.7**	0.8*	0.1
Bang Ngarm	3	C4—63	2.5	4.9	2.4	1.8**	0.6	0.2	—0.2
	Av.		4.1	6.3	2.2	1.5	0.4	0.3	0.0

[a]Rats damaged one site in Wang Yang.
**significant at 0.01 LSD. *significant at 0.05 LSD.

During the 1975 dry season, the yield obtained with farmers' practices was higher in Wang Yang than in Bang Ngarm. That was because the variety WP 153 used by farmers at Wang Yang had higher yield potential than C4—63, which was grown by the Bang Ngarm farmers. Furthermore, the soil fertility is higher in Wang Yang than Bang Ngarm. The high level of inputs was more effective in Bang Ngarm, where with the farmers' level of inputs, the average grain yield was only 3.2 t/ha. It was possible to increase grain yield more at Bang Ngarm than at Wang Yang.

At Wang Yang, the differences in grain yield between farmers' input level, and the high level were similar during the 1974 wet season and the 1975 dry season.

During the 1975 dry season, there was more stem borer damage at Bang Ngarm than at Wang Yang. Therefore, the high level of insect control gave a significant increase in grain yield due to insect control on two of the three farms while no significant effect was observed at Wang Yang. Evidently, WP—153, grown by the Wang Yang farmers has a high level of resistance to insects.

Management package

During the wet seasons, the input packages higher than the farmers' levels gave increasing yields with maximums obtained at M_4 or M_5 (Table 10). In the dry season of 1975, M_5 gave the maximum yield on all but one farm.

Table 10. Yield of rice (t/ha) at five levels of input management packages compared to farmers (M_1) levels. Suphan Buri, Thailand, 1974—75.

Tambon	Farm	Variety	Grain yield (t/ha)				
			M_1	M_2	M_3	M_4	M_5
			1974 wet season				
Wang Yang	1	RD 5	3.7 c[a]	4.4 bc	5.0 ab	5.5 a	5.2 a
Wang Yang	2	RD 5	3.7 b	3.9 ab	3.9 ab	4.5 a	4.6 a
Wang Yang	3	Fa5	3.9 c	4.1 c	4.9 b	5.4 a	5.4 a
	Av.		3.7	4.2	4.6	5.1	5.0
			1975 wet season				
Wang Yang	2	RD 5	4.1 a	3.7 a	3.7 a	3.8 a	3.9 a
Wang Yang	3	RD 7	4.1 a	3.8 a	4.3 a	4.4 a	4.6 a
Bang Ngarm	1	RD 7	3.7 a	3.0 b	4.1 a	4.3 a	4.3 a
Bang Ngarm	2	RD 5	4.0 ab	3.7 b	4.0 ab	4.2 ab	4.5 a
Bang Ngarm	3	RD 5	3.6 b	4.1 ab	4.5 ab	4.6 a	4.4 ab
	Av.		3.9	3.7	4.1	4.3	4.3
			1975 dry season				
Wang Yang	1	WP 153	6.0 b	5.7 b	6.3 b	7.3 a	7.5 a
Wang Yang	2, U	WP 153	5.0 c	5.7 bc	6.3 ab	5.4 bc	6.9 2
Wang Yang	2, L	WP 153	3.8 c	3.3 c	4.9 b	5.8 a	6.1 a
Wang Yang	3	WP 153	5.0 b	5.1 b	4.9 b	6.0 a	6.5 a
Bang Ngarm	1	C4—63	3.2 c	3.8 c	5.5 b	6.0 ab	6.3 a
Bang Ngarm	2	C4—63	3.9 d	3.3 c	4.4 c	5.1 b	6.1 a
Bang Ngarm	3	C4—63	2.5 c	2.8 c	4.1 b	5.2 a	4.8 ab
	Av.		4.1	4.2	4.1	5.6	6.3

[a]Means followed by a common letter are not significantly different from others in the same row.

During the 1975 dry season, farmers' practices generally gave higher yields than during the wet seasons, with grain yield differences between farmers' levels and high packages significant on all farms.

There was no response to high-level management over the farmers inputs at either site during the 1975 wet season. The results obtained, however, were not consistent because of rat damage. One site in Wang Yang was heavily damaged by rats at the tillering and booting stage of the crop during the 1975 wet season. Moreover, it was observed that all farmers used a high level of inputs, particularly fertilizer.

Profitability of input packages

The economic performance of the input management packages was evaluated by comparing costs and returns of each package to the combinations used by farmers (M_1). In the analysis the costs included only those inputs used in the agronomic experiment -- fertilizer, insect control and weed control, including the cost of hand weeding. The average farmers input costs ranged from $459 to $1,250/ha, while costs of levels of inputs used in the experiment (M_2 to M_5) ranged from ฿916 to ฿7,017/ha (Table 11).

The maximum net return was obtained at M_3 level during the 1974 wet and 1975 dry seasons, but during the 1975 wet season, net return tended to decrease progressively for the high level packages (Table 12). That was because farmers used higher levels of inputs, particularly fertilizer, from the 1974 dry season onwards (Table 6), and because the response of the crop to higher level inputs during wet 1975 was not significant (Table 10). Note also that the progressive farmers in those areas rapidly adopted new technology.

IDENTIFYING SOCIOECONOMIC CONSTRAINTS

To understand the social, economic and institutional environment in which the Suphan Buri farmers operate a farm survey was undertaken in the same areas where the experiments were conducted. The data from that survey were used to compare the farms with experiments to a larger sample of farms, to determine what factors farmers think restrict them from obtaining higher yields, and to determine what reasons farmers give for not adopting components of modern rice technology.

Survey methodology

The irrigation farm ditches were used as the basis for sampling in the survey in order to insure a full range of water control conditions and because it was easier to contact and make friends with farmers through irrigation zonemen than through other means. Tabular analysis and chi-square tests of independencewere the principle methods of data analysis.

Sampling. A total of 165 farm operators were selected using three-stage stratified sampling. Zones were taken as the first stage for sampling, irrigation turn-outs with farm ditch as the second stage (some turn-outs do not have farm ditches), and farm operators as the third stage.

Table 11. Average cost of farmers' level of inputs (M_1) and alternative management packages in agronomic experiments in farmers fields. Suphan Buri, Thailand, 1974-75.

Package	Farms (no.)	Cost of input (B/ha) Ferti-lizer	Weed control	Insect control	Total
		1914 wet season			
M_1	3	298	75	86	459
M_2	3	578	330	290	1198
M_3	3	1156	165	517	1898
M_4	3	1734	495	2295	4524
M_5	3	2562	1285	2322	6165
		1975 wet season			
M_1	5	333	147	24	504
M_2	5	438	440	38	916
M_3	5	875	165	1539	2579
M_4	5	1313	605	3012	4990
M_5	5	2025	1380	3072	6447
		1975 dry season			
M_1	6	832	38	50	920
M_2	6	562	460	38	1060
M_3	6	1125	165	1539	2828
M_4	6	1688	625	3012	5385
M_5	6	2525	1420	3072	7017

There are 28 zones in the Samchook Irrigation Project (Figure 2). Zones were classified into two groups. The first group consisted of 8 zones where more than 10% of the area was planted to crops other than rice, mainly sugarcane. The second group of 20 zones were mainly rice areas. One zone from the first group was chosen at random, and two zones were chosen at random from the second group. Another two zones, were included because the experimental sites were located there. One of the latter is in the Pho Phraya Irrigation Project adjacent to Samchook Irrigation Project.

To select sample irrigation turn-outs with farm ditches, all turn-outs with ditches in a zone were numbered. Then 4 or 5 ditches were drawn at random from each zone, keeping track of the order in which they were drawn. Then the farmers in the first sample ditch were listed. At least 60 farm operators in each zone were listed. If less than 60 occurred in

Table 12. Economic comparison of farmers' level to four alternative levels of input management packages in experiments on farmers' fields. Suphan Buri, Thailand, 1975—76.

Management package	Cost (Ƀ/ha)	Cost over (Ƀ/ha)	Gross return (Ƀ/ha)	Gross return over M_1 (Ƀ/ha)	Net return (Ƀ/ha)
			1974 wet season, three farms		
M_1	459	-	9300	-	8841
M_2	1198	739	10375	1075	9177
M_3	1898	1439	11575	2275	9677
M_4	4524	4065	12825	3525	8301
M_5	6165	5706	12725	3425	6560
			1975 wet season, five farms		
M_1	881	-	9562	-	8681
M_2	916	35	9175	-387	8259
M_3	2579	1698	10237	675	7658
M_4	4990	4109	10675	1113	5685
M_5	6447	5566	11275	1713	4828
			1975 dry season, six farms		
M_1	920	-	8127	-	7207
M_2	1060	140	8631	504	7571
M_3	2828	1908	10521	2394	7693
M_4	5385	4465	11424	3297	6039
M_5	7017	6097	12768	4641	5751

the first sample ditch, the farmers in the second sample ditch were listed. This process was repeated until 60 farm operators were obtain in each zone. Fourteen farm turn—outs with ditches were thus chosen by this process. Systematic random sampling was used to select 50% of the listed farm operators along each ditch as the sample. That avoided undue clustering.

Questionnaire. The first part of the questionnaire covered costs of production and yield, with data carefully obtained on every parcel of each farm operator (Chungtes and Welsch, 1975). One intensive—data parcel was chosen at random from the parcels on each farm, and specific information, such as reasons for not adopting some physical inputs and cultural practices, was obtained for that parcel.

The farmer interview was conducted individually at farmers' houses, or at schools or temples during May—June 1975 to obtain 1974 wet season information. Interviews at local stores which sold farm inputs were conducted to measure the availability of inputs, and to cross check the input prices given by farmers. Other necessary information was obtained from government reports, case studies and other documents.

Scoring and analysis. Farmers could not report the magnitude of yield constraints from water, insects, or pest problems. To score the factors according to importance, farmers were asked to identify as many as three yield constraints. A score of 3 points was assigned for the most important, 2 points for the second most important, and 1 point for the least important constraint. A zero-score was assigned to factors not reported. The scores were aggregated across farms, providing a ranking of yield constraints reported by farmers.

To test differences between input use and yield of the sample farmers, and of the experimental farmers, t-tests of unpaired observations and unequal variance were employed. The chi-square test and contingency coefficient were used to test for independence of non-continuous variables.

The same farmers were interviewed during October-November 1975 to obtain 1975 dry-season information. The main purpose of the second round was to compare the results from wet and dry seasons.

Input use by farmers

At Sri Prachan, most rice fields are transplanted, irrigated, and double cropped with adequate water throughout the year. The irrigation system consists of a main canal, laterals, and farm ditches with fields sloping from main canal to drainage ways. Therefore, the use of modern varieties and fertilizer depend to some extent on the topography of particular fields.

Varieties used. During the wet season, farmers choose varieties according to topography and water depth. On high land, short duration nonphotoperiod sensitive modern varieties are mostly grown while local, photoperiod sensitive varieties are grown in low-lying fields. Common modern varieties found in the area are C4-63, RD 1, RD 5 and WP 153, whereas Khaoluang, Gonkaew, Phrayachom are common photoperiod sensitive varieties grown in the area. The location also affects the use of inputs such as fertilizer and weeding because farmers apply fertilizer where modern varieties are grown because those areas are less risky.

During the dry season, nearly all the rice grown is the non-photoperiod sensitive type. Some farmers who have close contact with researchers are likely to have a better chance to obtain newly released or promising lines.

Fertilizers. The most common form of fertilizer used is ammonium phosphate (16-20-0). A few farmers apply ammonium sulphate. Fertilizer is broadcast 2 to 4 weeks after transplanting depending on water level and availability of the fertilizer. Although the recommendation is to apply fertilizer one day before transplanting, farmers complain of chemical toxicity to the skin while transplanting.

The average rates of fertilizer applied are low, in the range of 8—10 kg of nitrogen per ha, and 10-12 kg of phosphorus per ha. Even though the application of nutrients is low high yields can be obtained with good water control and other good cultural practices. That may be because the soils of Suphan Buri are rather newly weathered. Application of potassium has not been observed, and it is not recommended because sufficient potassium occurs in the soils of Central Plain.

Plant pest. Attacks of insects and diseases are seasonal and localized. Common insect pests are stem borer, green and brown planthoppers, mealy bug, and rice thrips. Rat damage is a major problem and is difficult to control. Before initiation of the project in the 1974 dry season, there was an attack of brown planthopper at Tambon Wang Yang and fields planted to RD 1 with high rates of fertilizer were heavily damaged.

Use of insecticides before insect attack is rarely observed, although insecticides are found in most farm houses. Common insecticides used are Endrin, Sevin, Malathion, Dieldrin, and g - BHC. Zinc phosphide obtained from the extension office or chemical shops is used as a bait for rats.

Weeds. Farmers realize that weeds are a constraint but do not regard them as a serious one. Weed infestation is heaviest during the wet season when *Marsilia quadrifolia, Sphenoclea zeylanica* and *Cyperus* spp. are common. Mostly *Cyperus* spp. are observed during the dry season.

Control of weeds, chemically or manually, is not extensively practiced. A number of farmers attempt to control weeds by mixing 2,4-D (sodium salt) with fertilizer and broadcasting that where weeds are present. Preemergence granular herbicide is still a new practice that has yet to be properly extended to the farmers. Hand weeding is done only if family labor is abundant. Labor is rarely hired due to the cost.

Comparison of experimental and interviewed farmers

The levels of inputs reportedly used by farmers where the experiments were conducted and by the survey farmers are shown in Table 13. There was no significant difference in either season between the level of fertilizer used by the two groups. The average cost of insect and weed control practices in experimental farms was slightly, but not significantly higher because the farmers' tried to follow the experimental treatments. Significant differences were observed in the average yields between the two groups of farmers. That might be because the two yields were obtained by different methods. Crop cutting was used to estimate yields of experimental farmers, and the farmer's estimate of production on the whole farm to estimate yields of interviewed farmers.

The different yield estimating methods might give different estimates even for identical yields, as was clearly shown in a comparison of the two methods. Interviews were used to estimate the average yield of a set of farms where 8 sq m crop cuts were also made. The comparison of the two techniques in Table 14 shows that the yield estimate obtained from crop cutting was

Table 13. Average ($\bar{x}$) and standard deviations (s.d.) of inputs used and yields of farmers with experiments and a random sample of farmers on the same irrigation ditches, Suphan Buri, Thailand, 1974—75.

Item	Wet season 1974				Dry season 1975			
	Random sample		Experiments		Random sample		Experiments	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.
Farmers (no.)	3	-	165	—	6	-	160	-
Nitrogen (kg/ha)	9	11	9	1	23	11	22	8
Phosphorus (kg/ha)	11	13	11	1	28	17	28	11
Fertilizer (฿/ha)	326	381	298	40	894	481	831	331
Insecticide (฿/ha)	27	72	86	136	43	68	52	102
Herbicide (฿/ha)	5	16	75	75	a	20	38	41
Weeding labor (฿/ha)	2	12	0	0	22	84	0	0
Yield (t/ha)	2.1	0.7	3.7*	0.2	3.0	1.3	4.2*	1.2

*Differed significantly from the random sample.

significantly higher than yield obtained from interview in five of the seven cases, and higher, but not significantly so, in the other two cases. The difference varied by season, and also by the time that the interview was made. The best time for interview is soon after the farmers had sold their products. The data in Table 14 suggest that crop cuts lead to yield estimates 10 to 20% higher than interviews. If the yields in Table 13 are adjusted by this amount, differences still persist, indicating that the experiments were conducted on farms having higher than average yields.

Observed yield constraints. During the agronomic experiments yield constraints on the specific farms with experiments were discovered. The more important of those were lack of fertilizer and weed control.

The use of fertilizer by farmers was not at optimum rate in either dry or wet season as shown in Table 9. This was traced to a number of factors including:

1. High water level in the field, which discouraged farmers from using fertilizer.

2. Use of local photoperiod sensitive varieties during the wet season which gave a low response to fertilizer.

3. High price of inputs and lack of cash and credit.

It was observed that weeds were not controlled adequately or were controlled late. That might be due to any of the following:

Table 14. Comparison between grain yield (t/ha) estimated by crop cutting and by interview, Suphan Buri, Thailand, 1974—75.

Tambon	Farms crop cut (no.)	Type of variety[a]	Yield (t/ha) Crop cutting	Yield (t/ha) Interview	Difference	% different of crop cut over interview[b]
			1974 wet season[c]			
Wang Yang	5	MV	3.8	3.0	0.8*	20 + 12
	6	LV	3.7	2.6	1.1**	28 ± 13
			1975 dry season[d]			
Wang Yang	14	MV	4.4	3.8	0.6**	13 ± 7
Bang Ngarm	13	MV	2.9	2.6	0.3**	7 ± 7
			1975 wet season[e]			
Wang Yang	7	MV	3.1	2.9	0.2^{ns}	6 ± 20
	9	LV	3.2	2.6	0.6**	19 ± 15
Bang Ngarm	9	LV	2.3	2.2	0.1^{ns}	4 ± 31

[a] MV = modern varieties, LV = local varieties.
[b] The average % difference ± the standard deviation.
[c] The interview was made several months after the selling of the products.
[d] The interview was made one month after the selling of the products.
[e] The interview was made immediately after the harvesting.

1. Limited time between harvest of the dry season crop and planting of the next crop forced the farmers to sacrifice thorough land preparation, and hurry the wet season planting.

2. Shortage of water in the dry season at an early stage of the crop.

3. Lack of knowledge of proper chemical weed control.

4. High cost of hand weeding.

There was not much insect problem in the areas under study. One season before initiation of the experiment, brown planthopper was wide spread. A mild attack of stem borer was observed at a few sites during the 1975 dry season. Most farmers, however, were not aware of effective protective measure for insects, although insecticides were found in many farms.

Perceived yield constraints. The farmers were asked to report their actual yields, and the yield they believed would have occurred if some limiting input or practices had been removed. The farmers were also asked to identify up to three yield constraints, and rank them according to importance.

The five most important factors for both seasons were the same: fertilizer, rats, insects, disease, weeds and water shortage (Table 15). Among secondary constraints, land preparation, excessive water, variety, birds and crabs, and soil problem were ranked the same in both seasons. Water problems, however, cannot be solved by individual farmers. Soil problems seem to be created by cultural practices. At the beginning of the dry season, the land was plowed and leveled, and top soil was moved from one place to another. Most other perceived constraints could be corrected by proper use of inputs, but farmers were using very low levels of such inputs.

Table 15. Yield constraints reported by survey farmers, Suphan Buri, Thailand, 1974 wet season and 1975 dry season.

Perceived constraint			
Rank	Wet season 1974	Rank	Dry season 1975
1	Fertilizer	1	Fertilizer
2	Rats	2	Rats
3	Insects and disease	3	Insects and disease
4	Weeds	4	Water shortage
5	Water shortage	5	Weed
6	Land preparation	6	Land preparation
7	Excessive water	7	Excessive water
8	Variety	8	Variety
9	Bird and crab	9	Bird and crab
10	Soil problem	10	Soil problem
11	Other, e.g. spacing	11	Other, e.g. old seedling

Levels of input use and rates of adoption

In the wet season, only 25% of the sample farmers grew modern rices, but in the dry season, 100% grew them. Fertilizer use was also different in the two seasons. The expenditure on fertilizer in the dry season (Ƀ894/ha) was nearly three times as high as in the wet season, and nearly all farmers applied some fertilizer in the dry season, but 40% did not use any fertilizer in the wet season (Table 16).

Insecticide costs were Ƀ27/ha in the wet season, and Ƀ43/ha in the dry season (Table 13). Nearly the same proportion of farmers applied insecticide in the wet (40%) and dry season (34%).

Table 16. Percentage of survey farmers using stated frequency of given practices. Suphan Buri, Thailand, 1974—75.

	Wet season 1974 frequency					Dry season 1975 frequency				
	0		12		34	0		12		34
Fertilizer	42	39	19	0	0	8	41	51	0	0
Plowing	6	82	11	1	0	2	84	14	0	0
Harrowing	89	7	3	1	0	87	9	3	1	0
Puddling	7	48	43	1	1	6	46	44	4	0

Land preparation was identified as a problem by farmers, but it was difficult to identify the reasons. Nearly all were able to plow their land in the wet and dry seasons, but only about 12% did any harrowing (Table 16). Most farmers appeared to substitute puddling for harrowing as nearly 50% did one puddling, and the others did two.

Cost of hired labor for hand weeding were different in the wet and dry seasons, averaging less than B2/ha in the wet season, but ฿22/ha in the dry season. The expenditure on herbicide was low in both seasons. In the wet season, 30% of farmers did not spend anything on weed control, whereas in the dry, 17% did not.

Reasons for not using inputs

Farmers were asked why they did not use inputs such as modern varieties, fertilizer, insecticide, herbicide, and land preparation (Tables 17 and 18).

Varieties. In the 1974 wet season, only 25% of the farmers grew modern varieties. The most important reason given by farmers for not growing modern varieties was the desire to avoid the risk of low yields brought about by low temperature, In the 1973 wet season, temperature went quite low at the time of flowering and grain filling stages, which resulted in low yields, especially on modern varieties. Physical problems such as too deep water were nearly as important for not growing modern varieties, In the dry season, all farmers who planted rice grew modern varieties on their entire area indicating that there is no bias against using modern varieties.

Fertilizers. In the 1974 wet season, only 10% of 165 sample farmers used a relatively high level of fertilizer, while 42% did not use any, and 48% used very little. For those farmers who used little or no fertilizer, the main reason given for doing so was economic. They thought the fertilizer was expensive and cited fluctuating paddy price.

Table 17. Percentage of survey farmers giving various reasons for non—adoptionof six modern practices, Suphan Buri, Thailand, 1974 wet season.

Reason	% giving identified reason for the practice of					
	Modern varieties	Fertil— izer	High rate Pertil— izer	Insect— icide	Herb— icide	Good land preparation
Economic	12	36	56	30	11	31
Risk aversion	36	14	18	10	7	5
Not available	2	0	0	3	2	2
Traditional practices	12	19	4	7	18	7
Debt aversion	0	12	20	7	2	1
Beliefs	0	0	0	0	18	0
Physical problems	34	19	2	0	0	3
Lack of technical knowledge	2	0	0	16	42	14
Others	2[a]	0	0	27[b]	0	37[c]

[a] Lower yield of HYV's.
[b] 14% cannot stand its smell, 3% cannot find hired labor to spray at that time needed, 7% are allergic, 3% do not spray because they don't have insect and disease problems.
[c] 35% have no time, after dry season, they have to do land preparation hurriedly, 1% hired tractor does rough job in moving to other fields, 1% have to do hurriedly for some neighbors are going to transplant and he will find no way to get a tractor into the field.

In the 1975 dry season, 30% of 141 sample farmers used a high level of fertilizer, while 62% used low levels and 8% used none. For those farmers who used little or none, the most important reasons again given were the high price of fertilizer and the fluctuating price of paddy.

Insects. In the 1974 wet season, 57% of 81 sample farmers who reported insect problem did not use any insecticide. The most important reason for not using any insecticide was economic. Farmers had no money or thought that the cost of insecticide would have been greater than the value of rice saved by the insecticide. Lack of technical knowledge was also an important reason. Farmers did not know what kind of insecticide would control particular insects, and did not know how to use it at the proper rate and time.

In the 1975 dry season, 35% of 52 sample farmers who reported serious insect problems did not use any insecticide. The most important reason given was lack of technical knowledge, followed by economic reasons.

Table 18. Percentage of farmer's giving various reasons for non—adoption of six modern practices, Suphan Buri, Thailand 1975 dry season.

Reason	% giving identified reason for the practice of					
	Modem varieties[a]	Fertil—izer	High rate fertil—izer	Insect—icide	Herb—icide	Good land preparation
Economic	0	55	57	22	8	41
Risk aversion	0	0	21	6	14	3
Not available	0	0	0	0	3	1
Traditional practices	0	9	8	11	10	6
Debt aversion	0	0	0	0	0	0
Beliefs	0	0	0	0	16	0
Physical problems	0	36	6	0	0	7
Lack of technical knowledge	0	0	7	28	46	13
Others	0	0	1	33[b]	3	29[c]

[a]All farmers who grew rice in the dry season used some MV.
[b]16.5% cannot stand its smell. 16.5% cannot spray it when needed because rice plants are in tillering stage.
[c]29% no time, after wet season, they have to do land preparation hurriedly.

Weed. In the 1974 wet season, 62% of 72 sample farmers who had serious weed problems, did not use any herbicide. The most important reason for not using herbicides was that farmers did not know the proper rate and timing, and did not know what kind of herbicide would control their weeds. Other important reasons related to their perceptions of effectiveness. Some farmers had applied herbicides previously but they believed it was not effective, and that hand weeding was better. Some farmers believed that herbicides stop the growth of rice because their rice plants looked red and weak after applying herbicide.

In the 1975 dry season, 69% of 104 sample farmers who had serious weed problems did not use any herbicides. The most important reason was the same as in wet season 1974, lack of technical knowledge. Some farmers had tried herbicides but believed they were not as effective as hand weeding. Also, some farmers did not want to take the risk using herbicides because they were not sure what other factors might damage their rice, such as rodents, flood, rain, and they were not sure that herbicide application would increase yield significantly.

Land preparation. In both seasons nearly 55% of the sample farmers said they thought they had rather poor land preparation, 5% poor land preparation, and 40% good land preparation. One reason given by those farmers with rather poor and poor land preparation was lack of time. Especially after the dry season, they had to hurry their land preparation. In addition, economic reasons were also important -- farmers had no money to buy a tractor to do their own work, and hired tractors did not do the work properly. Some farmers thought that better land preparation would result in higher yield, but they feared their rent would be raised. Some farmers did not have enough time to prepare their land because at the beginning of the season, the irrigation project released water into the system for only a short period. Farmers were forced to hurry their land preparation, otherwise there would not be enough water to soften the soil for plowing.

Relationship of input use to yields

To understand the factors associated with input use, chi—square tests of independence were run between the distribution of fertilizer, weed control, and insect control expenditures and a number of possible socioeconomic constraints. Farms were classed as zero, low and high users of fertilizer, weed control and insect control inputs. The median level was used as the dividing point between high and low levels. In the wet season that was Ƀ560/ha for fertilizer, Ƀ65/ha for weed control, and Ƀ34 for insecticide. In the dry season when more inputs were used, the dividing point was Ƀ852/ha for fertilizer, Ƀ160/ha for weed control and Ƀ69 for insecticide.

In the 1974 wet season there was no relationship between input use and credit use (Table 19). In the 1975 dry season there was no relationship between fertilizer and credit use, although about 93% of farmers applied fertilizer. The chi—square test rejected the hypothesis of independence for weed control and insecticide, indicating a relationship between the levels of those inputs and credit.

Farmers were classified as members or non—members in farmers' associations to determine whether such membership had any relationship to fertilizer, weed control and insecticide cost. The chi—square tests for these three inputs were not significant in either season, indicating that there was no relationship between farm association membership and fertilizer use, weed control, or insecticides.

Tenure was also tested using the chi—square test for the three inputs, and no relationship was found.

The water depth reported by each farmer was tested against input use. Farms were grouped into those reporting low (0—5 cm), medium (5—10 cm), and deep water (more than 10 cm). The chi—square test for the 1974 wet season indicated a relationship between fertilizer and water depth, and insecticide and water depth, but not between weed control and water depth. In the 1975 dry season, input level was independent of water depth.

The distance from irrigation ditch turnout to each farm was also tested against input use. Farms were divided into those close (adjacent to the turnout), intermediate (less than .15 km), and far (more than .15 km). In both the 1974 wet season, and the 1975 dry season, there was no relationship between distance from farm turnout and fertilizer, weed control, and insecticide.

Table 19. Summary of Chi-square test results

Season	Variable 1	Variable 2	x^2	d.f.	test result
Wet 1974	Credit availability	Fertilizer	2.05	4	n.s. at .05
Wet 1974	Credit availability	Weed control	4.75	4	n.s. at .05
Wet 1974	Credit availability	Insecticide	5.18	4	n.s. at .05
Dry 1975	Credit availability	Fertilizer	6.61	4	n.s. at .05
Dry 1975	Credit availability	Weed control	9.58*	4	sig. at .05
Dry 1975	Credit availability	Insecticide	9.54*	4	sig. at .05
Wet 1974	Member farmers group	Fertilizer	2.31	2	n.s. at .05
Wet 1974	Member farmers group	Weed control	3.63	2	n.s. at .05
Wet 1974	Member farmers group	Insecticide	1.89	2	n.s. at .05
Dry 1975	Member farmers group	Fertilizer	1.22	2	n.s. at .05
Dry 1975	Member farmers group	Weed control	1.08	2	n.s. at .05
Dry 1975	Member farmers group	Insecticide	0.26	2	n.s. at .05
Wet 1974	Tenure	Fertilizer	4.36	2	n.s. at .05
Wet 1974	Tenure	Weed control	1.68	2	n.s. at .05
Wet 1974	Tenure	Insect control	3.41	2	n.s. at .05
Dry 1975	Tenure	Fertilizer	1.52	2	n.s. at .05
Dry 1975	Tenure	Weed control	0.18	4	n.s. at .05
Dry 1975	Tenure	Insect control	3.47	2	n.s. at .05
Wet 1974	Water depth	Fertilizer	13.99**	4	sig. at .01
Wet 1974	Water depth	Weed control	7.10	4	n.s. at .05
Wet 1974	Water depth	Insect control	10.21*	4	sig. at .05
Dry 1975	Water depth	Fertilizer	2.73	4	n.s. at .05
Dry 1975	Water depth	Weed control	2.51	4	n.s. at .05
Dry 1975	Water depth	Insect control	3.46	4	n.s. at .05
Wet 1974	Distance to turn—out	Fertilizer	3.94	4	n.s. at .05
Wet 1974	Distance to turn—out	Weed control	6.88	4	n.s. at .05
Wet 1974	Distance to turn—out	Insect control	8.11	4	n.s. at .05
Dry 1975	Distance to turn—out	Fertilizer	9.43	4	n.s. at .05
Dry 1975	Distance to turn—out	Weed control	1.13	4	n.s. at .05
Dry 1975	Distance to turn—out	Insecticide	2.58	4	n.s. at .05
Wet 1974	Yield	Fertilizer	9.12*	2	sig. at .05
Wet 1974	Yield	Weed control	1.28	2	n.s. at .05
Wet 1974	Yield	Insecticide	0.01	2	n.s. at .05
Dry 1975	Yield	Fertilizer	11.73**	2	sig. at .01
Dry 1975	Yield	Weed control	0.10	2	n.s. at .05
Dry 1975	Yield	Insecticide	0.67	2	n.s. at .05

The yield of paddy was compared to input use following the same procedure. Farms were classified into two groups: those with yields below 3,125 kg/ha, and those with yields over 3,125 kg/ha. The chi—square test rejected the hypothesis of independence between yield and fertilizer for both seasons, but did not reject independence of yields with weed control and insecticide costs.

Regression. An attempt was made to measure more precisely the relationship of yield/ha and various input factors such as fertilizer (X_1), weed control cost (X_2) distance of the parcel from the turnout (X_3), land tenure (X_4, dummy variable), and rice variety (X_5, dummy variable).

The data and informations for this analysis were obtained from one parcel from each of 165 farms in the 1974 wet season, and from one parcel each of 141 farms in the 1975 dry season. The linear regression equations were as follows (standard errors shown in parentheses):

Wet season—1974

$$Y = \underset{(14.69)}{412.61} + \underset{(2.19)}{5.71^*}\, X_1 - \underset{(.38)}{.23}\, X_2 + \underset{(10.22)}{1.5}\, X_3$$

$$- \underset{(17.06)}{2.21}\, X_4 + \underset{(20.06)}{52.78^*}\, X_5$$

$R^2 = 0.1175$ F—value = 4.2754

Dry season-1975

$$Y = \underset{(26.29)}{452.78} + \underset{(2.34)}{7.31^*}\, X_1 - \underset{(0.34)}{0.01}\, X_2 - \underset{(13.52)}{0.04}\, X_3$$

$$+ \underset{(23.28)}{11.64}\, X_4$$

$R^2 = 0.0718$ F—value= 2.7422

For the wet season there is a weak relationship between yield, fertilizer, and variety but no impact of weed control or tenure on yield. For the dry season only fertilizer had a significant impact on yield. Rice variety was not used as a variable in the dry season equation because only modern varieties were grown. Other possible independent variables, included in earlier equations, were found to be not significantly related to yield.

DISCUSSION AND IMPLICATIONS

In Thai rice production, water control is the most important yield constraint. Experimental work can be done well only in areas with good water control. Such areas cannot represent all rice producing areas of the country because of the difference of water control, but they can represent the irrigated rice—growing area of the Central Plain.

Research started in the 1974 wet season. In this paper, we report results for the 1974 wet, 1975 dry, and 1975 wet seasons. Socioeconomic surveys in the same areas were done for the first two seasons.

The average yield gap was about 1 t/ha in the wet season, and about 2 t/ha in the dry season (Table 20). Of that, the main contribution, about two—thirds, was from fertilizer in both seasons. Twenty—percent of the gap was from weed control, and 18% from insect control. The gap was larger in the 1974 wet season than in the 1975 wet season.

Table 20. Relative contribution of three inputs toward increasing rice yields in experiments on farmers fields. Suphan Buri, Thailand, 1974 wet season, and 1975 dry and wet seasons.

Year and season	Grain yield (t/ha)		Increase		Increase (t/ha) due to			
	Farmer's level	High level	t/ha	%	Insect control	Fert—ilizer	Weed control	Resi—dual
1974 wet	3.7	5.1	1.3	35	0.3 23%	0.7 52%	0.3 20%	0.1 5%
1975 wet	3.9	4.6	0.6	15	0.2 34%	0.5 85%	0.1 16%	—0.2 —35%
Average wet	3.8	4.8	1.0	25	0.3 27%	0.6 62%	0.2 18%	-0.1 -7%
1975 dry	4.1	6.3	2.2	53	0.3 15%	1.5 67%	0.4 20%	-0.4 —2%
Average wet and dry	4.0	5.5	1.6	40	0.3 18%	1.0 66%	0.3 20%	—0.1 —4%

Among the four packages of increasing input levels, M_2 to M_5 which were compared to the farmers' level of M_1, the most profitable package was M_3 during the dry season, and M_2 during the wet season. At these input levels yields could be raised by about 0.3 t/ha in the wet—season and 1.0 t/ha in the dry. The reduced profit from added inputs above the M_2 or M_3 levels was due to high price, and modest response to added inputs like fertilizer. Farms are subject to physical risk from deep—water, cold weather or other factors so farmers adopt only to the M_1 level.

The inputs used to get high yields are easily available from the local stores in the study area. Compound and single fertilizers recommended for rice could be obtained for cash as well as on credit. Herbicides such as 2,4—D are available in the sodium salt form, but those effective for grass, *Marsilia,* and algae are not available. Pre—emergence granular herbicides have not been introduced to the farmers. Insecticides are easily available and are usually found in most farmers' houses.

The farmers seem to know that use of inputs will increase rice yields but whether they know how to use them with maximum efficiency is questionable. The investigation shows that farmers need education in time and optimum rate of fertilizer application. Knowledge of effective chemical weed control is lacking. Farmers seem to know more about insect control, but their skills are still inadequate when peculiar or serious insect attacks occur.

The internal constraints of attitude and beliefs of farmers toward input use are considered quite negligible. For some inputs like chemical weed control, farmers may not want to bear risks, but if chemical weed control practices are proved effective, there is no doubt that the farmers would accept the technology. Their rate of adoption is already high. It seems clearly possible to change their attitudes and beliefs by proper demonstration of particular technologies.

Implications

It is evident that most physical constraints are likely to be influenced, directly or indirectly, by a single main factor, water control. Farmers experience an extreme lack of water control, with shortages in the dry season and excessive amounts in the wet season. Use of purchased inputs and varieties are directly conditioned by the degree of water control.

Water control. Water control influences most of the other factors and is a problem that farmers cannot solve by themselves. Farmers face water shortage as well as excess water. The only solution to the problem is to improve land levelling, and provide minor irrigation systems with proper drainage as is being done with land consolidation. The projects of land consolidation by the Ministry of Agriculture and Co—operatives have been tried successfully in two provinces, Chainat and Sing Buri. The expansion of such projects should be encouraged, particularly where the water control is identified as a problem.

Fertilizer. Fertilizer is one of the main inputs for increasing rice yields, especially with modern varieties in irrigated areas. If the farmers could be trained a bit more in its proper management use of fertilizer would be more efficient. For example, a rice crop cannot utilize phosphorus from the application of ammonium phosphate 30 days after transplanting, a common practice. Application of single nitrogen fertilizer like ammonium sulphate or urea will pay more at that time. Other cultural practices such as weed control could also increase the efficiency of fertilizer use.

During the study period, the price of fertilizer was high while the price of rice was low and fluctuating. The government should adopt a price policy with a guaranteed minimum rice price and a subsidy for fertilizer to help farmers avoid the risk and uncertainty of using fertilizer.

Variety. The problem of selecting suitable varieties for particular areas is difficult in the wet season. Farmers hesitate to grow the modern recommended varieties due to various reasons -- high water level in low land, susceptability to diseases and insect pests, and low temperature at the flowering stage. The breeding program should be aimed at overcoming those drawbacks.

Land preparationn. Poor, hurried land preparation occurs particularly after harvest of the dry season crop when land is to be prepared for the wet season crop. This problem is created when transplanting of the dry season crop is as late as April or May due to shortage of irrigation water and harvest of the dry season crop coincides with the beginning of the monsoon in July or August, resulting in shortage of time and labor to prepare land for the wet season crop. Moreover, threshing is a problem because threshing grounds are wet and farmers have neither storage for unthreshed grain nor facilities for drying grain.

The problem is more serious if farmers are short of labor and machinery for land preparation. One solution is an institutional approach beginning with irrigation system improvement to supply adequate water for planting the dry season crop earlier than presently done. But this must be done over large areas, otherwise rat and bird problems are created. A policy of building seed storage equipped with drying could be encouraged on the basis of cooperatives or farmers' clubs.

Weed control. Another problem caused by poor land preparation is weed infestation. It is also serious when there is a shortage of water. Some notorious weeds can be controlled only by mechanical means, for instance Marsilia quadrofolia. Hand weeding requires time and labor. Economical and effective chemical weed control should be encouraged and recommended to the farmers. At present, there has not been any extensive recommendation of chemical weed control to Thai rice farmers. Moreover, fanners seem to lack knowledge of weed control by chemicals.

Insect control. The problem of insect attack is rather localized in the study areas. During the seasons studied, there was no serious insect problem, although before initiation of the project, an attack of brown planthopper was observed on RD 1. The farmers have been growing varieties that are fairly resistant to insects.

Future research direction

The results of the study have answered certain questions on factors constraining rice yield, but some constraints seem to be affected by factors that are not clearly explained. Further investigation should emphasize only the factors that have been observed as major constraints. For instance, fertilizer use, which has been observed as major physical constraint, is likely to have an interaction with weed control. Water control, the single most important variables seems to influence the use of other inputs in the area.

Another factor worth studying further is variety. The question of why farmers grow modern varieties during the dry season, but not in the wet season is still unanswered. Future research should use a simpler design. Insect infestation, because it is localized and seasonal, should be omitted from the experiment.

The rate of adoption of farmers in the Suphan Buri area is comparatively high. At the initiation of the project, the yield gap observed was considerable, but it narrowed in the succeeding seasons. For this reason, it is suggested that the project should shift to an area where the modern rice technology has not been as well adopted by farmers.

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