THE INTERNATIONAL RICE RESEARCH INSTITUTE

LOS BAÑOS LAGUNA
PHILIPPINES

1961-62

ANNUAL REPORT

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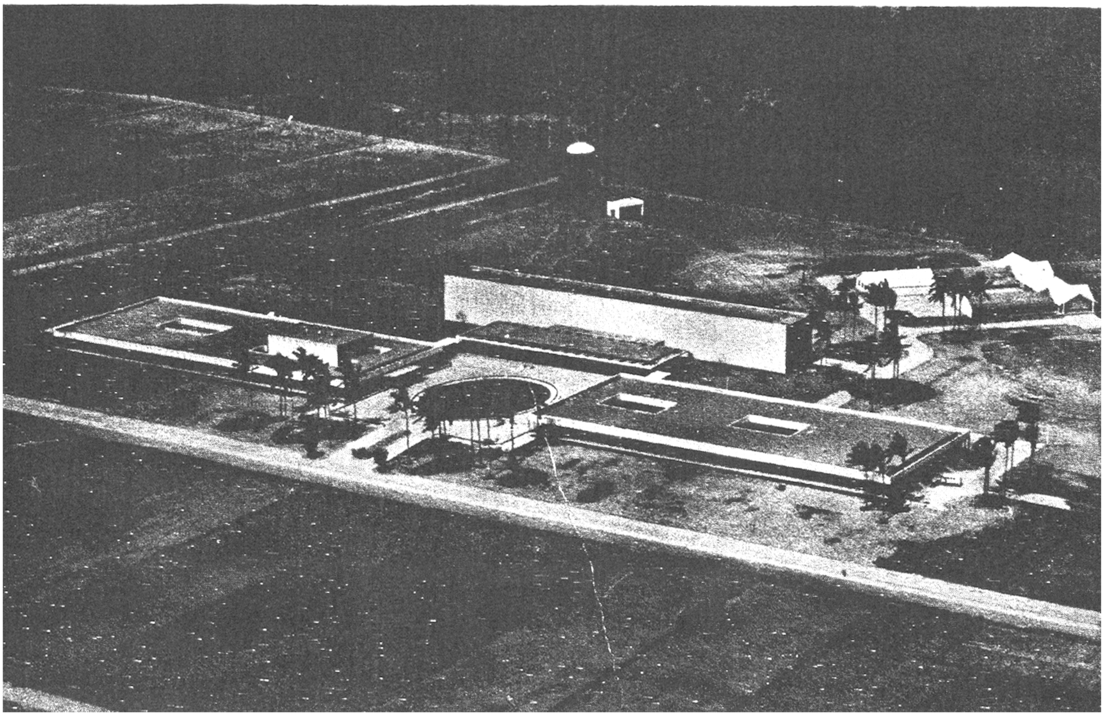

Rice Research Institute

THE INTERNATIONAL RICE RESEARCH INSTITUTE

1960

Mail Address
and City Office:
Manila Hotel, Manila

Location:
Los Baños, Laguna
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ANNUAL REPORT
1961-1962

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Quarter-hectare experimental plots, each of which can be irrigated or drained independently of the others, have been developed on most of the 200-acre farm.

Director's Introduction

This is the first published annual report of The International Rice Research Institute. Mainly, it consists of a description of the research work that has been accomplished during the year. It covers only a portion of the activities that would normally take place in one year because many of the research projects did not get underway much before the middle of the year. The full results of this year's research will appear in later annual reports and in papers published in various scientific journals.

The construction program of the Institute was essentially completed in 1962, with the principal buildings being occupied in January. During the year, a new women's dormitory was built along with several additional specialized research facilities. At the close of 1962, nearly all of the Ford Foundation grant of $7,150,000 had been spent or committed for constructing and equipping the buildings and for developing the experimental fields. In fact, there are several research facilities still needed for which funds are not now available.

The operating costs of the research program were met by an appropriation of $405,000 received as an outright grant from The Rockefeller Foundation. In addition, a grant of $750,000 was received from the Ford Foundation to provide, over a three-year period, the funds for training various young scientists from Southeast Asian countries and for the support of regional research projects involving cooperation between the Institute and various already established research organizations in the rice-growing countries of Asia.

In view of the fact that the Institute was not inaugurated until February 7, 1962, it is with some pride that we present the results of the first year of research. With the exception of three programs, all laboratories and other experimental facilities were in full operation by mid-1962. The three programs to be inaugurated in 1963 are agricultural economics, soil microbiology, and agricultural engineering. The agricultural economist has been selected and is due to arrive on May 1, 1963. The soil microbiologist also has been chosen and will be ready to start his program by July 1, 1963. The agricultural engineer has been devoting his full attention to the development of the experimental fields but in 1963 the research program will be undertaken. The Statistician joined the Institute staff November first. His initial activities included a review of the curriculum in mathematics and statistics at the College of Agriculture, assistance to the Institute staff in the analysis of 1962 data, and design of new experiments.

During the early part of the year, considerable time went into the establishment of the objectives of the research program of the Institute. Special credit is due the Associate Director, Dr. Sterling Wortman, for his contributions to this effort. Also, several consultants were provided by The Rockefeller Foundation to assist the Institute in developing its program. Among them were Dr. Richard Bradfield, Dr. William I. Myers, and Dr. Sterling B. Hendricks.

It should be mentioned that each major scientist spent several months thoroughly reviewing the literature in his field of specialty. Also, several of the senior scientists travelled extensively to acquaint themselves with the current status of work in their fields. This is an essential part of any research effort which, naturally, does not reveal itself in terms of immediate results.

The overall research program of the Institute is oriented toward both basic and applied research. It is concerned with understanding rice as a living organism and with determining ways and means of producing more grain of higher quality on a given area of land. The Institute's scientists are attempting to question all practices used in growing rice, whether they have been in existence for several thousand years or whether they are of recent introduction. For example, is transplanting rice a real advantage? Is it necessary to flood rice or would the maintenance of a continuous moisture supply in the soil be adequate? All such questions are being intensively studied in the field and in the laboratory.

Although the size of the Institute is such that it cannot expect to solve all of the problems pertaining to rice, it is believed that with an intensive and efficiently conducted program, it can add most significantly to our knowledge of the rice plant and to the practices used in its production. It is entirely possible that within the next five years a variety of rice will be available that will yield well almost any time and anywhere in the torrid zone. Such a variety would, of course, be non-sensitive to variations in length of day, would have resistance to lodging and to the more common diseases and hopefully to certain insects, would have a dormancy period of a few weeks, and would respond to increased soil fertility levels. It appears that this plant would have certain rather definite physical characteristics which are described in this report under the varietal improvement program. Along with this development would come a much better knowledge of the cultural requirements of rice, perhaps reducing much of the back-breaking labor that now occurs in growing rice in Asia.

The Institute is most fortunate in possessing excellent physical facilities and in having a highly competent staff of young scientists who are attacking their research programs with exceptional vigor and imagination. The administrators of the Institute are confident that these advantages will produce new knowledge which eventually will be reflected in greater productivity on the farm, and in the well-being of the people of the rice-growing countries of the world.

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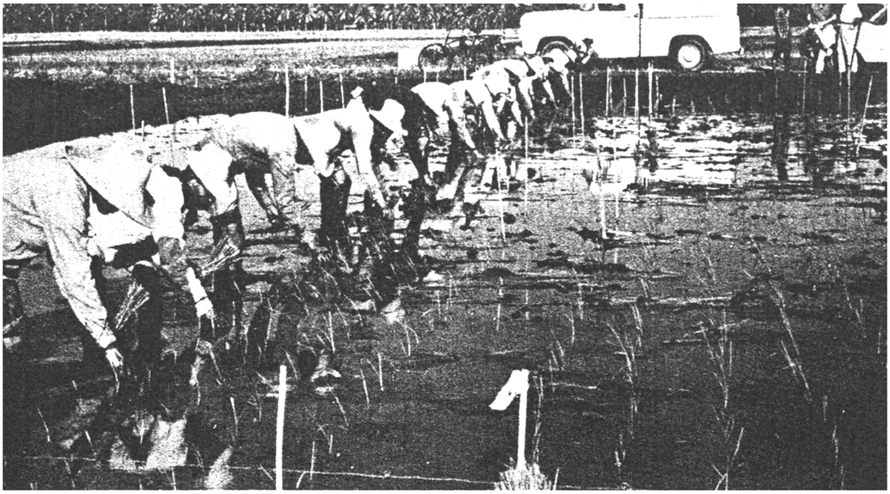


Transplanting a portion of the 5,800 varieties which were compared in field tests in 1962.

Varietal Improvement

One of the most important factors contributing to the frequently low yields of tropical rice is the unavailability of suitable varieties. The most commonly occurring tropical varieties have been selected over several hundred years for their ability to produce a modest crop under conditions of low soil fertility and minimum care. When fertilizers and other good management practices are used, these varieties produce an over-abundance of foliage with undue shedding of the lower leaves. Furthermore, they usually lodge (fall over before harvest). It appears that the development of early-maturing, high-yielding, stiff-strawed, disease-resistant varieties which are insensitive to length of day — allowing them to be planted any month of the year — is a prerequisite to the rapid increase of rice production in the tropical countries.

Development of improved varieties

An initial planting of nearly 5,800 varieties from the world collection was repeatedly observed during the year to select those types meriting continued interest. Approximately 800 appeared to combine certain of the characteristics felt to offer greatest promise of high yield in the tropics. These varieties were planted in December 1962 in an unreplicated test involving high and low nitrogen levels, and the following characteristics will be recorded for each: subspecies, temperature, photoperiod and nitrogen responses, maturity, disease reaction, stem, leaf and panicle types, and yield. This detailed observation of the promising varieties should suggest their usefulness in the various parts of Asia, should indicate which are most worthy of inclusion in future yield trials at the Institute and abroad, and should reveal their value as parental material. Grouping these varieties according to plant type will permit future comparative studies of the relationship between plant type and yield and will provide sets of material of varying appearance and origin for genetic and agronomic studies.

A set of about 260 standard varieties from eight Asian countries and the United States has been observed carefully over three successive plantings. In late 1962, 80 of the better varieties were entered in four replicated yield trials for more critical evaluation. One set consisting of *japonicas* from Taiwan is especially interesting because of their relative insensitivity to tropical temperatures and photoperiods. Their stiff straw, response in grain yield to high fertilizer levels, earliness and wide adaptability suggest an important future role in the varietal improvement work. Three *indica* yield trials involving about 20 varieties each, should allow proper selection of a limited number of superior varieties for preliminary hybridization.

Considerable observation and analysis has been made of the possible improvement through plant breeding of the plant characteristics related to the low yield of rice in the tropics. Tropical rices are usually cultivated once annually and are typically weak-strawed, tall, leafy, unresponsive in yield to fertilizer, late in maturity and often are photoperiod sensitive. It would seem that the following plant type might be useful in the near future throughout much of the tropics — a combination of short, stiff culms bearing erect, moderately sized, dark-green leaves; responsiveness in yield to fertilizer; mid-season maturity and, in most cases, photoperiod insensitivity to permit double cropping practices. These objectives are being pursued in the initial stages of the plant breeding program with both *indica* by *indica*, and *indica* by *japonica* hybridization.

World collection of rice germ plasm

Emphasis by national breeding programs on the development and extension of widely adapted varieties has already reduced the number of existing varieties, especially in the areas of the greatest natural diversity of rice. Since this trend will continue, it follows that a thorough collection of germ plasm now extant is worthwhile before additional variability is lost. The International Rice Research Institute has accepted the responsibility of collecting, multiplying, classifying, cataloging and making available seed of as large a sample of genetic variability in cultivated rice as possible.

To date, 6,867 varieties originating from 73 countries and territories have been received. These include the large collection maintained by the United States Department of Agriculture and the FAO *indica* and *japonica* sets kept at Cuttack, India and Hiratsuka, Japan. Each accession is being classified on the basis of over 50 of its taxonomic-morphologic characteristics. Varietal observations are predominantly those of probable economic value, supplemented by others of possible interest for future genetic studies. About 2,000 entries can be completely classified each year. Following this, 500 grams of seed of each are being placed under low temperature and humidity conditions for long-term storage.

The data will be sorted and transcribed to form a usable varietal stock catalog which will be distributed to all interested persons. In this manner, seed requests by varietal name or by indication of type desired can be filled conveniently and rapidly.

A second collection of genetic stocks consisting mainly of species, mutants, and testers now numbers 867 entries. These are being handled in much the same manner as the collection of cultivated rices.

Already, over 400 seed lots have been sent from the International Rice Research Institute collection to 17 requesting institutions in 14 countries. A duplicated set of 60 yield trial entries, seeded at the Institute, was sent to Chiayi, Taiwan for evaluation under sub-tropical conditions.

Floret emasculation studies

It is rather difficult to obtain crossed seed in rice. Any of the common techniques of emasculation are useful when few crossed seeds are needed, but they are inadequate for production of the large numbers of seed required for the Institute's breeding program. A method has been developed in which florets are clipped so that anthers are cut in half and destroyed before pollen grains are functional. Emasculation can be accomplished during afternoons, leaving pollination for the short period during the following mornings when pollen is available. It does not seem necessary to remove the dessicated parts of the stamens before pollinating. Pollination is easily accomplished by dusting shedding panicles over the clipped florets. This technique has consistently given excellent results of over 50 per cent seed set. Self-fertilization has been limited to about three per cent, and it is expected that further practice will reduce this amount. This clipping technique, however, usually causes poorly formed crossed seeds which have reduced germination due to glume removal. The results indicate, however, that crossed seed resulting from floret clipping, if properly protected with a fungicide, can be successfully sprouted in a germinator, but not in non-sterilized soil. Therefore, poor seed development does not seem to be a deterrent to the use of this rapid emasculation technique.

Breaking grain dormancy

Grain dormancy of several weeks is a necessary varietal characteristic in all high rainfall areas; however, this desirable period of dormancy interferes with a breeding program involving bi-yearly plantings. Consequently, a rapid, dry technique is necessary for breaking seed dormancy, and initial studies indicate that it can be broken with dry heat at 48-50°C in three or four days. Some varieties, however, appear to have a stronger, but not necessarily longer, dormant period, and these may require additional periods of heat treatment.

Yield components of "japonica" varieties

Four *japonica* varieties from Taiwan were grown at five levels of nitrogen (0, 30, 60, 90, 120 kilograms per hectare) in a replicated yield trial. Data on grain yield and the three yield components — number of panicles, number of grains per panicle, and weight of 1,000 seeds — were taken.

Highest yields in this test were obtained with the addition of 60 kilograms per hectare of nitrogen. Additions of nitrogen increased the number of panicles per plant slightly (but not significantly), reduced the number of well-formed seeds per plant, and increased the number of sterile spikelets.

Significant differences among varieties were observed for all four characteristics, but the variety x nitrogen reaction was statistically insignificant in every case.

Five *indica* varieties included in the same test had not been harvested at this writing.

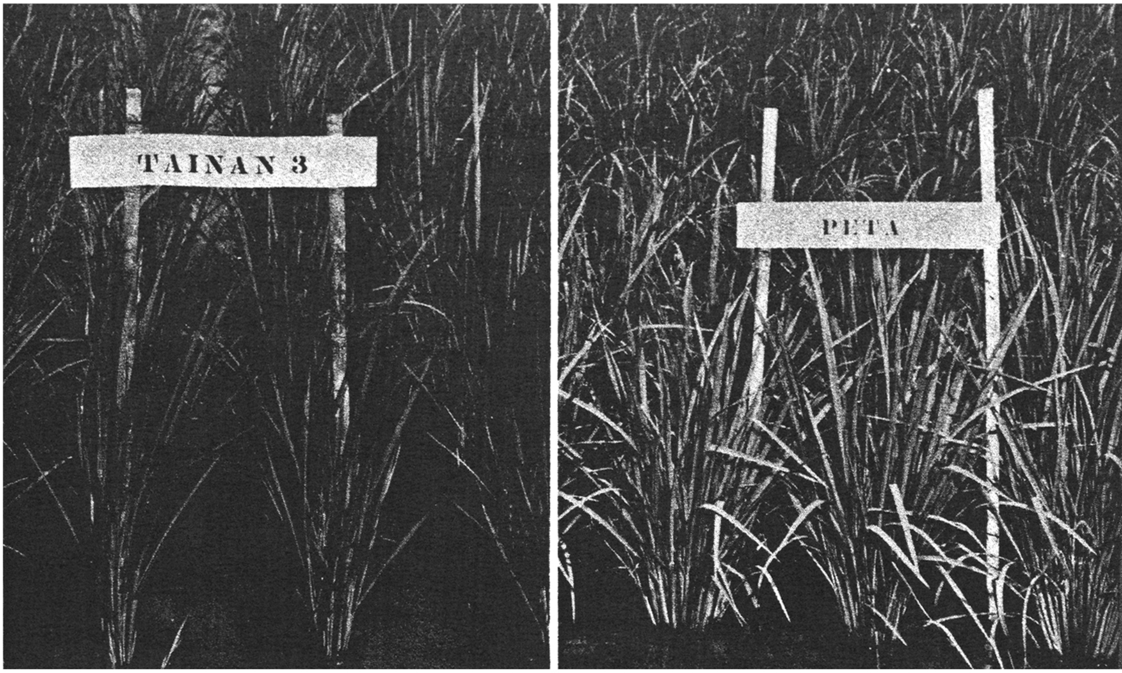


Figure 1. Plants of a *japonica* variety, Tainan-3, and an *indica*, Peta, one month after planting. Note the more abundant tillering and vigorous early growth of Peta which prevents light from reaching the lower portions of the plant.

Plant Physiology

Average yields of rice in the tropics generally are much lower than in the temperate zone countries. The lower grain yields commonly are attributed to differences in variety, in climate, and in management practices.

In Japan and parts of Taiwan, varieties of the *japonica* type are grown. Generally speaking, these are early in maturity, have relatively short, strong straw, are usually grown at relatively high levels of fertility, and receive excellent care. On the other hand, varieties grown in the tropics are typically tall and leafy, have weak straw and lodge after heading. Usually they are grown at relatively low levels of fertility with less care than is given a crop in Taiwan or Japan. Some scientists have stated that lower yields in the tropics also may be associated with higher temperatures, shorter day lengths, and low light intensities during the rainy season.

It has been known for years that, relatively speaking, tropical *indica* varieties respond inefficiently to nitrogenous fertilizer applications. They usually produce an unnecessary abundance of foliage, unlike the *japonicas* which are able to utilize added nutrients efficiently in producing grain. It appears that tropical varieties have been selected over hundreds of years for moderate production under conditions of low fertility and minimum care, while plant breeders in Japan and Taiwan have carefully developed varieties for high production at high fertility levels.

In 1961, about 250 varieties from the United States and from Asian nations were planted at the Institute for observation. Among them were a number of varieties from Taiwan which appeared well adapted to Philippine conditions, even though they were unsuitable for commercial production in the tropics because of their lack of dormancy and their different eating and cooking qualities. Such varieties are useful as research tools, since they allow comparisons in the tropics of the growth processes and yield of *indicas* and *japonicas*, and permit an investigation of the cultural practices which will be most desirable when short, early, non-seasonal *indica* varieties are developed.

The growth processes of "indica" and "japonica" varieties

In 1962, characteristics of Tainan-3, a short, early *japonica* variety from Taiwan were compared with those of the *indica* varieties BPI-76 and Peta. BPI-76, a variety recently developed by the Bureau of Plant Industry of the Philippines, is shorter, has stiffer straw, and produces fewer tillers than most tropical varieties, but it is sensitive to photoperiod. Peta is a tall, weak-strawed, non-seasonal but high-yielding *indica* variety which is popular among farmers in parts of the Philippines.

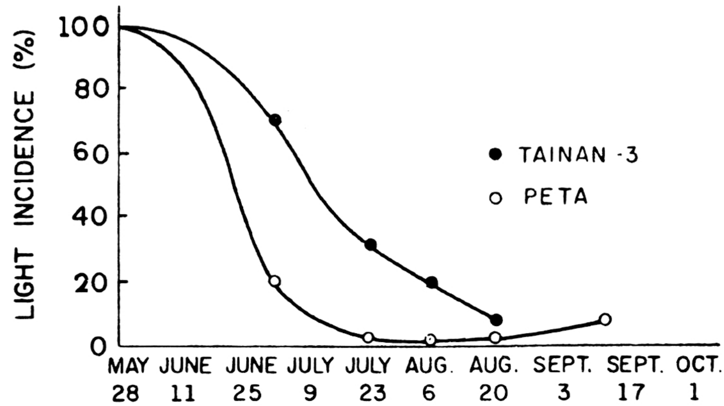
In this experiment, the seeds were planted May 3, 1962 and the seedlings were transplanted on May 28. Single plants were spaced 30 cm. x 30 cm. apart. Representative plants were harvested at two-week intervals to obtain notes on morphological characters and for chemical analysis. The data for BPI-76, which did not flower until the days became short late in 1962, were not complete at this writing, so the comparisons are limited to Tainan-3 and Peta.

The growth of Peta was much more vigorous than that of Tainan-3; the leaves were willowy and light green, and the plants were overcrowded within one month after transplanting (Figure 1). The effect of the crowded condition on light intensity at the base of the plants is evident in Figure 2.

Tainan-3 flowered 90 days after sowing and was harvested 123 days after planting. Peta flowered 116 days after sowing, lodged severely three days later, and was harvested 151 days after sowing. In spite of the differences in maturity, yields were about equal; *viz.*, 4,854 and 4,861 kilograms per hectare for Tainan-3 and Peta, respectively. However, it was necessary to provide costly support for the plants of Peta; otherwise the yield undoubtedly would have been considerably lower.

Peta reached a maximum height of about

Figure 2. Percentage of available light reaching the ground under the plants of Peta and Tainan-3 at various dates during the crop period. The plants of Peta lodged badly on August 30, a month before harvest, while those of Tainan-3 remained erect until maturity.



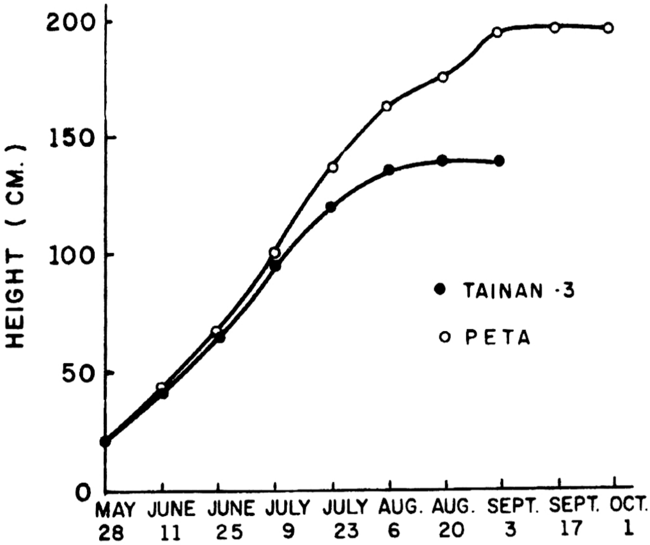


Figure 3. Height of the plants of Tainan-3 and Peta at successive dates between transplanting and harvest.

200 cm., while Tainan-3 grew to about 140 cm. and remained erect without support (Figure 3).

Tillering of the two varieties differed markedly, even though both reached the maximum tillering stage at about the same

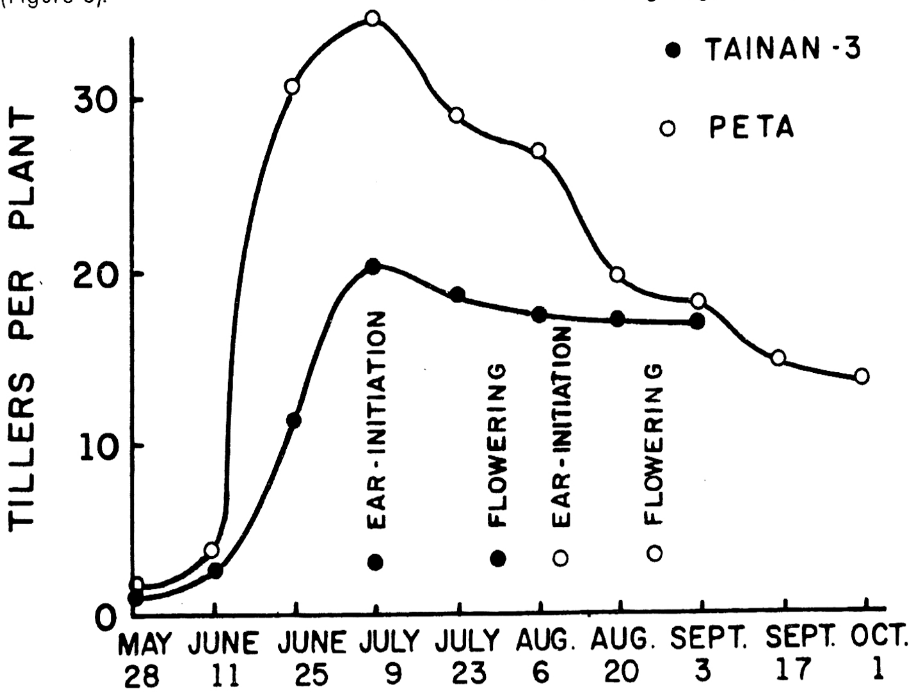


Figure 4. Number of tillers per plant of Tainan-3 and Peta at successive dates between transplanting and harvest.

time — six weeks after transplanting (Figure 4). Peta developed a maximum of 35 tillers per plant, but the number then declined steadily until maturity, when only 14 per plant remained. Only 40 per cent of the Peta tillers produced normal panicles. On the other hand, the maximum number of tillers of Tainan-3 was 20 and at maturity 83 per cent were productive.

The time of ear initiation and of maximum tiller number occurred almost simultaneously in Tainan-3, while in Peta, ear initiation occurred about a month after the maximum tiller number had been reached.

The total dry weight of Tainan-3 continued to increase until harvest; that of Peta decreased slightly after flowering (Figure 5). The straw weight of Tainan-3 remained almost constant after flowering and few leaves died. But in Peta, many leaves were already dead at the flowering stage, the number continued to increase during ripening, and the dry weight of living straw decreased from a maximum of 102 grams per plant at flowering to only 40 grams at maturity. Evidence indicated that ripening of Tainan-3 depended mostly on products of assimilation during ripening, while in Peta, production of grain depended greatly on substances stored in the straw before flowering.

The ear/straw ratio for Tainan-3 and Peta, respectively, were 0.81 and 0.57.

At flowering, no living leaf blades of Peta were found between 0 and 60 cm. from the ground and almost no light passed through the foliage. This indicates that after flowering, the 60 cm. basal portion of the Peta plants, containing 40 per cent of the dry matter, was useless — at least for photosynthesis.

There were interesting differences in leaf

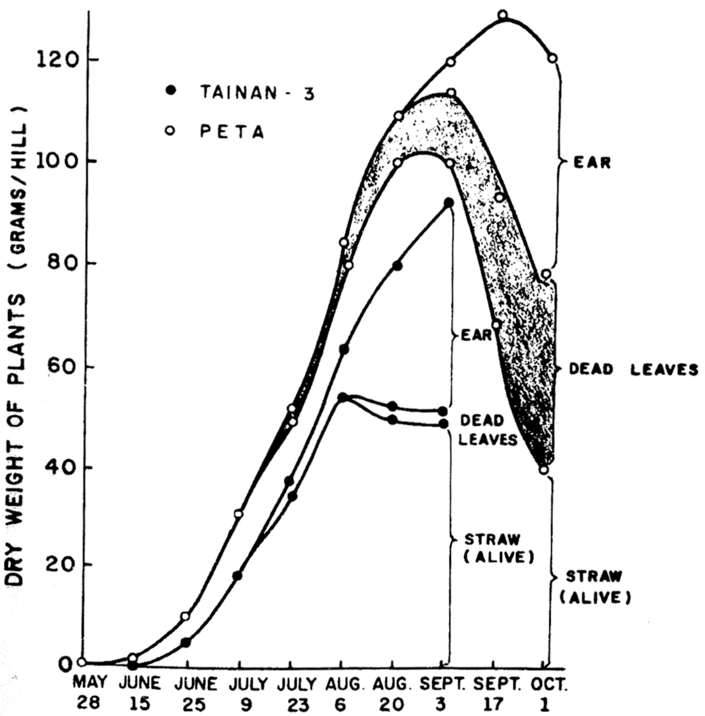


Figure 5. Dry weight (grams per hill) of plants of Tainan-3 and Peta at successive dates between transplanting and harvest.

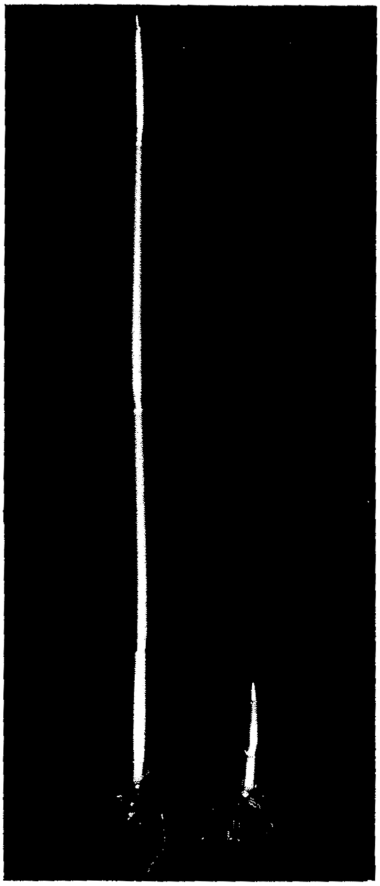


Figure 6. Elongation of internodes at the ear-initiation stage of the variety Peta (left) and of Tainan-3.

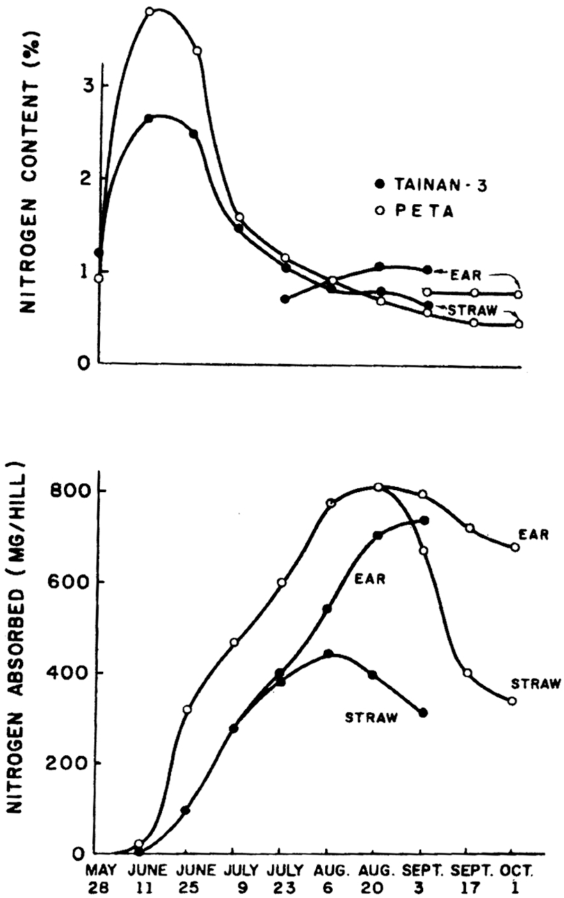


Figure 7. Nitrogen content (%) and nitrogen absorbed (mg./hill) of Tainan-3 and Peta at successive dates between transplanting and harvest.

development. Peta produced a total of 21 leaves, but at flowering only the two upper ones were entirely active, the next two lower ones were half dead, and all others were completely dead. Tainan-3 had fewer leaves — 15 — but all except the three oldest basal ones functioned efficiently. It seems clear that under high nitrogen levels and with close planting, the Peta variety forms so many leaves that it shades many of them out of existence.

In Tainan-3 there were only two slightly elongated internodes at the ear initiation stage; in Peta, there were five and the difference in elongation was great (Figure 6).

In both varieties the content of nitrogen in the plants increased suddenly within two weeks after transplanting (Figure 7), and the maximum content of Peta (3.8%) was considerably higher than that of Tainan-3 (2.6%). The decrease during the next 2-3 weeks was also sudden and when the maximum tiller number stage was reached, the value for both varieties was about 1.5 per cent. The decrease in both varieties then proceeded more slowly until a value of about 0.6 per cent was reached at maturity.

The uptake of nitrogen by Peta was very rapid in the early stages of growth, slowed down after ear initiation, then the total

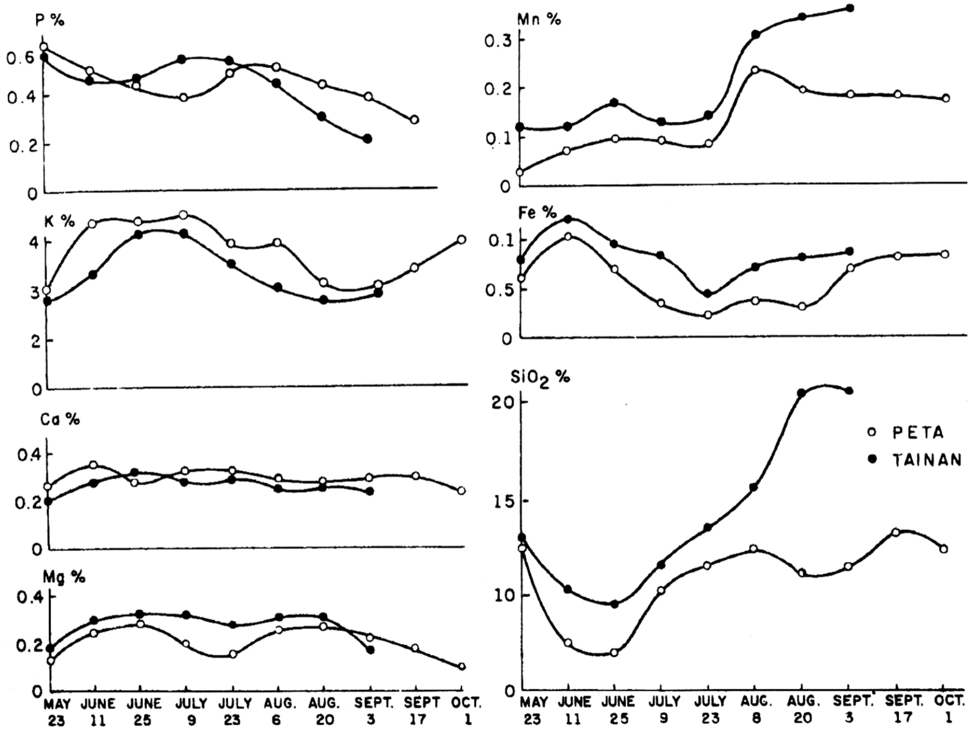


Figure 8. Mineral element content of Tainan-3 and Peta at various dates. Seedlings were transplanted on May 28.

amount in the plants actually decreased about 14 per cent after flowering. Uptake by Tainan-3 was slower in the early stages but continued until maturity.

The straw of the two varieties was analyzed at two-week intervals for content of phosphorous, potassium, calcium, magnesium, iron, manganese, and silica (Figure 8). Generally speaking, the silica content was higher in Tainan-3 than in Peta at all stages of growth. This might partially explain the more erect leaves of Tainan-3.

Effect of temperature on "japonica" and "indica" varieties

The mean annual temperature in Los Baños is about 26.8°C. During the coolest months of the year — December through February — mean temperatures range from 24-26°C, while in April and May, monthly averages of 28-29°C are usual. Since high temperatures in the tropics have often been mentioned as one reason for low rice yields, the effect of temperature on the growth of two Philippine *indica* and two Japanese *japonica* varieties was studied at the Institute in a preliminary manner using controlled-environment growth chambers.

The optimum constant temperature for obtaining maximum grain yields of the *japonica* varieties (Norin 20 from northern, and Zuiho from southern, Japan) was 25°C, while for the Philippine *indica* varieties it was 30°C. The use of 15°C night temperatures seriously reduced yields of the *indica* varieties but affected the *japonicas* less; on the other hand, night temperatures of 30°C adversely affected the *japonicas*. These

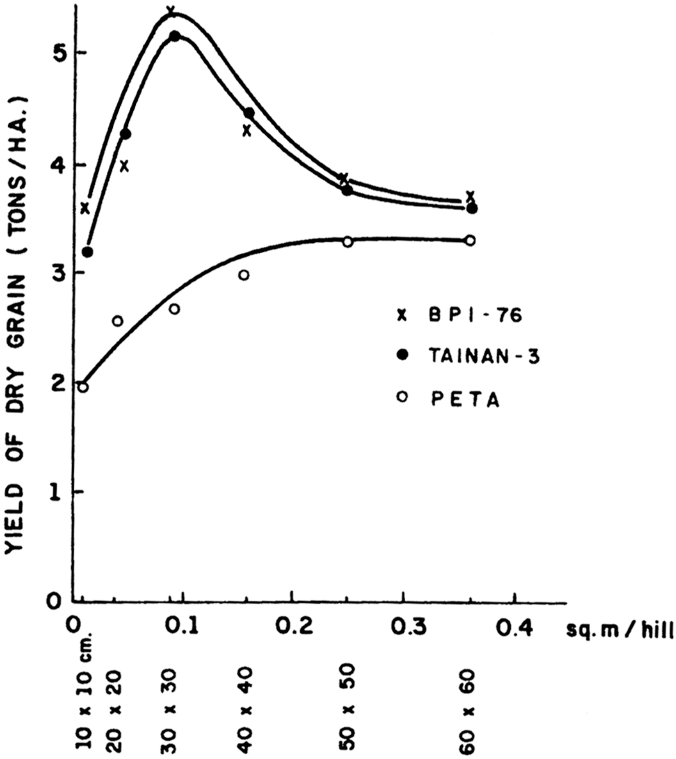


Figure 9. Yield of dry grain of varieties Tainan-3, Peta, and BPI-76 at various spacings, when applied nitrogen was held constant (40 kg./ha.).

and other data confirm the fact that varieties differ in their reactions to temperature, and that the optimum temperature for the growth of tropical varieties is higher than for varieties used in temperate zone regions.

Effects of spacing and nitrogen levels on rice yields

In rice, as in any crop, the attainment of high yields depends upon the use of a productive variety, sufficient water, an adequate and balanced supply of nutrients, the proper number of plants per unit area, and the control of detrimental factors such as diseases, insect pests, and weeds.

Light and nitrogen are most often the limiting factors in the growth of rice. Since the mode of competition of a variety will depend upon such characteristics as tillering capacity, size and shape of leaves, rate of leaf expansion, nitrogen requirement, and rate of nitrogen uptake, it follows that varieties will differ in their space requirements. It is known also that the optimum spacing for each variety will, in turn, vary with fertility and climatic conditions.

To obtain an understanding of the effect on yield of competition for light and nitrogen, the *indica* varieties Peta and BPI-76, and the *japonica* variety Tainan-3 were compared at spacings of 10 x 10, 20 x 20, 30 x 30, 40 x 40, 50 x 50, and 60 x 60 cm. Before the final puddling, 40 kg./ha. each of nitrogen, phosphoric acid, and potash were applied to all plots.

This study was particularly interesting since it permitted a direct comparison of the requirements of an early, short, lodging-resistant *japonica*, Tainan-3, with those of the tall, later-maturing, leafy, lodging-susceptible, abundant-tillering tropical *indica*, Peta. The decision to include the photoperiod-sensitive BPI-76, an *indica* which produces fewer tillers than Peta, appears fortunate.

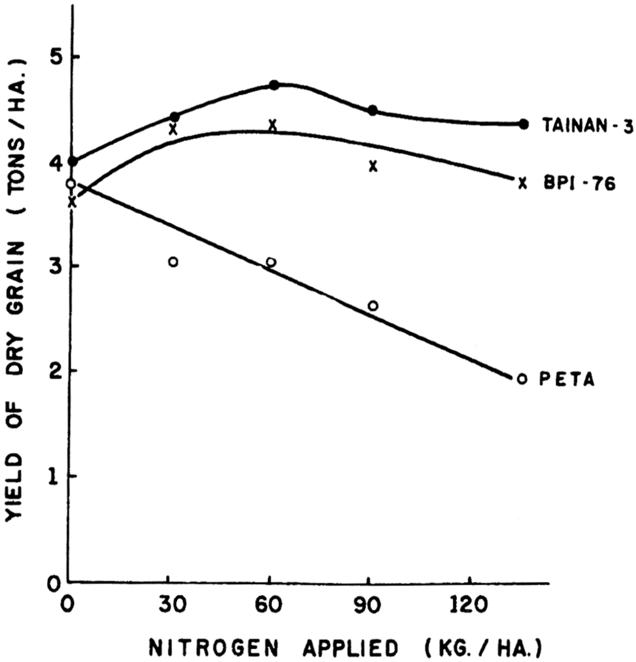
Its performance probably reveals the behavior to be expected of future short, moderate-tillering *indicas*.

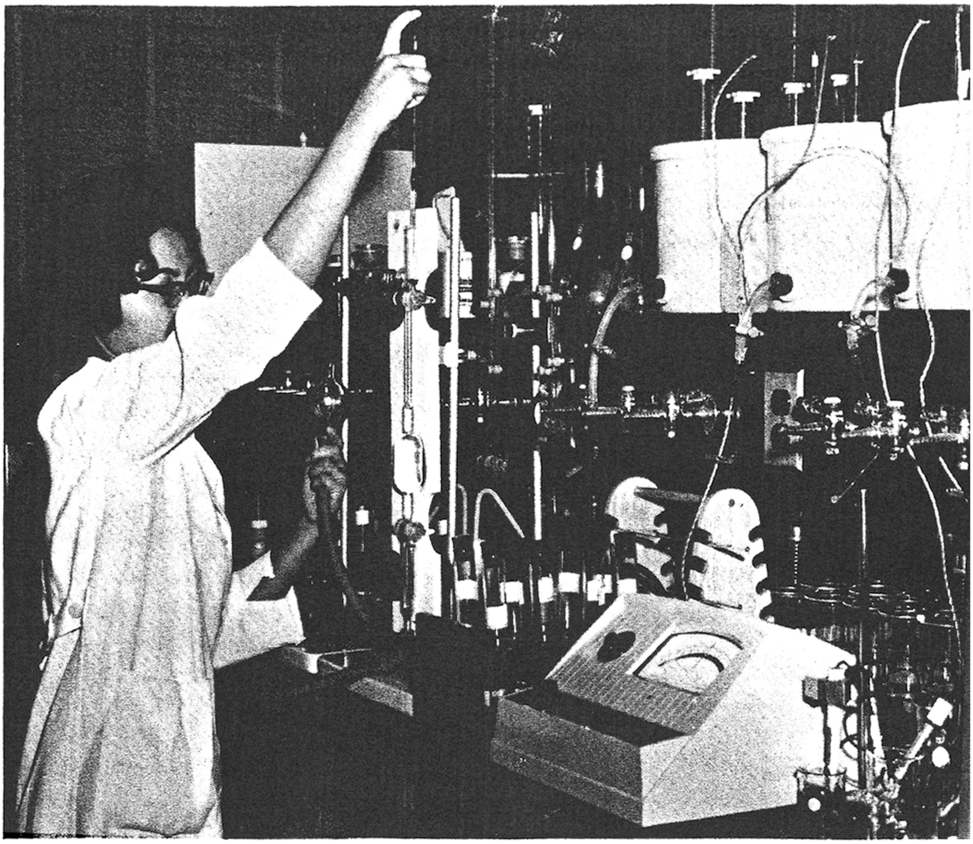
Under the conditions of this experiment, yields of Peta increased from 1.96 tons per hectare of dry grain at a spacing of 10 x 10 cm. to a maximum of 3.30 tons at 50 x 50 cm. (Figure 9). On the other hand, Tainan-3 produced only 3.2 tons per hectare at 10 x 10 cm., reached a maximum of 5.2 tons at 30 x 30 cm., then less at the wider spacings. Interestingly, BPI-76, the *indica*, behaved much like the *japonica*, Tainan-3, yielding only 3.7 tons at 10 x 10 cm., a maximum of 5.4 tons at 30 x 30 cm., and somewhat less at the wider spacings. In this test, Tainan-3 was harvested only 121 days after sowing, while Peta and BPI-76 required 139 and 155 days respectively to mature.

The above experiment demonstrated the behavior of the three varieties when nitrogen level was held constant and spacing was varied. In another test, spacing was held constant (at 30 x 30 cm.) while nitrogen level was varied by applications of 0, 30, 60, 90, or 120 kg./ha. of nitrogen. The results indicated that there must have been residual nitrogen in the soil, since Peta produced its maximum yield of 3.8 tons per hectare when no nitrogenous fertilizer was applied (Figure 10). Tainan-3 and BPI-76 produced maximum yields of 4.7 and 4.4 tons dry grain per hectare, respectively, when 60 kg./ha. of nitrogen was added.

From the data of these and other experiments, it is evident that a typical, tall, abundant-tillering *indica* variety, such as Peta, produces its best yields with relatively low nitrogen levels and wide spacing. Contrarily, a *japonica* such as Tainan-3, or a short, moderate-tillering *indica*, requires closer spacing and a relatively high nitrogen level to produce maximum yields.

Figure 10. Yield of dry grain of the varieties Tainan-3, Peta, and BPI-76 at various levels of nitrogen fertilization when spacing was held constant (30 x 30 cm.).





Amount of CO_2 in the soil solution is determined as part of a study on the chemical kinetics of submerged soils.

Soil Chemistry

Although much of the world's rice is grown on flooded land, the physiological reasons for the necessity of this practice are not clearly understood. Before flooded soils can be properly managed, the soil scientist must clarify his knowledge of the chemical processes that occur under anaerobic conditions. Indeed, the soil scientist and agronomist alike should question seriously the need for flooding rice soils and should direct major attention to this all-important question. Toward the answer to such problems, the Institute's soil chemistry research program is oriented.

With the intensification of rice culture, physiological diseases of rice associated with reducing conditions in the soil are assuming increasing importance. "Akiochi" and "akagare" in Japan, "penyakit merah" in Malaya, "mentek" in Indonesia, and "suffocating disease" in Taiwan are causing serious losses, if not crop failures. There is a strong suspicion that these diseases may be due to accumulation of reduced products, organic acids and other substances formed during the anaerobic decomposition of organic matter, but their identity and the environmental factors that favor their production are not known. A study of the anaerobic decomposition of organic matter under paddy field conditions is, therefore, a pressing necessity.

Submergence of the soil has a profound effect on the availability of nutrients and their losses. Chemical analysis of the dry soil, therefore, is of little use in predicting fertilizer needs or the danger of physiological diseases of rice. A kinetic approach is necessary. For this, new techniques for the analysis of reduced soils have to be developed.

The physical condition of flooded soils has received little attention in spite of the marked influences which the physical state of the soil can have on water and nutrient losses, diffusion of oxygen, and the accumulation of toxins. A knowledge of the physics of flooded soils is necessary for rational soil and water management.

The research program in soil chemistry is planned with a view to: (a) obtaining a deeper knowledge of the chemical, biochemical, and physicochemical changes that take place in flooded soils; and (b) understanding the behavior of the rice plant in terms of its peculiar chemical and physical environment. In 1962, research was initiated on (1) ionic equilibria in submerged soils with special reference to ferrous iron, (2) electrochemistry of submerged soils with emphasis on redox phenomena, (3) chemical kinetics of submerged soils, (4) iron nutrition, and (5) the water regime in rice soils.

Problems which will receive attention in the near future include: (1) the role of organic matter, the factors that influence its anaerobic decomposition, and the identification of the products of decomposition; (2) physical properties of puddled soils and their effects on the growth of rice; (3) liming; (4) silica nutrition of rice; (5) microenvironment of the rice roots; and (6) soil testing techniques for rice soils.

In the sections that follow, certain preliminary results of work done in 1962 are reported.

Ionic equilibria in submerged soils with special reference to iron

Although the reduction of iron is the most important chemical change that takes place in a flooded soil, there is little information on: (1) the distribution of ferrous iron between the solid and solution phases, (2) the distribution of soluble iron between the ionic and the complexed or chelated states, or on (3) the effects of varying Fe^{++} activity on cation exchange reactions. Studies of ionic equilibria should also provide information on the availability to the plant of NH_4^+, K^+, Fe^{++}, Mn^{++}, and HPO_4^{--}, the losses of these ions, and the problems of iron and hydrogen sulfide toxicities.

To permit the study of ionic equilibria in rice soils, techniques have been developed for preventing samples from coming in contact with oxygen, through the use of a nitrogen atmosphere. Progress was made on the development of techniques for equilibration of the soil solution and the solid phase, for clarification of the soil solution, and for abstraction of the cationic and anionic Fe^{++}.

Preliminary results indicated that in anaerobically incubated Maahas clay, the bulk of the soluble ferrous iron was present as cationic rather than complexed Fe^{++}. The concentrations of exchangeable iron and cationic Fe^{++} decreased as the pH increased (Table 1).

Table 1: *Influence of acid, alkali, and salt on the distribution of ferrous iron between exchangeable and soluble Fe^{++} in a Maahas clay incubated anaerobically for three weeks.*

Treatment	pH	Fe^{++} in soil solution (ppm)		Exchangeable Fe^{++} (ppm of soil)
		Cationic	Complexed	
H_2SO_4	6.3	398	0.7	18,700
$(NH_4)_2SO_4$	6.4	102	1.6	13,400
Control	6.9	116	0.6	12,600
NaOH	7.4	62	1.3	4,000

It is possible that the exchangeable Fe^{++} may be slightly high because some Fe^{++} could be brought into solution during the salt-leaching process by the dissociation of $Fe(OH)_2$.

Retardation of the reduction of a submerged soil by oxidizing agents

When a soil undergoes rapid or excessive reduction, a high concentration of reduced products, some of which are toxic to rice, is built up. The simple remedy of draining the soil may not always be feasible. Hence, the need for alternative methods of preventing physiological diseases of rice associated with reduction of the soil.

Among the numerous substances that can retard reduction are higher oxides, oxyacids and their salts. Since these were easily obtainable they were selected for use in this preliminary study.

Ten oxidants, at active oxygen concentrations of 0.05 per cent and 0.10 per cent of the soil were added to 10 grams of Maahas clay, pH 6.4, in flasks, and sufficient water was added to submerge the samples. After incubating the flasks at 30°C for periods of 2, 4, and 6 weeks, the extent of reduction was determined by estimating total ferrous iron extracted by an acetate buffer at pH 2.8.

The results obtained at an active oxygen concentration of 0.05 per cent are presented in the following table:

Table 2: *Increase in concentration of total reduced iron in ppm of Maahas clay soil, after addition of oxidants and incubation at 30°C for periods of 2, 4, and 6 weeks.*

Oxidant	Incubation time in weeks 2	4	6
Control	345	290	360
$KClO_3$	0	0	0
$KClO_4$	0	0	0
HNO_3	0	0	125
$NaNO_3$	0	175	280
NH_4NO_3	0	125	130
H_2O_2	340	340	540
MnO_2	290	290	390
$KMnO_4$	335	335	800

Potassium chlorate and perchlorate at an active oxygen concentration of 0.05 per cent prevented the reduction of the soil for at least six weeks. The nitrates behaved alike: they prevented reduction for two weeks, after which their effect was only a retarding action. The results obtained at an active oxygen concentration of 0.10 per cent essentially were the same as those obtained at 0.05 per cent except that in some instances the effects were prolonged. The most unexpected result of this experiment was the acceleration of reduction by manganese dioxide, hydrogen peroxide and potassium permanganate.

The action of these oxidizing agents can be explained in terms of their chemical stability. MnO_2, H_2O_2 and $KMnO_4$, owing to the ease with which they give up their oxygen, presumably degraded soil organic matter to simpler forms that served as a substrate for soil micro-organisms and, therefore, accelerated reduction instead of retarding it.

The relatively stable nitrates retarded reduction and lost their efficacy as they were used up. (The more marked effect of HNO_3 is due to depression of bacterial activity at low pH.) The stable oxysalts of chlorine, $KClO_3$, and $KClO_4$ completely prevented the reduction process without being expended. Hence, their action is probably bacteriocidal or bacteriostatic.

If potassium chlorate and perchlorate at about one-tenth of the rates used above should prove effective in retarding reduction and are non-toxic to rice, they may offer a simple practical remedy for physiological diseases associated with excessive reduction of the soil. They are relatively cheap chemicals which have the added advantage of containing potassium, an element that often alleviates these physiological diseases.

Retardation of nitrification by 2-chloro-6-trichloromethyl pyridine

If nitrogenous fertilizers such as ammonium sulfate — $(NH_4)_2SO_4$ — or urea — $CO(NH_2)_2$ — are top-dressed on a flooded rice crop, some of the ammoniacal nitrogen will be utilized directly by the plant; however, a considerable portion is converted to nitrites (NO_2^-) by *Nitrosomonas* bacteria in the thin oxidized surface layer of the soil. The nitrites are then readily oxidized to the nitrate (NO_3^-) form, primarily by *Nitrobacter*. These nitrates then move down into the soil, and undergo reduction with N_2 gas as the end product. NO and N_2O, though intermediates, are rarely found in flooded soils owing to the ease with which they are reduced to N_2. Portions of the nitrates, of course, may be leached and lost in the drainage water, or they may be utilized by the plant or by soil micro-organisms.

Losses of top-dressed ammoniacal nitrogen can be averted or minimized if nitrification of ammonium in the surface oxidized layer can be prevented or retarded. Chemical control of nitrification, by controlling *Nitrosomonas*, appeared possible with the new chemical, 2-chloro-6-trichloromethyl pyridine. Consequently, the chemical was evaluated in replicated laboratory tests at 0, 1, and 2 parts per million of soil in half-saturated, saturated and submerged soils with 0, 50 and 100 ppm added N as ammonium sulfate. The samples were incubated at 28°C, 32°C and 36°C and the NH_4 contents determined after three and six weeks.

The addition of one part per million of the chemical gave a highly significant average increase of 16 per cent of ammonium while the addition of two parts per million gave a highly significant average increase of 22.5 per cent. There was a decrease in nitrate production in the half-saturated and saturated soils as the level of the chemical increased, as would be expected. More importantly, retardation of nitrification by the chemical was more pronounced in the saturated and submerged soils than in the half-saturated (aerobic) soil (Table 3).

Table 3: *Percentage of added* NH_4 *recovered after six weeks incubation of half-saturated, saturated and submerged soils treated with 0, 1 and 2 parts of 2-chloro-6-trichloromethyl pyridine per million parts of soil.*

Concentration of chemical (ppm of soil)	Half-saturated	Saturated	Submerged
0	38.6	36.7	76.6
1	42.9	62.4	85.8
2	46.7	67.3	86.7

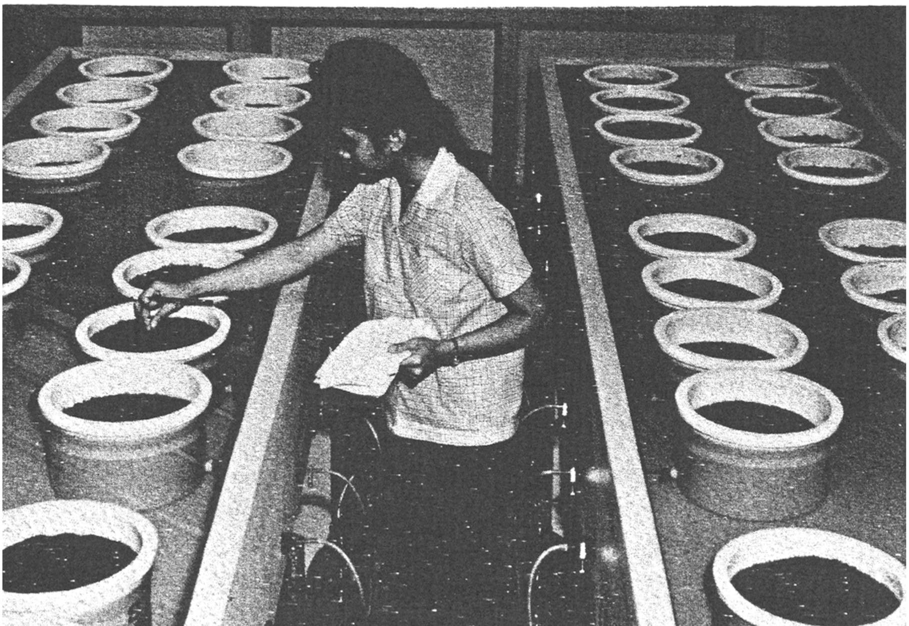
The effect of the chemical was least and lasted only three weeks in the half-saturated aerobic soils; it was marked and evident even after six weeks in the saturated, partially aerobic soils, as well as in the anaerobic, submerged soil samples.

These findings, if applicable under a variety of field conditions, would be of great practical significance. It would mean that considerable nitrogen losses in late applications on saturated or submerged soils could be prevented, and one of the major obstacles to production of rice in partially aerobic soils (*i. e.*, without standing water) would be overcome. For these reasons, this study will be continued and expanded.

Electrochemistry of submerged soils

When a soil is submerged, three important electrochemical changes take place: the redox potential decreases, and the pH and specific conductance increase. The magnitude and velocity of these changes are known to be governed by the soil, the nature and content of organic matter, and the duration of submergence, but quantitative interpretations are practically non-

Greenhouse studies of the effects of flooding.



existent. This is a result of insufficient knowledge about the redox systems in submerged soils and the underlying causes of the increases in pH and specific conductance. A thorough understanding of the physical chemistry of these changes is necessary if the high potential that these properties hold for diagnostic and interpretative purposes in rice culture is to be fully exploited.

Of the electrochemical changes initiated by submergence of a soil, the decrease in redox potential is the most important for it is the single electrochemical property that serves to differentiate an anaerobic soil from an aerobic soil.

The redox potential of a submerged soil is determined by the system that is present in excess. In the early stages of submergence, the potential is likely to be that of the oxygen system: $O_2 + 4H^+ + 4e^- = 2H_2O$. As the oxygen concentration falls and the soil undergoes reduction, other systems take over in their thermodynamic sequence. The most likely ones are the Fe^{+++}–Fe^{++}, MnO_2–Mn^{++}, NO_3^-–NO_2^- systems and certain organic systems involved in anaerobic respiration. These systems may be considerably modified by changes in pH, precipitation reactions, complexing and chelating agents and the presence of colloids. Thus, identifying the redox systems present in a submerged soil is a difficult task.

In this investigation, the following criteria for identification of redox systems are being used: (1) Eh; (2) dEh/dpH; (3) chemical analysis; and (4) specific conductance. Eh and dEh/dpH are being determined for several soils at successive stages of reduction in the presence and absence of organic matter of different kinds. Chemical analyses and conductance changes will be used to support the potential determinations .

During the year, satisfactory laboratory techniques for studying redox systems in flooded soils were identified using the ferric-ferrous system, since it is amenable to theoretical treatment and it may be the dominant system in submerged rice soils. These techniques were then applied to a preliminary study of the redox-potential-pH relationship of aerobic Maahas clay and the same soil incubated anaerobically for nine and 34 days.

The results indicate that the oxygen system is dominant in an aerobic Maahas clay. When this soil has undergone appreciable reduction, the operative system appears to be a modified version of the $Fe(OH)_3$–Fe^{++} system.

Iron nutrition of rice

There is abundant evidence that the apparent iron requirement of rice plants is considerably higher than that of other crop plants and that increased availability of iron is one of the important benefits of flooding rice soils. On the other hand, excess iron has been shown to be toxic to rice. There is, however, no information on the critical limits of deficiency and toxicity. The numerous studies reported in the literature suffer from one or more of the following drawbacks: (1) a strongly acid culture solution; (2) semi-aerobic environment; and (3) the use of stable chelates or complexes as the source of iron. Since the lower capacity of rice roots to take up iron is due probably to oxidation and precipitation of iron on or outside the roots, iron nutrition of rice must be studied in the context of factors that affect this reaction. Among them are: (1) concentration of iron; (2) pH of the medium; (3) kind and content of organic matter; (4) oxidizing power of the roots (variety); (5) the concentrations of Mn^{++}, NO_3^-, and HPO_4^{--}; and (6) temperature and light intensity.

The chief difficulty in a study of this kind is the prevention of oxidation and precipitation of iron in the culture solution. Previous workers attempted to overcome this by the artificial expedients of acidification or frequent changes of the solution and by the use of stable chelates of iron. In this study, a novel method of overcoming this difficulty is proposed, *viz.*, growing rice in anaerobic culture solution.

To accomplish this, plants were grown in pots which were fitted with paraffin-impregnated plaster of paris covers having a central hole 2 inches in diameter. Caps were sealed with molten paraffin and appropriate tubes were provided which would prevent influx of air but which permitted addition and regulation of the culture solution. A plastic foam plug impregnated with silicone oil, with a hole in the center, was used to support the seedlings.

Plants were grown in culture solutions of pH 7 having 5, 50, and 100 ppm iron as $FeSO_4$.

The rice plants tillered and grew normally, indicating that the silicone impregnated plastic foam was neither phytotoxic nor an impediment to tillering. Symptoms suggestive of iron toxicity were observed at 50 ppm and 100 ppm Fe, after one month. This shows that oxidation and precipitation of iron could not have been appreciable. In other words, little oxygen entered the system through the plastic foam plug. Examination of the solution, however, indicated the presence of a brown precipitate of $Fe(OH)_3$ showing that oxygen was not completely excluded. Next year, it is hoped to achieve complete exclusion of atmospheric oxygen by replacing the plastic foam plug with the new, room-temperature-vulcanizing, non-toxic, silicone rubber.

This technique holds great promise in the investigation of physiological diseases of rice. The effect of toxic components in the solution of a reduced soil on the rice plant cannot be tested in ordinary culture solutions owing to their instability in air. Anaerobic culture solutions will permit testing separately the cationic, anionic, and un-ionized components after their separation by ion-exchange chromatography. The toxic factor or factors can then be identified.

Water regime in rice soils

As stated earlier, although rice is almost universally grown on flooded soils, the physiological reasons for the necessity of this practice are not understood.

Among the possible physiological benefits of flooding are: (1) regulation of microclimate; (2) elimination of water stress; (3) effect of the water layer on tiller and ear primordia; (4) increased availability of iron, silicon, and phosphorus; and (5) absence of nitrate.

A greenhouse study was initiated late in 1962 to determine to what extent benefits of flooding can be achieved by chemical treatments.

In 1962, an outdoor facility was constructed for studying, in drums, the benefits of submergence and to determine if these benefits can be achieved with only a partially saturated profile; *i.e.*, a reduced amount of water. These experiments will be supplemented by field studies.

The results of these studies will be of the utmost practical significance in rice production. If rice can be grown in a partially saturated or saturated soil without standing water, the water requirements of rice will be reduced by over 50 per cent, enabling the extension of rice acreages, with existing irrigation facilities. It will also provide the simplest remedy for the numerous physiological diseases of rice associated with reduced soils.

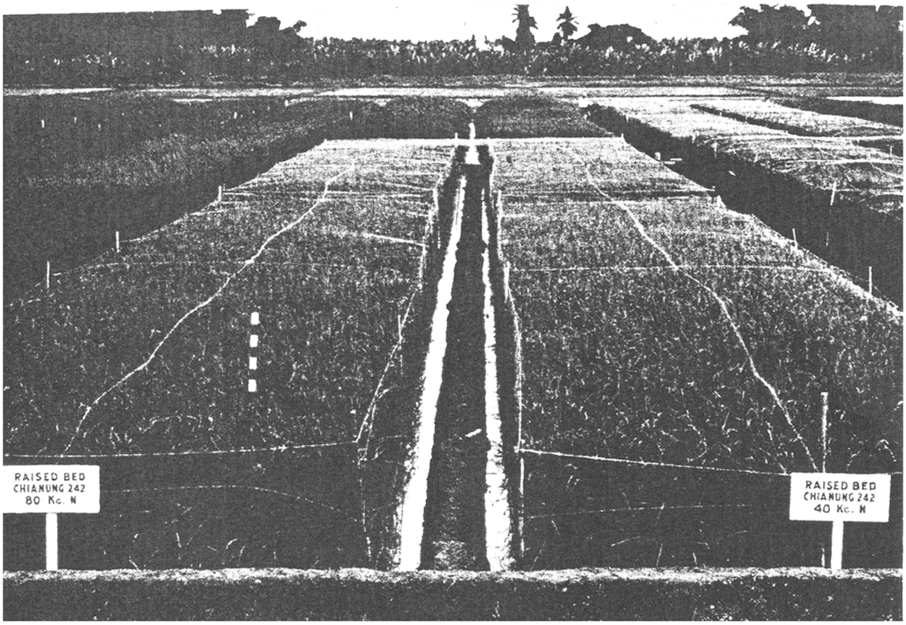


Figure 11. The lodging-resistant *japonica* variety Chianung 242 from Taiwan, in an experiment involving four levels of nitrogen fertilization and three systems of water management, produced an average of 4,739 kg./ha. of dry grain in 111 days after seeding. Lack of grain dormancy, however, makes the variety unsuitable for general use in the humid tropics. The nylon netting prevented damage by birds.

Agronomy

High yield experiment

During the year, results were obtained from a yield trial involving two varieties — the *japonica* Chianung-242 from Taiwan, and the Philippine *indica* FB-121 — grown under three different water regimes and at four levels of nitrogen fertilization. In this experiment, an attempt was made to apply the best known practices, even though they might be too costly to use on a field scale. Information obtained from other Institute experiments in 1962 indicates that a number of the measures chosen were not optimum, and the appropriate changes will be incorporated in future trials of this type which are expected to continue indefinitely.

The seeds of each variety were sown May 24 in a heavily fertilized seed bed, and were transplanted in the main field 18 days later.

Four tons of horse manure, 2 tons of milled rice straw, and added fertilizer were plowed under. The manure and straw contributed a total of about 32 kg. nitrogen, 36 kg. P_2O_5, and 288 kg. SiO_2 per hectare. In addition, commercial fertilizers containing 40 kg./ha. of P_2O_5 and 40 kg./ha. of K_2O were plowed under on all plots.

Four levels of nitrogen fertilization were employed, as follows: (1) 40 kg. nitrogen at planting; (2) 80 kg. nitrogen at planting; (3) 60 kg. nitrogen at planting plus 60 kg. nitrogen, 40 kg. P_2O_5, and 40 kg. K_2O at ear initiation; and (4) 80 kg. nitrogen at planting plus 80 kg. nitrogen, 40 kg. P_2O_5, and 40 kg. K_2O at ear initiation.

Chianung-242 was harvested 111 days after sowing (Figure 11). No significant differences in yield were obtained (Table 4), but the production of an average of 4739 kg./ha. of dry rough rice in a period of only 111 days was notable, and indicates the potential value in the tropics of early maturing, lodging resistant, photoperiod insensitive varieties. Failure to obtain significant differences in yield associated with the high levels in nitrogen fertilization in this experiment is not surprising, since it is shown elsewhere (see Figure 10) that 60 kg./ha. of added nitrogen was optimum for Tainan-3, a variety similar to Chianung-242.

Table 4: *Average yields in kilograms per hectare and other characteristics of the japonica variety Chianung-242 from Taiwan, under three systems of water management, and over four levels of nitrogen fertilization, IRRI, May 24-September 11, 1962.*

Water Treatment	Height at Maturity (cm.)	Unfilled grains (%)	Grain-straw ratio	Weight 1000 seeds (gm.)	Yield of dry rough rice [1] (kg./ha.)
Continuous submergence	143	20.2	.769	27.1	4809
Alternate flooding	138	13.7	.773	28.0	4513
Raised bed	131	10.3	.847	29.2	4896

[1] *Differences among yield means were not statistically significant.*

Also important was the finding that the yields with the "raised bed" treatment (no flooding) were as good as those obtained with continuous submergence. This is the Institute's first direct, though preliminary, evidence that flooding may not be a requisite for high production of rice.

Yields of FB-121, which was harvested 171 days after sowing, were disappointingly low (Table 5).

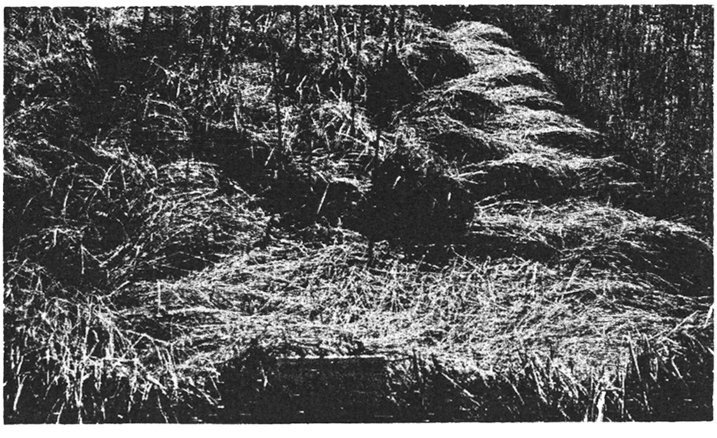


Figure 12. The *indica* variety FB - 121 produced only 1,872 kg./ha. of dry grain in 171 days in a test involving four high levels of nitrogen fertilization and a spacing of 20 x 20 cm. Note the severe lodging.

Table 5: *Average yields in kilograms per hectare of the Philippine indica variety FB-121 at four levels of nitrogen fertilization and under three systems of water management, IRRI, May 24-November 9, 1962.*

Water Treatment	Average yield in kg./ha. of dry rough rice Nitrogen level (kg./ha.) [1]				
	40	80	120	160	Mean
Continuous Submergence	2443	1766	1902	1168	1819
Alternate flooding	2564	1336	1533	1230	1666
Raised bed	2855	2791	1481	1391	2130

[1] *Plus 32 kg./ha. of nitrogen in rice straw and horse manure plowed under prior to planting.*

The minimum amount of nitrogen applied to any plot was at least 72 kg./ha.—32 kg. from the manure and rice straw plus 40 kg. in the fertilizer — and there undoubtedly was additional nitrogen present in the soil at the time of land preparation. Data obtained in another experiment (see Figure 10) with a variety (Peta) similar to FB-121 indicate that even the lowest nitrogen level utilized in this trial was far too high for FB-121, at least at a spacing of 20 x 20 cm.

Crop plants for use in rotations or as green manures

The development of cropping systems which allow maximum food production per unit of land per year already is advanced in certain countries, including Taiwan and Japan. However, in Southeast Asia there has been relatively little research on rotations or on the other crops such as corn, sorghum, or the legumes which might be useful in cropping systems involving rice.

During the year, 92 accessions of more than 40 species of legumes were received by the Institute for evaluation. These came primarily from the Philippines and Taiwan and from Cambodia and the United States. Initial plantings were made in an introduction garden and phenological data and yields were obtained. Preliminary results indicated that *Crotalaria juncea* and *Sesbania sesban* (*S. aculeata*) are suitable as green manures (Figure 13), and production of seed was begun to supplement importations from Taiwan. Also, two varieties of cowpea and three of soybean appeared promising.

Eight species of legumes were planted in a replicated trial under two water treatments to determine the practicability of legume culture under flooded conditions. Only *Sesbania* sp. and *Phaseolus lathyroides* grew well under such conditions.

Weed control

Control of weeds in Asian rice fields is accomplished by use of thorough tillage, a layer of flood water, by hand weeding, by use of small push-type weeders, or frequently by a combination of these practices. In upland rice, weed control is particularly difficult and usually involves a great amount of tedious labor. Often the weeds are not adequately controlled and yields obviously are reduced.

In recent years, interest in chemical weed control has intensified with the introduction on the market of herbicides which kill most objectionable grasses in rice fields

Figure 13. *Crotolaria juncea* appears suitable for use as a green manure at the Institute.

without seriously affecting the crop. The use of herbicides already has gained wide acceptance among farmers in the United States and Japan. Their adoption in the tropical countries will probably be slower because of the present relatively high cost of the chemicals, lack of simple equipment for their application and the various difficulties in explaining to farmers their proper use. Nevertheless, certain newer herbicides may become particularly valuable for upland rice crops, or for lowland rice in certain areas if their use will permit a reduction in irrigation water requirements.

One of the newer herbicides, DPA, was tested at rates of 1, 2, 4, 8, and 16 kg./ha. on five varieties of rice grown under upland and lowland conditions. The reduction of weed populations appeared to be satisfactory at about the recommended rate of 3 kg./ha., although the degree of control of *Echinochloa spp.* and other major weed species was less than has been reported in other countries. Trials of DPA under a variety of field conditions are being continued.

Since DPA apparently does not effectively control certain broad-leaf weeds, the herbicide 2, 4-D also is being tested in combination with DPA.

A number of even newer herbicides, some still in the experimental stage, are being evaluated; late in 1962, a field trial was installed to test 66 substances of interest. It is hoped that with the advent of cheaper, more selective, and more effective herbicides, chemical weed control in the tropics will become economically feasible.

Figure 14. Testing seedlings of varieties for reaction to *Piricularia oryzae*. Note border rows of the susceptible spreader variety.

Plant Pathology

Rice blast

The rice blast disease, like the rusts of wheat in the Western Hemisphere, is of major concern in all rice-growing countries. The complex problems of physiological races of the causal organism, of the varietal resistance to the disease and its nature and genetics, of the alternate hosts, and of the possibilities of control with antibiotics or other chemicals merit immediate and careful study.

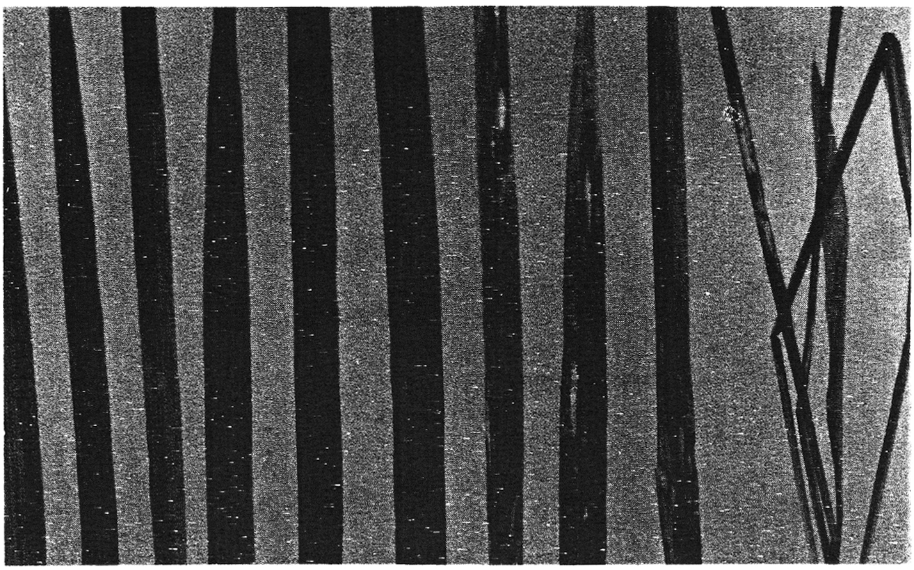
Development of resistant varieties is being pressed at the Institute and encouraged elsewhere in the Philippines and in other countries. The study of the races will require cooperative research among Asian pathologists and geneticists on a scale apparently unprecedented in agriculture in the region.

Blast is most likely to occur in serious proportions when a susceptible variety is used, when the soil fertility level is high, and when rainfall is abundant. Other factors, such as a high number of plants per unit area and prolonged periods of cloudy weather may also predispose a variety to blast attack. In other words, the very practices which farmers in the tropics are being urged to adopt — higher fertility levels and larger numbers of plants per unit area — may present a new and serious problem unless resistant varieties are made available. Consequently, plant breeders should screen all new experimental or introduced varieties for resistance to blast before they are released to farmers.

Fortunately, the testing of the seedling reaction to blast is a simple procedure. At the Institute, seeds of varieties are planted about 10 cm. apart in single rows ½ meter long (Figure 14). Single rows of a susceptible check or spreader variety are alternated with two rows of varieties being tested. Two or three rows of the spreader variety are planted around the outer edge of the nursery bed. Water is applied frequently and fertility is kept at a high level.

In 1962, a blast nursery area was constructed at the Institute which allows the testing of 2,000 varieties or lines at any one time. A number of varieties were checked for reaction, including 707 from a Philippine collection, 258 commercially important varieties submitted by nine countries (Ceylon, India, Japan, Malaya, Philippines, Taiwan, Thailand, the United States, and Viet-Nam) and 116 varieties from the U.S. Department of Agriculture International Blast Nursery. Late in the year, 71 varieties from ten countries, forming the FAO Uniform Blast Nursery, and about 170 other varieties from Japan, Okinawa, and Indonesia were being evaluated. In addition, 666 varieties which are considered as among the best from the 5,800 observed by the Varietal Improvement group in 1962 are being studied for their reactions.

Figure 15. Varieties vary in reaction to *Piricularia oryzae* from highly resistant (left) to highly susceptible (right).



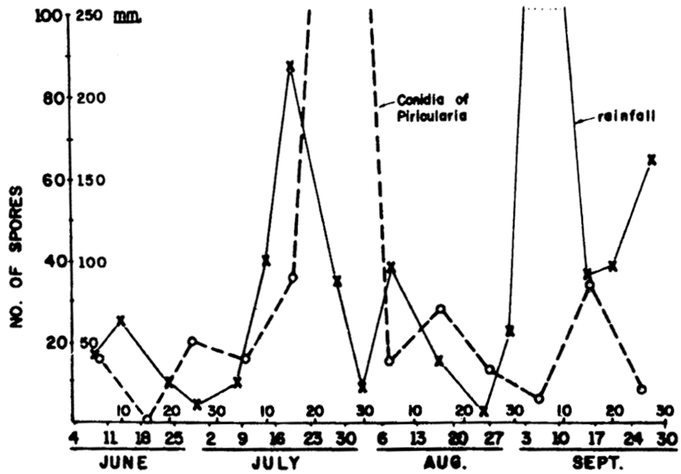


Figure 16. Number of spores (conidia) of *Piricularia* trapped on slides at IRRI by ten-day periods, and the weekly rainfall, June-September 1962.

In each group of varieties that has been studied, reactions have varied from very susceptible to very resistant (Figure 15). Many varieties have been giving a resistant reaction. A number of *japonica* varieties which are susceptible in Taiwan are highly resistant in the Philippines, and some of the resistant *indicas* from that country are very susceptible in the Philippines. In another group of 69 varieties from Japan, 32 were considered resistant in that country, based on the report from Japan to the International Rice Commission working party of 1959 held in Ceylon. In the Philippines, the reactions were as follows: 21 resistant; two intermediate; nine susceptible. Of the nine varieties classified as intermediate in Japan, six were resistant, and three were susceptible in the Philippines. And, of the 28 considered susceptible in Japan, 23 were resistant, two were intermediate, and three were susceptible at the Institute. Many of the varieties from these two countries showed much changed reaction to blast in the Philippines.

In the United States, a set of ten differential varieties is used for the classification of races of *Piricularia oryzae*. All ten of these appear resistant in the Philippines, at least in the seedling stage. In Japan, 12 differential varieties were used, and of these, six were resistant, four were intermediate in reaction, and two were susceptible in the Philippines.

Studies of physiological races of *Piricularia oryzae* have been carried out independently in several countries including Japan, the United States, and Taiwan. Sixteen races have been identified in the United States and Central America. In Japan, 14 have already been separated but the differential rice varieties used were not the same as those employed in the United States. To promote international cooperation on the problem, and to design an international blast research program, a small group of Japanese and Indian scientists met with the Institute staff in November. Meanwhile, in preparation for the study of races at the Institute, a collection of blast samples throughout the Philippines has been initiated.

Early in the year, a spore trap was placed in the field, and slides were exposed and examined daily for spores of *Piricularia* and other fungi. There appeared to be an association between the increase or decrease of the airborne conidia of *Piricularia* with amounts of rainfall (Figure 16).

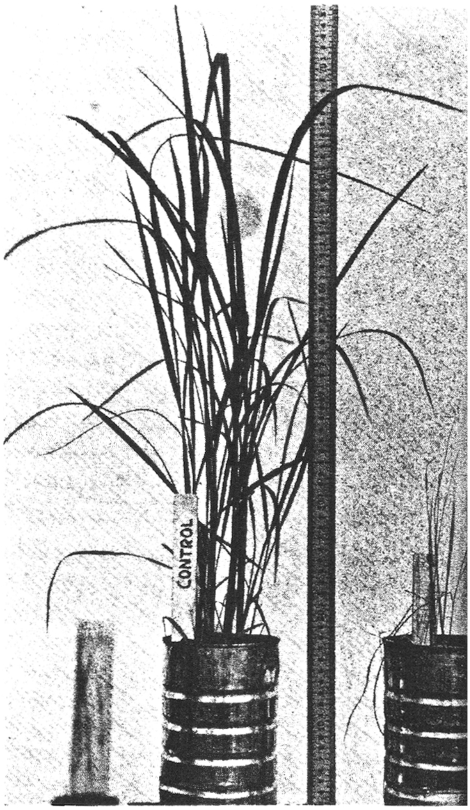
At least 15 species of hosts of *Piricularia* have been accumulated. These will be used for the study of the host range of the various species of *Piricularia*. The fungus found on each of the host plants has already been isolated.

Virus diseases of rice

Several virus diseases of rice have been observed in the experimental plots of the Institute and in other parts of the Philippines. By their symptoms, several types may be distinguished including mosaic, stunt (dwarf), and yellow dwarf.

Another disease occurs in which the leaf color of the affected plant may range from shades of orange to yellow, depending upon the variety. Plants of some varieties are stunted and die if infected early. This latter disease, probably a virus, was particularly destructive in the world variety collection plots of the Institute in 1962. It was also observed in other localities in the Philippines both in lowland and in upland rice fields.

Because of the destructiveness of the disease, transmission studies were begun immediately—testing seed, mechanical means, and several insects (leafhoppers, aphids, and mites). During the course of these studies, a collection of the general adult population of rice leafhoppers was caged with healthy plants of the Nahng Mon S-4 variety of rice which had proved to be particularly susceptible to the disease in the field. In a few of these plants, symptoms of the disease were observed 10-15 days after caging. Thereafter, individual species of leafhoppers were caged with separate plants. These tests implicated the leafhoppers *Nephotettix apicalis motsch, Nephotettix bipunctatus* F, and *Cicadella spectra* Distant, while the plants caged with other species did not show symptoms. Further experiments with *Nephotettix* were conducted until finally, single leafhoppers were caged on the first leaf of plants and symptoms similar to those found in the field were developed in higher leaves 6-10 days later. Further studies of the disease are underway to remove any doubts concerning its nature, to develop resistant varieties, and by studies of the life cycles of the implicated leafhoppers, to find other means of control.



Differences between control plants and plants exposed to leafhoppers previously fed on plants showing symptoms of the disease called "orange-leaf." Both plants are one month of age.

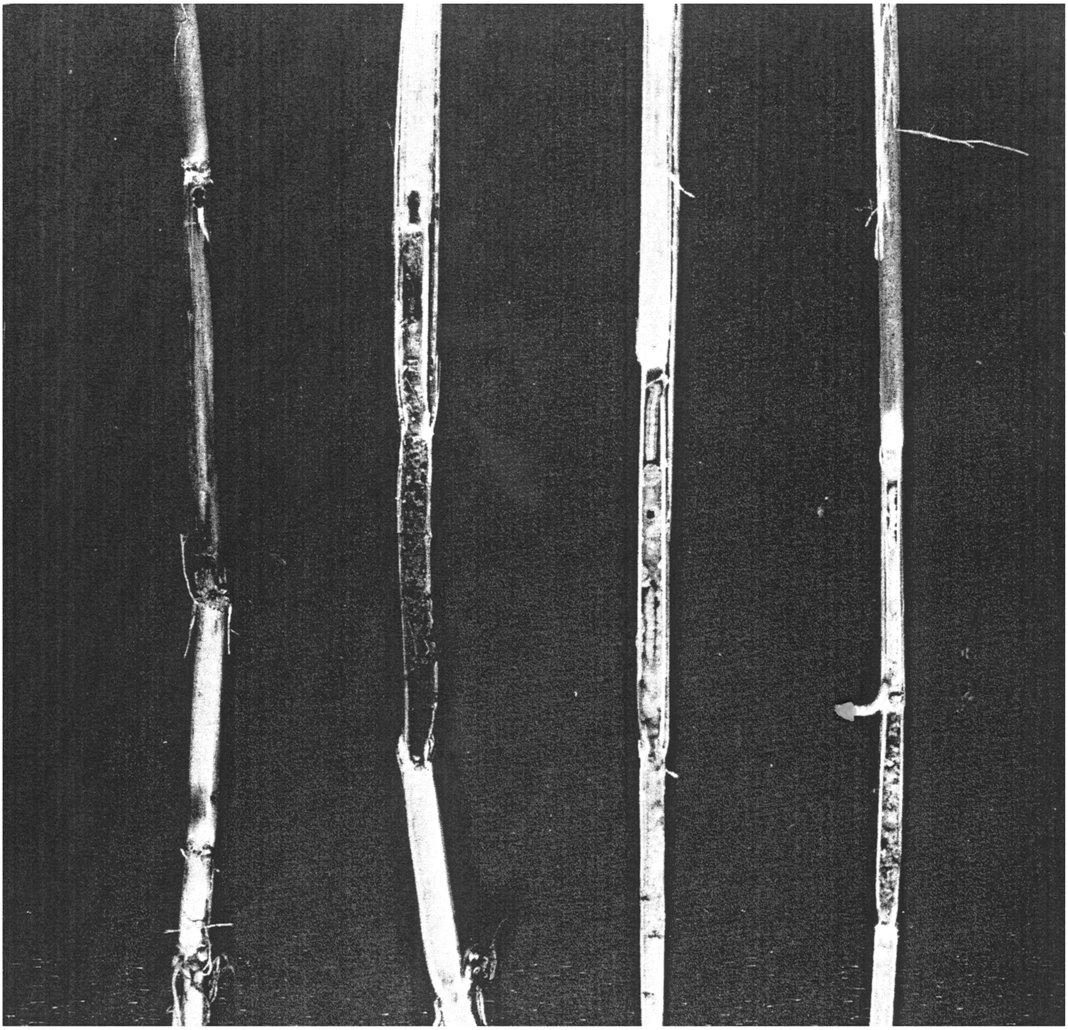


Figure 17. "Exit holes" made by stem borer larvae and the feeding galleries within the stems.

Entomology

The rice stem borers

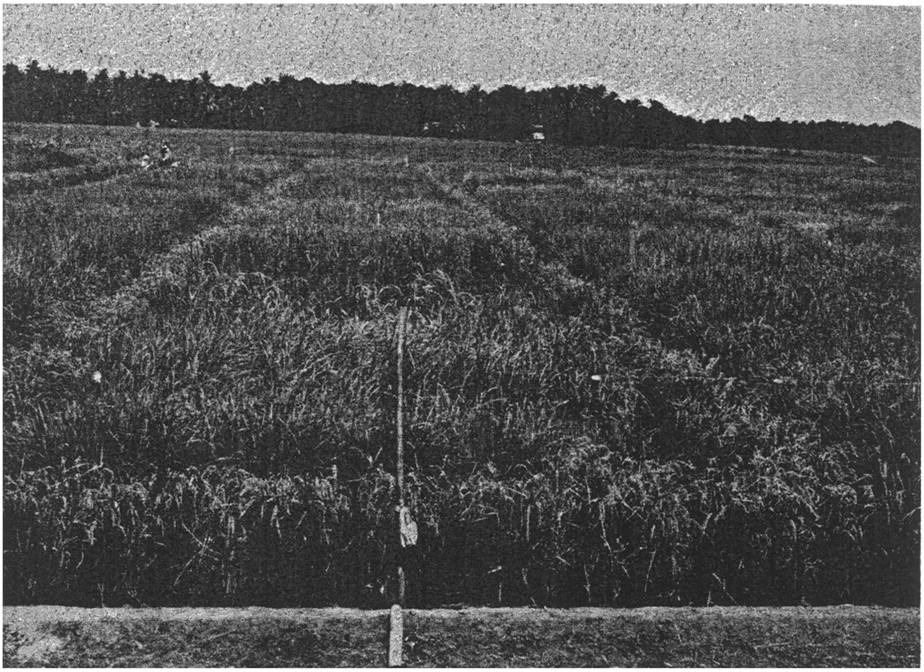
About 100 species of insects are known to feed on rice plants in the field. Of these, the stem borers are the most destructive in almost all rice-growing areas of Asia and, in spite of conventional methods of control with chemicals, an important percentage of the crop is lost because of the damage the borers cause. The use of insecticides is the only practical control measure known, but insecticides often are washed off by frequent rains in the tropics, and the insect spends most of its life within the plant (Figure 17), thus minimizing the time when contact insecticides are effective. Mammalian toxicities of many insecticides, coupled with their cost and the inconvenience of repeated applications, also diminish their utility.

The rice stem borer complex consists of at least five important lepidopterous species. Three of these species, *Chilo suppressalis* Walker, *Schoenobius incertulas* Walker, and Sesamia inferens Walker, have been recorded as occurring in the vicinity of the Institute. *Chilo suppressalis* Walker constitutes 90-94% of the natural borer population in this area. This species has, therefore, been the major test-insect in the several trials reported here.

Resistance of rice varieties to the stem borer

One approach to control of the stem borer is the development, if possible, of tolerant or resistant varieties. During the year, 243 rice varieties were planted in a three-replicate test in the field, and an additional replicate was artificially infested in the greenhouse. In the field, the percentage of "dead hearts" or dead young tillers (Figure 18) ranged from 2.6 to about 25 per cent at harvest; percentage of infested stems varied from an encouraging 8.4 to about 49 per cent (Table 6).

Figure 18. "Dead hearts" in young plants (left) and "white heads" in mature plants (right) are caused by feeding of the stem borer larvae in the stems of rice plants.



In a three-replicate field test, 243 varieties were screened for resistance to the stem borer. At harvest, the percentage of infested stems in the different varieties ranged from nine to 49 per cent.

Table 6: *Percentage of dead hearts, and white heads (empty panicles), percentage of infested stems and percentage of living larvae per hill at harvest, for twelve varieties of rice.*

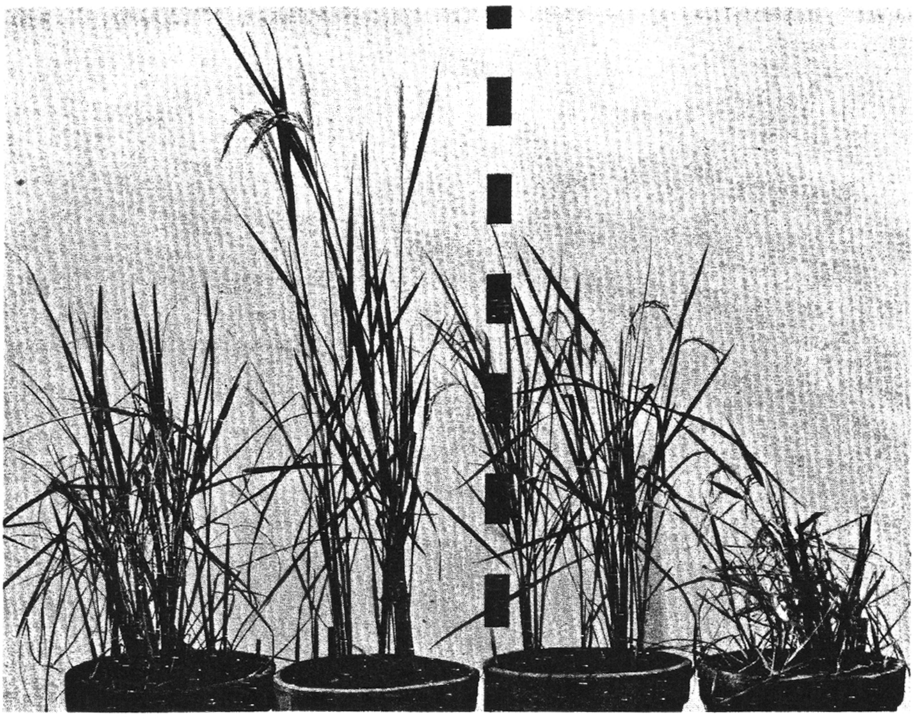
	PERCENTAGES			
Variety	**Dead hearts**	**White heads**	**Infested stems**	**Living larvae**
Ginmasari	2.6	1.3	8.7	0.3
Chianan-2	2.8	3.2	21.5	2.1
Taitung-16	4.4	2.1	17.9	1.3
Caloro	4.3	1.6	8.4	0.3
Kwanfu-401	4.1	2.3	19.5	1.3
I-geo-tze	7.9	6.7	15.0	0.1
Radin Kling	17.5	6.1	42.1	5.4
Nhta-5	16.1	4.6	38.2	4.3
Sapan Kwai-3	12.6	4.1	47.5	9.9
FK-165	12.3	4.1	49.5	5.8
Machang	22.9	Further data awaited		
Mayang Sagumpal-16	26.7	Further data awaited		

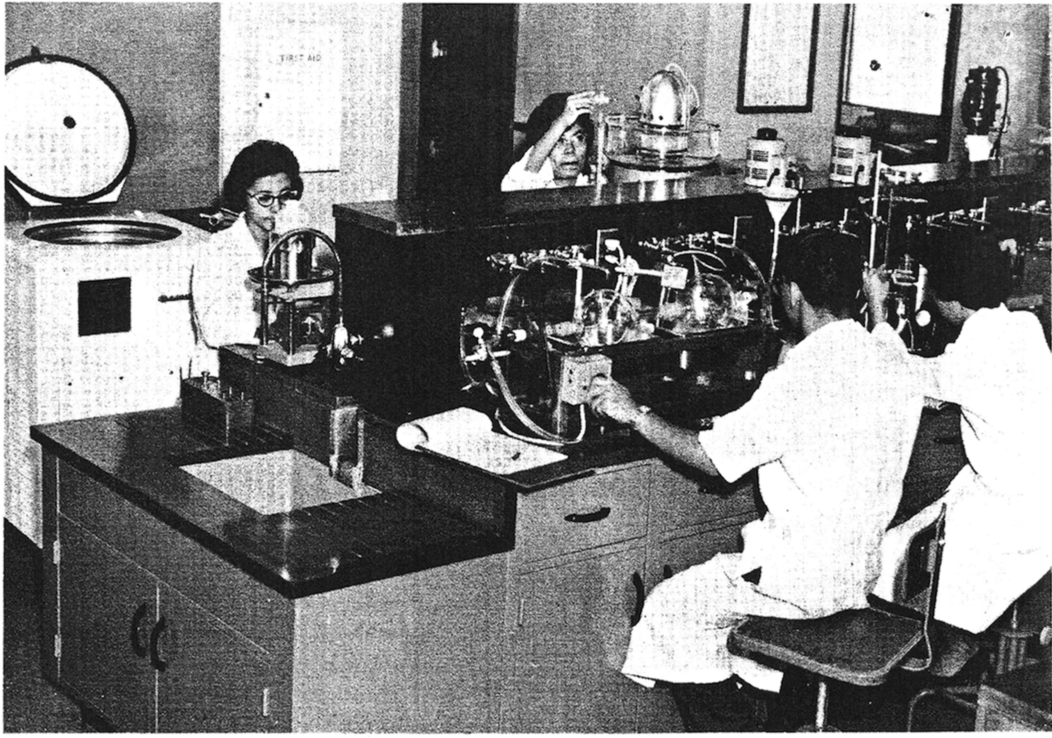
A number of varieties which suffered most and least damage in the above field test were then artificially infested with freshly hatched larvae in the laboratory. Apical parts of the stems, cut into 2-inch pieces, were placed in jars, the larvae were introduced, then the stems were changed every few days. Temperature and moisture were carefully controlled. Preliminary data indicate a higher mortality of the larvae on the varieties Ginmasari, Chianan-2, and Taitung-16, while there was a greater survival on Machang, Mayang Sagumpal-16, and Sapan Kwai-3. It is encouraging to note that the former varieties appeared more resistant and the latter more susceptible in the field trial. However, the data are only suggestive and the demonstration of effective resistance will require additional field and laboratory tests under a variety of conditions.

Effectiveness of insecticides

Screening of a number of insecticides also was initiated late in 1962. The most practical insecticide for borer control would be one having a long residual effect, some penetration in plant tissues, and low mammalian toxicity. In preliminary field trials, three appeared promising, while two others may be useful in controlling the rice stem maggot. Other tests in progress will provide information on the timing of spray applications and the minimum effective number of sprayings. A one-man spray boom is being developed which will direct the insecticide toward the underside of the plants as well as toward the tops of the leaves.

Variation in performance in the greenhouse of varieties infested with equal numbers of stem borer larvae.





Studies of the chemical basis of rice quality are conducted in modern laboratories.

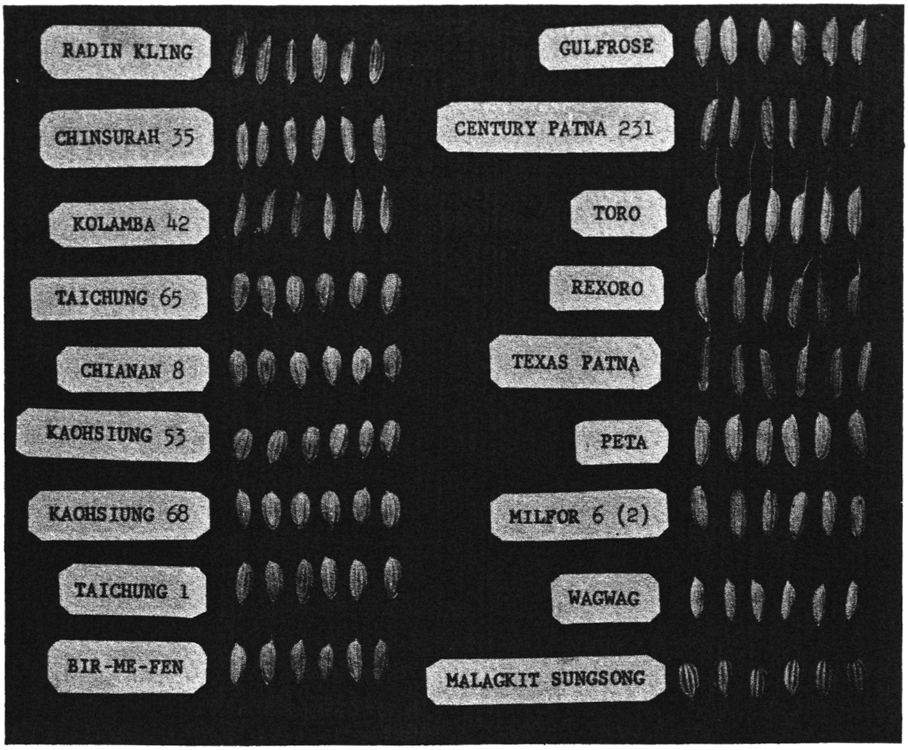
Chemistry

Studies of the eating and cooking quality of rice have been conducted at a number of institutions in various countries, yet the relationships between chemical composition of the kernel and cooking characteristics, milling losses, texture, or nutritional value are not well understood. Consequently, the organic chemist and three research assistants are devoting full attention to factors responsible for variations in rice quality.

Sixteen varieties were grown under comparable conditions during the 1962 dry season, and rough, brown, and polished rice grain samples of each were analyzed in duplicate for chemical composition by standard laboratory methods. Data on the samples of polished rice (Table 7) revealed a wide range in protein content and considerable variability in crude fiber and pentosans values. The polished rice of Rexoro had an extremely high protein content of 12.54 per cent, whereas the popular Philippine variety Peta was lowest with 6.52 per cent.

In brown rice, percentages of fat ranged from 2.37 for Peta to 3.11 for Texas Patna; percentages of ash varied from 1.53 in Peta to 2.13 in Century Patna 231; and the lowest and highest crude fiber values were 0.82 and 1.46 for Peta and Taichung 1. The values are in agreement with published results which show that most of the crude fiber and much of the ash of rough rice is in the hull and that most of the fat is concentrated in the bran-polish fraction, which is also high in ash.

Preliminary cooking quality tests included



Grain characteristics of varieties used in quality studies in 1962.

determination of gelatinization temperature, of Brabender amylograph viscosity, of starch amylose, and of alkali spreading and clearing. The *japonica* varieties had lower gelatinization temperatures and setback values than had the *indicas*. The U.S. varieties had generally higher gelatinization temperatures than commonly are reported in the United States.

During the year, the organic chemist visited most of the laboratories in the United States which are, or have been, engaged in, rice quality studies. An exchange of standard samples with the Rice Quality Laboratory, Beaumont, Texas has been arranged. This is important since it will allow the complete correlation of empirical quality tests done at the two laboratories.

A number of additional studies were initiated late in 1962. Twenty-three varieties, including all those in Table 7, except Milfor 6 (2), were grown during the 1962 wet season and values from chemical analyses and quality tests are being compared with the results for the same varieties grown during the previous dry season.

In view of the wide variation in crude protein among the varieties analyzed, total amino acid analyses of these polished rices are in progress using the Beckman Model 120 B Amino Acid Analyzer. Preliminary results on the chromatography of the amino acids reveal slight differences in their relative proportions among these varieties. The levels of essential amino acids in polished rice are of particular interest.

Further work on the "hemicelluloses" is in progress to determine whether the varietal differences in pentosans content also involve differences in hemicellulose composition. For example, the determination of the arabinose to xylose ratio is being attempted by quantitative paper chromatography without prior isolation of the hemicellulose fraction. The hydrolysis of rice powder of the Peta variety has been followed polarimetrically and aliquots have been analyzed by chromatography during the course of the hydrolysis. In preliminary runs using pure glucose, arabinose and xylose (198:1:1), the irrigation solvent system, ethyl acetate: pyridine:water (8:2:1), gave complete separations of these sugars by paper chromatography for 24 hours. Alkaline silver nitrate was the most sensitive spray reagent.

For studies of the glutinous cooking characteristic, a waxy and a common *japonica* rice, Taichung-46 (glutinous) and Taichung-65, respectively, were obtained from Taiwan. The seed of each is being multiplied along with their *indica* counterparts, Malagkit Sungsong and Peta or Wagwag. Later the various kernel constituents, particularly carbohydrates, proteins, and lipids, will be determined by chemical analysis. Extraction of the rice bran oil from the Taiwan glutinous and non-glutinous varieties allows a study of possible differences in their fatty acid composition by gas liquid chromatography.

Exploratory work is underway on the influence of various environmental factors on the physical and chemical changes accompanying storage of rough rice.

The biochemist arrived at the Institute in mid-July, and later in 1962 studies were initiated on nitrogen metabolism and diagnostic measures of the nutritional status of the plant, on the enzymatic mechanism of starch biosynthesis in developing rice grain, on the biosynthesis of lysine, and on a comparative study of polyphenolic compounds in *indica* and *japonica* varieties.

Table 7: *Proximate percentage composition of polished rice, dry basis, of 16 varieties grown during the 1962 dry season.*

Variety	Origin	Subspecies	Grain Shape	Proximate Analysis					
				NFE	Nx5.95	Crude fat	Crude fiber	Ash	Pentosans
Radin Kling	Malaya	indica	medium	91.42	7.37	0.54	0.13	0.54	1.11
Chinsurah-35	India	indica	medium	90.12	8.49	0.49	0.40	0.50	1.82
Kolamba-42	India	indica	medium	87.81	10.68	0.39	0.45	0.67	1.58
Taichung-65	Taiwan	japonica	short	89.90	8.70	0.54	0.24	0.62	0.91
Chianan-8	Taiwan	japonica	short	90.83	7.86	0.47	0.30	0.54	1.37
Kaohsiung-53	Taiwan	japonica	short	90.12	8.47	0.47	0.44	0.50	1.64
Kaohsiung-68	Taiwan	japonica	short	89.74	9.08	0.45	0.26	0.47	1.92
Taichung-1	Taiwan	indica	medium	88.57	10.19	0.38	0.34	0.52	1.14
Bir-me-fen	Taiwan	indica	medium	89.15	9.74	0.31	0.28	0.52	1.19
Gulfrose	U.S.A.	indica	medium	86.22	12.09	0.48	0.54	0.67	1.15
Century Patna 231	U.S.A.	hybrid	long	86.25	12.22	0.40	0.39	0.74	1.16
Toro	U.S.A.	indica	long	87.20	11.39	0.46	0.34	0.61	1.26
Rexoro	U.S.A.	indica	long	86.19	12.54	0.40	0.29	0.58	1.30
Texas Patna	U.S.A.	indica	long	86.50	12.12	0.44	0.34	0.60	1.56
Peta	Philippines	indica	medium	92.56	6.52	0.32	0.20	0.40	1.43
Milfor 6 (2)	Philippines	indica	medium	90.40	8.38	0.40	0.45	0.44	1.45

Visiting Scientists

Dr. Ellis F. Wallihan, Associate Professor of Agricultural Chemistry, University of California, joined the soil chemistry laboratory on August 1, 1962. His program includes the following topics: (1) iron nutrition of rice at different oxygen tensions; (2) water stress and the growth of rice; (3) critical level of nitrogen in rice leaves.

Dr. Edward H. Tyner, Professor of Soils, currently on sabbatical leave from the University of Illinois, has been assigned to the Institute by The Rockefeller Foundation. During his one-year residence as Visiting Soil Scientist, he will work on the distribution of various phosphorus forms in the paddy soils of Southeast Asia, with particular reference to the factors of parent materials and age as these influence the equilibria phosphorus forms in paddy soils.

This investigation is designed to further an understanding of the paradoxical behavior of lowland rice, as contrasted with that of upland crops, to phosphate fertilization in major rice production areas. Another objective is to establish criteria for soil phosphorus tests that might prove useful in delineating areas of phosphate response.

Soil samples applicable to the objectives of the investigations have recently been collected in Indonesia in cooperation with personnel of the Soil Research Institute at Bogor, and in Australia from the Darwin, Ord River and New South Wales rice production areas. In conjunction with the collection of soil samples in the southern hemisphere, Dr. Tyner represented the Institute at the New Zealand Conference of the International Society of Soil Science, where he presented a paper dealing with some aspects of the problem of evaluating soil phosphorus tests for lowland rice soils.

The Experimental Farm

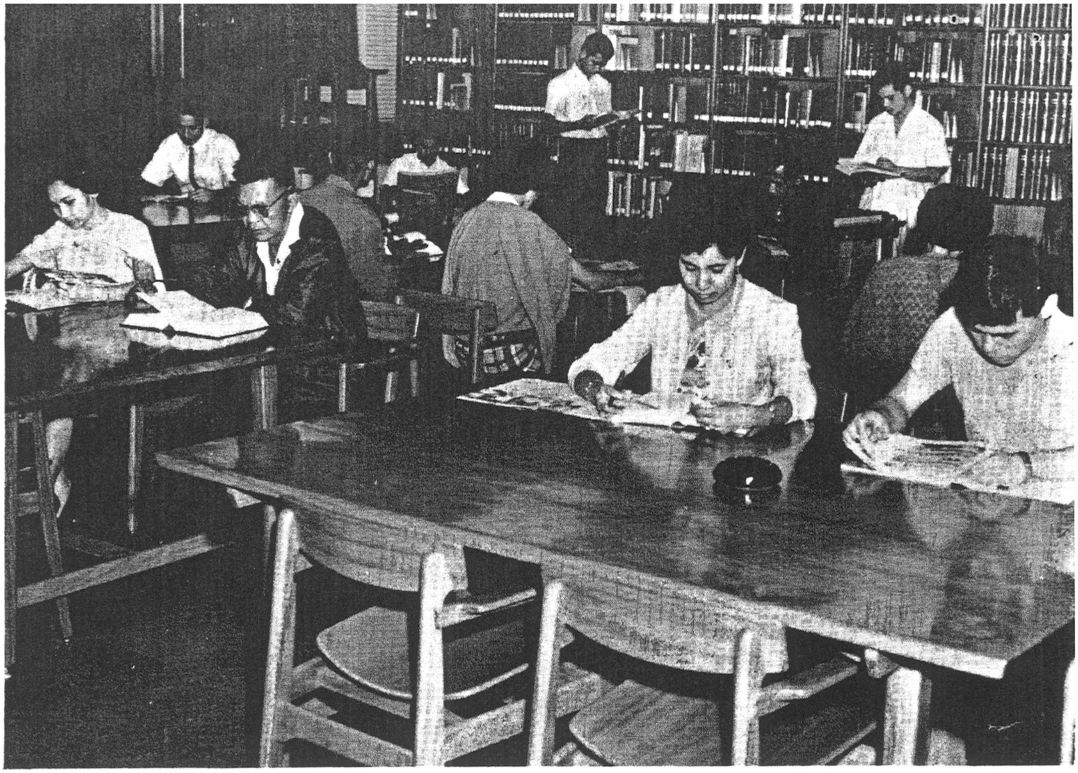
Most of the 200-acre farm was fully developed during the year under the general supervision of the agricultural engineer. An underground concrete-pipe irrigation system and a surface drainage system now serve the Institute's lowland rice areas. Roads, reservoirs for cooling the warm water from one of the four deep wells, and a compost shed, also were completed.

Approximately 100 laborers, plus seven equipment operators and two foremen assisted the Farm Superintendent and Assistant Superintendent during the year. In November, however, the number of laborers was reduced to 70 since most developmental work had been completed.

The use of PCP (pentachlorophenol) was adopted for controlling weeds on levees and along waterways, roadways, and the fence line. This has assisted materially in keeping the farm neat.

Birds and rats continue to be a problem. However, the use of plastic tapes in the fields and of nylon nets stretched over valuable plots help keep the birds away.

As a public service, the Institute continued to produce certified seed, primarily of the lowland varieties Peta and BPI-76, on 34 hectares of land not required for research use. However, increasing demands for land for research in 1963 will substantially reduce the amount of land available for seed production and the Institute may soon be forced to cease this activity.



The library reading room

The Library

One of the major objectives of the Institute is the development of the world's most comprehensive collection of technical rice literature for the benefit of scientists and scholars everywhere. The Institute recognizes the fact that a library is essential in any organization engaged in scientific research.

Towards this end, the Library, within the short period of eight months, collected, classified, and cataloged many volumes of materials which are now being used by students, scientists and research workers engaged in the pursuit of knowledge about rice and allied subjects.

At the end of the working day on October 31, 1962, there were 4,963 classified and cataloged volumes in the Library, representing books, reprints, and fiction, and 205 phonograph records, not to mention 2,100 additional reprints still to be sorted and processed. There were also about 5,000 articles on rice in microfilm for mounting in aperture cards. Translations numbered 402, of which 34 were done by the Institute's translators in Japan. Catalog card production totalled 13,500.

Also available were a total of 638 periodical titles. Of these, 328 are being obtained by subscription, 105 by exchange, and the balance represent gifts.

Three significant gifts of literature were received during the year: a collection of 2,100 reprints from Dr. H. H. Love and Dr. S. S. Atwood; Dr. Paul Sear's collection of scientific journals and books; and back issues of *Chemical Abstracts* from the National Institute of Science and Technology of the Philippines.

A bibliography of the world's rice literature, covering the years 1951-1960, will be published early in 1963. The bibliography is the result of several years' effort on the part of Dr. Dorothy Parker, library specialist of The Rockefeller Foundation; of the cooperation of many of the world's important agricultural libraries which kindly made available all their references on rice; and of Mrs. Margaret Bryant and her staff at the United States National Agricultural Library. About 12,000 references have been compiled. Included will be translated titles of most Japanese and Chinese technical papers on rice, which were assembled especially for this bibliography. All the items listed will be available in one form or another in the Institute's library.

Circulation and reference services to staff members and research scholars of the Institute are increasing steadily. By the end of October, there were 138 borrowers who had registered for library privileges.

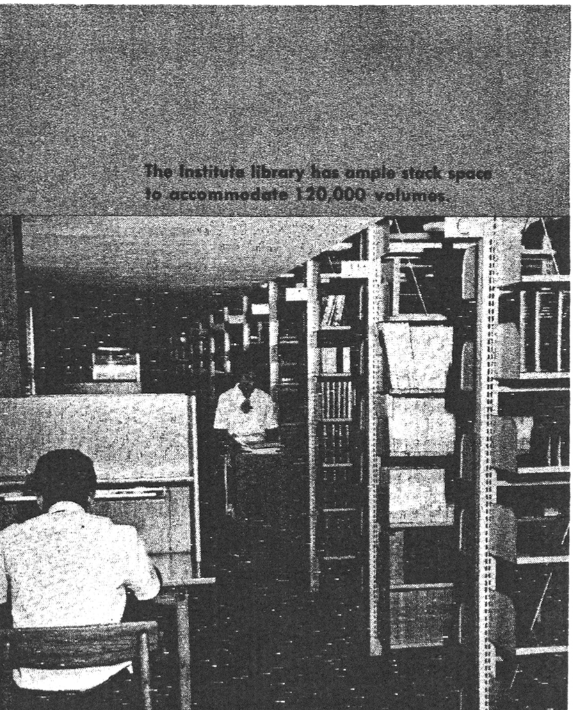
In addition, a number of faculty members and graduate students of the College of Agriculture of the University of the Philippines and research workers of the Bureau of Plant Industry have been availing themselves of the resources and services of the Library. Statistics reveal that a total of 6,090 books, reprints, and translations had been loaned to privileged users through the month of October.

For the benefit of the research staff, the Library maintains relations with the most important libraries in the country such as: the Main Library, the Medical, the Institute of Hygiene, and the College of Agriculture libraries of the University of the Philippines; and those of the National Institute of Science and Technology, the Weather Bureau, the National Museum, the Department of Agriculture and Natural Resources, and the Bureau of Plant Industry.

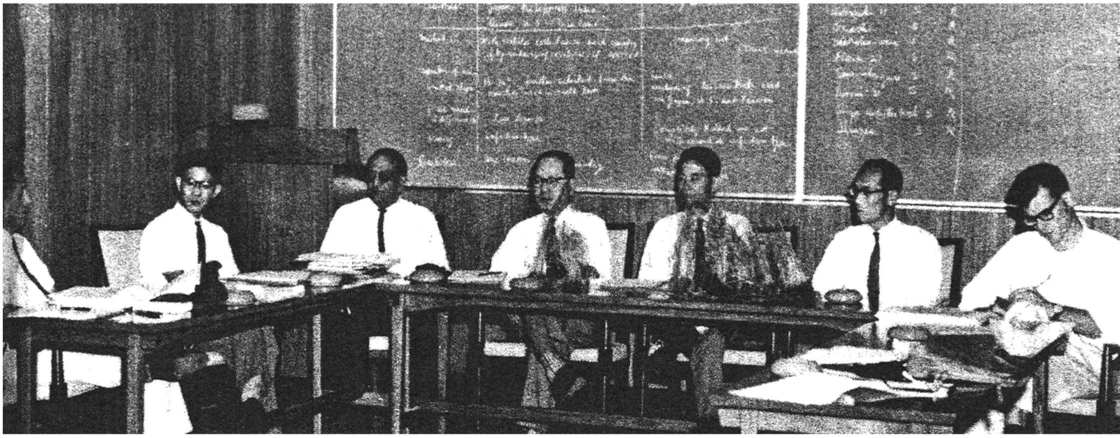
Translations of Japanese rice literature are being accomplished by two Japanese staff members of the Institute who have been provided office space by the National Institute of Agricultural Sciences in Tokyo. A number of Japanese scientists also translate for the Institute as time permits. As mentioned earlier, this group has already translated 34 papers. In addition, 368 translations have been obtained from other sources.

The Institute's bindery began full-scale operations during the fourth quarter, and temporary assistants for the binder were employed to help reduce the backlog.

Since May, the Library has sponsored 18 evening music appreciation sessions and has made 449 loans from its collection of 205 phonograph records.



The Institute library has ample stack space to accommodate 120,000 volumes.



An international blast research program was discussed at a small conference held at the Institute in November.

International Activities

It is realized that increased food production in the rice-growing nations must to a large degree be achieved through educational, research, and extension agencies in each individual country. It is largely through these organizations that most research results must reach the people who can benefit from them. Consequently, the Institute is interested in using its resources to strengthen national efforts wherever mutual interest exists and the Ford Foundation has provided $750,000 for such activities over a three-year period.

The universities and colleges must train the large numbers of young men and women who will return to the farms, teach, work in extension programs, carry on research, or participate in a multitude of other ways in the advancement of their nations' agricultural interests. These young persons must be taught properly by instructors who know their subjects well — preferably with knowledge based both on academic studies and on firsthand experience.

Similarly, the answers to the many practical problems facing the farmers in each nation, must, in large part, be obtained through its own research agencies. Varietal and fertilizer recommendations, advice in control measures for diseases and insect pests, and suggested soil and water management practices must emanate from a research organization capable of developing sound information. Only a few scientists can be trained abroad; these must, in turn, train others in the numbers needed to develop depth of experience over an entire country.

Extension workers usually receive their training at universities or colleges and often they are persons initially trained for research. Consequently, the training of university or college staff members and the development of young scientists will have a favorable impact on the quality of future extension workers.

The training program

The Institute is able to offer specialized training to a limited number of selected scientists and faculty members of other research or educational organizations concerned with rice. Research scholars serve as temporary members of the scientific staff to allow them to participate in, and to

Research scholars and assistants examine the seedling reactions of rice varieties to *Piricularia oryzae* during one of the regular Saturday morning classes.

become fully familiar with, the Institute's work in their fields of specialty. Training periods range from (a) one or two months for persons learning a new technique, (b) one year or more for those desiring research experience only, or (c) about two years for those working simultaneously for a Master's degree at the College of Agriculture.

Scholars are provided with quarters and meals in the Institute's dormitory and cafeteria, a modest stipend of 110 pesos (about 30 U.S. dollars) per month, and adequate facilities for study and work. Each scholar is also provided with a set of 10-12 reference books for his personal use, and all costs of studies at the College of Agriculture are paid by the Institute.

In June 1962, the Institute began accepting young persons for specialized training, and by November first, 27 research scholars were working and studying in six different fields of specialization:

Scholar	Position	Field
1) **Aspiras, Marcelo**	*Asst. Irrigation Project Supervisor, Irrigation Service Unit, Dept. of Public Works & Communication, Philippines*	Agronomy
2) **Aspiras, Ruben**	*Research Assistant, College of Agriculture, University of the Philippines*	Soils
3) **Bandong, Jose**	*Research Assistant, College of Agriculture, University of the Philippines*	Pathology
4) **Bueno, Aguinaldo**	*Agronomist III, Bureau of Plant Industry, Philippines*	Agronomy
5) **Cagampang, Isaac**	*Instructor, College of Agriculture, University of the Philippines*	Agronomy
6) **Caoili, Abraham**	*Instructor, College of Agriculture, University of the Philippines*	Engineering
7) **Carandang, Diosdado**	*Instructor, College of Agriculture, University of the Philippines*	Soils

Scholar	Position	Field
8) **Chuaviroj, Manee**	*Technician, San Patong Experiment Station, Chiengmai, Thailand*	Breeding
9) **Domingo, Isidro**	*Agronomist I, Bureau of Plant Industry, Philippines*	Agronomy
10) **Espada, Wilfredo**	*Instructor, Central Philippine University, Iloilo, Philippines*	Agronomy
11) **Frances, Amador**	*Pest Control Officer, Bureau of Plant Industry, Philippines*	Entomology
12) **Guevarra, Anacleto**	*Research Assistant, College of Agriculture, University of the Philippines*	Breeding
13) **Joano-Quintana, Imelda**	*Asst. Instructor, College of Agriculture, University of the Philippines*	Pathology
14) **Jootanon, Owaht**	*Junior Lecturer, Kasetsart University, Bangkok, Thailand*	Agronomy
15) **Kootin, Urai**	*Junior Instructor, Kasetsart University, Bangkok, Thailand*	Pathology
16) **Lantin, Reynaldo**	*Instructor, College of Agriculture, University of the Philippines*	Engineering
17) **Lanuza, Alberto**	*Research Assistant, College of Agriculture, University of the Philippines*	Agronomy
18) **Laysa, Patricio**	*Agronomist III, Bureau of Plant Industry, Philippines*	Breeding
19) **Obordo, Romeo**	*Instructor, College of Agriculture, University of the Philippines*	Agronomy
20) **Ona, Jose**	*Assistant Instructor, College of Agriculture, University of the Philippines*	Agronomy
21) **Patanakamjorn, Somporn**	*Instructor, Kasetsart University, Bangkok, Thailand*	Entomology
22) **Rajatapiti, Metha**	*Chief, Design Workshop Section, Rice Department, Ministry of Agriculture, Bangkok, Thailand*	Engineering
23) **Sitathani, Khemkhang**	*Instructor, Kasetsart University, Bangkok, Thailand*	Entomology
24) **Sornchai, Sukhee**	*Technician, Sakol Nakhon Expt. Station, Bangkok, Thailand*	Breeding
25) **Srisomboon, Sumon**	*Agricultural Officer, Rice Department, Ministry of Agriculture, Bangkok, Thailand*	Soils
26) **Trachoo, Paibool**	*Technician, Pimai Experiment Station, Nakhon Rajsima, Thailand*	Breeding
27) **Wathanakul, Luansark**	*Agricultural Officer, Rice Department, Ministry of Agriculture, Bangkok, Thailand*	Pathology

Additional research scholars from Indonesia, Malaya, Philippines, South Viet-Nam, and Taiwan already are in prospect for 1963.

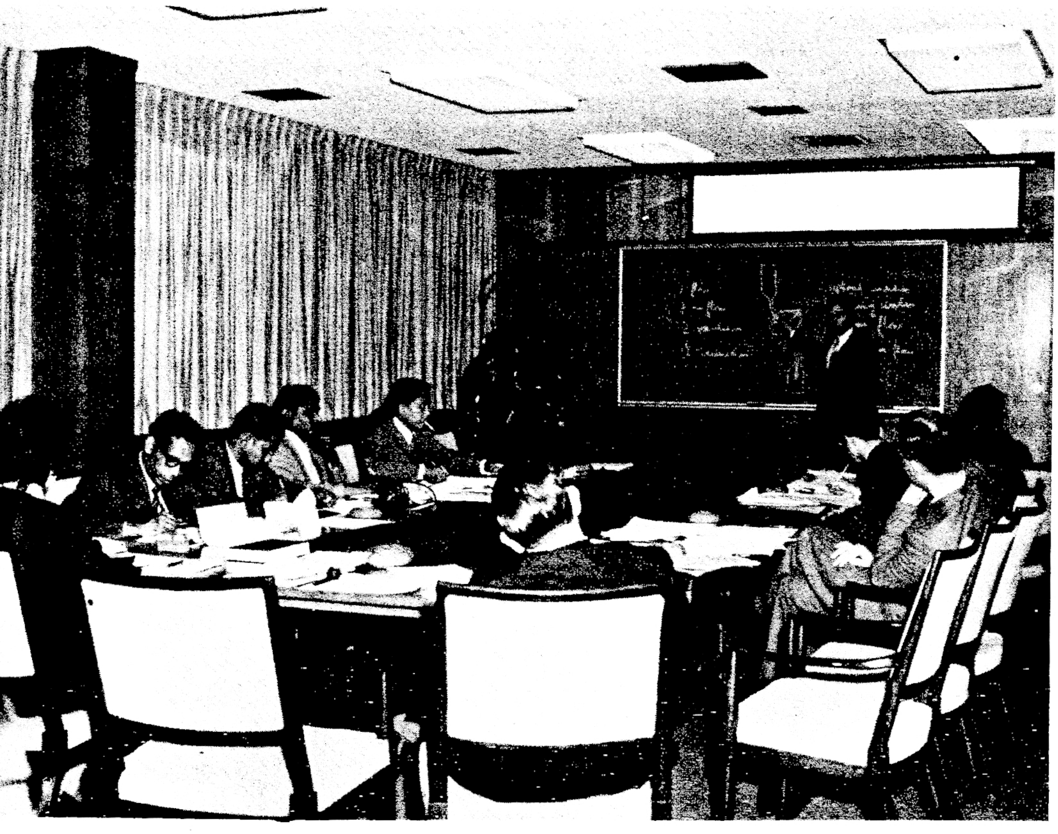
Fellowships

Three young scientists from Japan arrived during the year to undertake research on problems in chemistry and genetics.

Mr. Sadao Sakamoto, National Institute of Genetics, Misima, Japan, arrived October 30 to spend five months establishing the Institute's collection of genetic stocks.

Mr. Takao Minamikawa, Nagoya University, arrived in September to work for one year on the biosynthesis of starch in developing rice grains.

Mr. Takao Murata, of Tohoku National Agricultural Experiment Station, Japan, is concerned with the analytical study of protein metabolism.



Scientists cooperating with the International Atomic Energy Agency on the use of radioisotopes in fertilizer studies met at the Research Center in December under the auspices of the IAEA.

Promotion of International Cooperation in Rice Research

Scientists working on rice in most of Asia have had relatively little opportunity to keep abreast of technical advances outside their own countries. It appears that periodic, continuing visits to other countries by the Institute's scientists will be one of its important contributions to national research programs. The visits not only allow a scientist-to-scientist exchange of information, but stimulate interest and serve to encourage scientists elsewhere.

In 1960, the Associate Director and the Plant Breeder visited the Central Rice Research Institute, the Agricultural College and Research Institute at Coimbatore, the Indian Agricultural Research Institute, and the Chinsurah Agricultural Experiment Station near Calcutta. In 1962, the Plant Breeder, the Plant Pathologist, and the Soil Chemist visited these same institutions with the exception of Chinsurah. Later, Mr. M. S. Pawar, Deputy Commissioner, Indian Council of Agricultural Research, spent three days at the Institute reviewing the research program and discussing with the staff the possible areas for effective cooperation between Indian and Institute scientists.

The Associate Director and the Plant Breeder visited Ceylon for three days in 1960. Subsequently, arrangements were made with the College of Agriculture for the plant breeder at the Batalagoda experiment station to study in the Philippines. The Institute has indicated to the Government of Ceylon its interest in developing cooperative relationships with Ceylonese scientists and has suggested that members of the staff visit there again as soon as possible.

Officials in Indonesia expressed considerable interest in the Institute's program during the visits there by the Director and the Associate Director. Exchanges of seed have been made, and possible arrangements for training of Indonesian scholars, particularly from the Cereals Research Institute, have been explored. It appears that cooperative research on blast and on the effects of climate on rice yields will be initiated soon by the Cereals Research Institute and the International Rice Research Institute.

In Japan, there is a great reservoir of knowledge on rice. Unfortunately, much of the information is unavailable to the rest of the world because of language barriers. The Institute, for this reason, is supporting the translation of Japanese research papers of international interest. Japan's interest in the Institute is mostly in the opportunities for cooperation on fundamental research problems — in physiology, soil chemistry, genetics, biochemistry, pathology, entomology — rather than on the more practical problems of more importance to the tropical countries.

The Institute has accepted three research fellows from Japan. Two are conducting research in biochemistry and one is involved in genetic studies.

The Institute's Agronomist, the Plant Breeder, the Geneticist, the Pathologist, and the Agricultural Engineer have spent considerable periods of time in that country to acquaint themselves with research underway. The blast disease and the effects of climate on the productivity of rice are possible subjects of cooperative research in 1963.

In Malaya, considerable interest exists in the possibilities of cooperative work between Institute scientists and those in the Ministry of Agriculture or at the University of Malaya. The Associate Director has been in Malaya on two occasions and has visited the rice research stations in Penang and at Alor Star. The Physiologist and the Plant Breeder scheduled trips there in late 1962. The quality of the research seemed quite good, and the opportunities for cooperation are most promising. The Director and the Assistant Director of Agriculture have been invited to visit the Institute. The Professor of Agriculture of the University of Malaya was at the Institute in August. One of its physiologists will spend the month of March 1963, discussing with the Institute staff the University's research program in that field.

The Associate Director was in East Pakistan in August, where he conferred with officials of the U.S. Agency for International Development. Also, he reviewed the research programs of the Agricultural Research Institute and discussed possible areas of cooperation with the scientists concerned and with the Director of Agriculture, to whom he extended an invitation to visit the Institute. It is hoped that cooperative work in rice breeding, agronomy, and pathology, and possibly in other fields of research, will develop in 1963.

Members of the staff made a number of visits during the year to rice research stations in the Philippines, particularly the Maligaya Experiment Station in Nueva Ecija, the Bicol Experiment Station in Camarines Sur, and the Mindanao Rice and Corn Experiment Station near Cotabato, Mindanao. Arrangements are being made with the Bureau of Plant Industry to initiate cooperative work with both the Cotabato and Maligaya stations in 1963. Among the areas of research in which mutual interest exists are (a) weed control, (b) forms, rates, and timing of fertilizer applications, (c) effects of climate on yields of rice, (d) the blast and "orange-leaf" diseases, (e) stem borer control, and (f) rice breeding.

The Entomology Department at the College of Agriculture and the Institute are undertaking a joint two-year study of the factors affecting the distribution of species of the stem borer in the Philippines. The dominant species in the vicinity of the Institute, *Chilo suppressalis* Walker, apparently is not the most abundant species in northern Luzon, in the central and southern areas of the country, nor in other parts of Southeast Asia. It is hoped that as a result of this study, which is being financed in part by the Institute with funds from the Ford Foundation, information will be gained which will allow the development of varietal resistance to other stem borers as well as to *Chilo*. This could lead to cooperative testing by a number of research stations in this country, and eventually elsewhere in Asia.

Work on the chemical control of nitrification has been done cooperatively by the Institute's soil chemist, the agronomist, and the staff of the Department of Soils of the College.

There appears to be an excellent opportunity for cooperation between the Institute and the College in rice breeding and agronomy, particularly on upland rice problems, and a cooperative program is now being developed.

In Taiwan, both *japonica* and *indica* types of rice are grown commercially. Because of the relatively good facilities available there, the interest and competence of the research scientists, and a climate which permits normal growth of both types of rice, development of cooperative research projects by Institute and Chinese scientists is expected to proceed rapidly. Seed for a cooperative yield trial already has been sent to the Chiayi station. Plans have been completed for cooperative experiments on the effects of climatic factors on rice yield and on several aspects of the chemistry of submerged soils. The Agronomist, the Plant Breeder, the Geneticist, the Pathologist, the Physiologist, and the Soil Chemist have become acquainted with research underway in Taiwan. Dr. H. T. Chang of the Joint Commission of Rural Reconstruction spent three days at the Institute reviewing the research program and discussing with the staff the many opportunities which exist for mutually beneficial cooperation.

At least six scholars from Taiwan are expected to begin training at the Institute in 1963. Some of the trainees will be sponsored by the Agency for International Development; others will receive financial support from the Institute.

As mentioned earlier, there are 10 research scholars from Thailand now at the Institute. This reflects the interest that exists in cooperation between the Institute and the Rice Department, Kasetsart University, and other agencies in Thailand. Several of the Institute's scientists, including the Plant Breeder, the Pathologist, and the Soil Chemist, have become familiar with the research activities in that country. Arrangements are being made for cooperative field studies on the effects of climate on the growth of rice, and there have been free exchanges of seed by the plant breeders. Dr. Sala Dasananda, Director-General of the Rice Department, and Dr. Bhakdi Lusananda visited the Institute in 1962 to acquaint themselves with the research program and to discuss possible areas of future cooperative work. There is little doubt that during the next two or three years, a vigorous and close program of cooperative research will develop between the Institute and agencies in Thailand.

Effect of climate on the growth and productivity of rice

An interesting group of cooperative experiments is being arranged by the physiologist and the agronomist to study the effects of various climatic factors on the growth and yield of rice at a series of experiment stations, ranging from 6° south to 40° north latitude. Arrangements have been made for tests at one location in Indonesia, one in Malaya, two in Thailand, two in the Philippines, three in Taiwan, and two in Japan. A selected group of varieties will be grown at each location under two systems; one system will be stipulated by the Institute and the other will be the common local practice in the region.

Cooperative blast research program

In November, a small group of Indian, Japanese, and Institute scientists met at the Research Center to work out the details of a cooperative blast research program. Their proposals will be presented to possible cooperators from Asia, the United States, and elsewhere at a conference tentatively scheduled for July 1963. It is envisaged that this international program will involve a continuing series of uniform field trials of selected varieties to determine their reactions to the disease in the various localities. Information gained should reveal the major races of *Piricularia oryzae* which exist in the rice-producing countries, areas in which they occur, and the varieties which are resistant to each race. It is hoped that a single set of differential varieties can be developed for international use and that basic research on the important aspects of blast can be intensified.

Scientific conferences

A symposium to review the current status of genetic and cytogenetic investigations in rice and to identify those problems on which research should be encouraged in the future has been scheduled for the week of February 4-8, 1963. The subjects for discussion are: (1) Gene symbolization and nomenclature, (2) Chromosome morphology in *Oryza sativa*, (3) Genetic and cytogenetic evidence for species relationships, (4) Nature of intervarietal sterility in *Oryza sativa*, and (5) Inheritance studies, gene markers, and linkage groups.

Twelve eminent rice geneticists from India, Japan, Taiwan, the United States, and FAO have indicated that they will participate. They have submitted the titles of their respective papers and the manuscripts are expected to be received by the Institute before the end of the year.

Other conferences being considered for 1963 include ones on nitrogen utilization, on blast and on machinery development.