A REPORT ON PLANS AND PROGRESS WITH RICE IMPROVEMENT IN THAILAND

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INTRODUCTION

Before discussing the program for rice improvement let us consider what has been taking place in the plant world for ages.

For many thousands of years, since long before man made his appearance on the earth, nature has been working for the benefit of man in many ways. The rich deposits of oil, coal, and minerals, the great forests, and the vast expanses of fertile soil are evidence of this fact. One of the many ways nature has been working for mankind is in the development of better animals and plants. Nature has been doing this with plants by inbreeding, crossing, and subjecting the thousands of types to different environments so that myriads of different forms have been produced. The environment under which some of the plants were forced to grow was so severe that only the strong and most hardy were able to survive. This was good since it provided types adapted to hot and cold temperatures, wet and dry conditions, infertile and fertile soils, and many other situations.

When man arrived on the scene he was fortunate to find so many different plant forms readily available to furnish food and clothing for his use. To be sure, he observed plants for which he found no use, and the same is true today. However, with the advance of science, it may well be that some types of plants considered worthless today may in the future be the source of some valuable product. With the advance of chemical research it is certainly possible that weeds considered useless today and other plants may be found to be the source of new useful materials.

While in the beginning man accepted the plants as he found them and began to make use of them, it was not long before he was not satisfied with the types readily available and wanted better sorts. This characteristic of not being satisfied is one of the most valuable traits of mankind. It is responsible for most of the progress man has made.

With the desire for better types of plants, early man began to observe more closely the plants about him. He saw that some individuals seemed to produce more than others, or had a better quality of product. His next step was to select those better-appearing sorts and plant the seed from them. From some of these he obtained better plants than he had been getting from nature's own product. Thus man began to work with, or help, nature, and the art of plant breeding was born. The early efforts of man were based on observation. His methods were crude, yet he did much to make available the vast amount of material to be used by those who were to follow. While it may be that a large amount of valuable material and good types of plants were lost, yet much has remained for the use of the plant breeders today.

As man became more interested in plants, and as time passed, greater consideration was given to them and their improvement. One problem that concerned some of the early investigators was that of how to make plants vary in order to produce new or unusual types from which to make selections. That still is important to plant breeders today. Some of the early experiments involved growing plants at different altitudes, on different soils, under colored glass, and the like, in the hope of producing changes which would lead to new types of plants. Most of these experiments resulted in failure, in that no important heritable variations were produced. Such results would be predicted today with our knowledge of heredity and plant breeding.

Other simple experiments were conducted, such as selecting special plants that attracted the fancy of the observer, and the crossing of different sorts. Since the experimenter was working without any special knowledge of the processes involved, or the mode of inheritance of the characters concerned, many of those early experiments ended in failure. Some results of value were obtained, but it was not until the plant scientists began to conduct more careful and detailed tests that the way was opened for a sound program of plant improvement.

The scientists began detailed studies of plant characters and their mode of inheritance. That is, special crosses between plants of the same group, such as wheat, peas, rice, and many other types of plants differing as to certain characters were made, and the plants resulting in the first, second, and succeeding generations were studied in great detail. The first important study of this sort was that made by Gregor Mendel based on the inheritance of characters of garden peas. While Mendel's paper was published in 1866 it attracted little attention at the time, and remained unnoticed until 1900, when it was rediscovered at about the same time by three European scientists, Correns, Devries, and von Tschermak. The effect of this discovery was to set in motion a great number of investigations in the field of plant heredity. It also helped explain why many of the earlier experiments in crossing plants resulted in failure or a mixed lot of material from which it seemed hopeless to obtain any true-breeding plants of the desired type.

The research on plant inheritance that followed since 1900 demonstrated that many characters tend to follow definite ratios in their inheritance. Some illustrations will be presented later.

So while the art of plant breeding is very old the basic science of the subject is relatively new. From the standpoint of time we see that nature, and nature aided by man, has been working on the improvement of plants for ages, while the plant scientists began working, one may say, only a few minutes ago. Yet in those few minutes much has been accomplished. Even though this is so, the modern plant breeder is the first to admit that only a mere beginning has been made, and he looks forward hopefully to the great things yet to be accomplished as science leads the way. It may be mentioned here that a successful plant breeder needs to be an optimist. He must attack his problems with a spirit of optimism, and drive forward toward his goal of obtaining a better plant type. He may not always succeed, but if he retains his optimism and keeps working enthusiastically his efforts will be rewarded.

From the preceding statements it is apparent that plant breeding as followed at the present time is a process of developing new and better varieties from older varieties. Often special types of plants are needed for growing in certain environments or to resist certain diseases or insects. The work is accomplished by testing hundreds of varieties and selections, crossing different types of plants, and seeking new and unusual plants from various parts of the world.

The present expanded program for rice improvement began in 1950 following the request made by the Director General of Agriculture for Thailand, Nai Insee Chandrastitya, to the Office of Foreign Agricultural Relations of the United States Department of Agriculture for technical assistance in two basic fields of endeavor fundamental to greater yields of rice per rai–soil studies and plant breeding. This invitation was considered favorably and Dr. R.L. Pendleton, for several years advisor to the Thai Ministry of Agriculture before the last war, was asked to undertake a program of soil improvement and the author was asked to assume responsibility for the rice-breeding program. We arrived in Thailand March 17, 1950.

Previous to our arrival, the Thai Department of Agriculture had been conducting some studies in these subjects and certain facts regarding the value of fertilizer had been obtained, and some good rice varieties had been found and purified as a result of these earlier studies with varieties. Seed of some of these had been dis tributed and was being grown by farmers.

After we reached Thailand, in order that we could become familiar with the investigations that had been conducted previously and to determine what facilities were available for handling an extensive series of experiments, numerous conferences were held with members of the staff of the Department of Agriculture who had been working with rice. Following these discussions the program was developed and at present is being continued along the same general lines as were worked out in the beginning.

Following a change in policy of the Office of Foreign Agriculture Relations, this office withdrew its financial support and by mutual consent Dr. Pendleton and the auther were transferred to the Special Technical and Economic Mission to Thailand on July 1, 1952. However this did not result in any change in program.

A further change in organization took place January 1, 1954, when the Ministry of Agriculture established a Department of Rice separate from the Department of Agriculture, with Mom Chao Chakrabandhu Pensiri Chakrabandhu as Director General. This resulted in transferring the program from the Department of Agriculture to the Department of Rice. This new department is concerned with all problems of rice production, including breeding and fertilizer studies, as well as work with disease and pest control and other important rice research problems.

All the details of the program are worked out cooperatively with Doctors Krui Punyasingh and Sala Dasananda, rice breeders of the department. No changes are made or new experiments undertaken unless there is complete agreement on the part of all concerned.

PROGRAM

Training of Personnel

When the enlarged rice-improvement program for Thailand was being considered it was at once apparent that there would be needed a large number of men trained in the methods used for handling field plot tests, as well as in some of the basic principles of plant breeding, statistics, and other subjects. Men with this training were not available and there was not time to send them abroad for special training; nor were funds at hand for this purpose. Something had to be done quickly to provide the needed staff with some knowledge of the kind of experiments that were to be conducted. Specially planned short courses seemed to provide the only answer to the problem. Naturally some people wondered whether it would be possible to accomplish anything worthwhile in the short space of four or five weeks. Also some questioned the value of such courses if the lectures had to be interpreted from English into Thai. Personal experience gained from having conducted short courses for several years in China had shown that much could be accomplished by such short courses lasting from four to six weeks even when most of the lectures had to be interpreted from English into Chinese. Naturally, it would be better if all teaching could be done in the native language, yet when this cannot be done, it is possible to handle the instruction providing satisfactory interpreters are available. Fortunately this has been the case for the short courses conducted in Thailand.

The first short course was held in October 1950 and the daily attendance was about 80. It has not seemed desirable to set up any special requirements for admission. Those attending included a few staff members of the Thai Department of Agriculture and of the University of Agriculture, a few students from the University, and a large number of agricultural officers of the Department of Agriculture and stationed in different localities of the Kingdom. Most of the agents had not had the benefit of college training nor the opportunity for special technical instruction in agriculture.

The instruction for the first course included lectures on the nature of soils, especially tropical soils, and the importance of fertilizers. Some of the basic principles of genetics, including cell development and growth and their relation to genetic reactions, were presented. The methods of selection and hybridization and their application to plant improvement were discussed. The value and limitation of selection were illustrated with data from different types of crops, and how selection may be used in rice improvement was discussed in detail. How hybridization may be applied in producing new types of plants to meet certain needs was explained. The use of statistics as applied to the analysis and interpretation of the results of field experiments was exemplified by numerous examples. The kinds of experiments that may be used for field plot tests, including such points as size and shape of plots and number of replications needed, were discussed. Naturally, in the short time that was available it was possible to present only some of the most important phases of the several subjects; yet, as will be seen later, much was accomplished. Those who attended the course seemed anxious to become familiar with the various techniques presented and to learn how they might help in the development of the rice-improvement project.

Such short courses need to be repeated at least once a year. In this way it is possible to reach additional men, and former members may return for further training so that they may increase their knowledge and clear up some points that may not have been well understood the first time. Those who have attended previous courses should be urged to return for more training and their duties should be adjusted so that it will be possible for them to attend.

A second course was held from February 4 to March 15, 1952, and a third one from January 19 to February 25, 1953. The attendance at the second one was 90 and for the third was 94. A number of men who had attended the previous course, or courses, returned for further training. For each of these courses new material was presented, and some special lectures on different phases of agriculture were given by specialists working in those fields. For part of the time the class was divided so that more advanced work could be presented to those who had attended previously. Special laboratory sections were also held for the more experienced members so that they could carry through some of the statistical procedures required in the analysis of data from field experiments. A number of the members brought with them data from experiments they had helped conduct. These men used their own data in the laboratory work. The steps in the analysis of the data helped them to a fuller understanding of the purpose and meaning of field tests.

Experience has demonstrated that it is better to hold short courses on specifie subjects such as rice improvement rather than to hold one on broader lines such as general agriculture. Since it is usually not possible to continue such courses for more than four to six weeks at a time, it is not feasible to include lectures on a wide range of subjects.

The value of such special training courses may be illustrated by indicating what several of the agricultural agents who attended the first course in 1950 were able to do in connection with the experimental work of 1951. Before it was time to plant rice that year a number of those who had attended the first course were contacted to see if they were willing to help conduct field experiments for variety comparisons and for comparing the effects of different fertilizers. Many agreed to take part in this work. They were asked to come to Bangkok for further training and to receive special instructions on the laying out and arrangement of field plots. They were also instructed on the care needed in handling experiments of the kind being planned. The importance of transplanting all plots in as nearly the same way as possible was stressed, including such points as the same number of hills in each plot and the same number of plants in each hill. These men then returned to their home localities to arrange for the land needed for the test plots and to plan for the seed beds and other details.

Most of those who agreed to share in the program did satisfactory work. This is remarkable when one considers the fact that none of them had done anything of this sort before. It was to be expected that a few mistakes would be made, but on the whole the experiments were well-handled. In order to enable these men to see rice growing in different parts of Thailand, and to give them the opportunity of further training by observing the tests conducted by other agents, they were asked to return to Bangkok late in September. For a few days they were given further special Instruction, and then were taken on a tour, under direction, to see a number of experiments in central and northern Thailand. This proved to be most beneficial. The men agreed that they had learned a great deal from what they had seen. As they visited an experiment that was well laid out, cleanly cultivated, and with a uniform stand they could easily compare this with another one that may not have been so well handled. This kind of follow-up study adds much to the value of the short courses. Such observation tours should be an integral part of the short-course programs, and should be taken every other year if it is not possible to do so each year. Unfortunately, on account of the expense involved and the lack of accommodations, not all those who need to profit by such inspection tours can always be taken. Such trips enable the men to relate the material presented in the lectures to the practical problems concerned with well-handled field experiments. It has the added advantage of encouraging each one to make certain that his test plots will be among the best another year unless circumstances beyond his control make this impossible.

It was recognized in the very beginning of the enlarged program that the extent of the experimental work would be limited primarily by the number of available men with the type of training necessary for the proper conduct of worthwhile field tests for comparing the yielding ability of strains and varieties of rice and measuring the effect of different fertilizers. The short courses have contributed much to help meet this need.

Experience is showing that many of the men who have attended the short courses are proving to be especially valuable in this expanding rice-improvement program. In time some of them will have advanced to the point where they can conduct certain experiments independently. Since sufficient personnel is likely to be unavailable to meet all the demands for some time, the only alternative is to continue to train them by means of special short courses.

Some of these men are becoming so proficient that they may now serve as regional supervisors, helping those less experienced look after certain experiments in a particular locality, or several localities. The results so far have been very gratifying.

The training of personnel to participate in agricultural and similar prejects is the most important phase of these programs. Unless an adequate, well-trained staff is ready to continue the several programs much of the effort will have been of little value.

Rice Inprovement

In developing a plant-improvement project in a region or country where no extensive studies have already been under way, the plant breeder usually develops his project to include three phases: (1) variety evaluation; (2) selection of individual plants or heads; (3) hybridization or crossing different varieties, followed by selection.

(1) Variety Evaluation

What do we mean by variety evaluation? We mean that, insofar as possible, all the different varieties already avaliable in the region or country are collected so that they may be studied and observed under similar environmental conditions. As the work progresses the plant breeder does not confine his work entirely to the evaluation of varieties found in one country but he endeavors to obtain different sorts from all other parts of the world where the particular crop is grown.

Perhaps a short description of how these varieties are compared may be of interest. When one has a large number of native and foreign varieties it is not necessary to plan elaborate field tests. However it needs to be emphasized that the different sorts must be grown in some simple field tests. In the beginning the many kinds are grown in observation trials or tests. This means that small plots or short rows of each variety are grown on the same field under as uniform conditions as possible. From these observational tests one learns that there are many varieties that seem to be of little value from the standpoint of high yield while a few will be found that seem to possess merit and deserve more adequate field tests. It is possible that a number of the other varieties, while not satisfactory as they are, may possess certain characters which the breeder will want to use when he develops his hybridization program. When a large collection of different varieties has been made it is unwise to discard those that seem worthless until after careful study and observation for several seasons.

The more promising varieties, as judged in the observational trials, are used for more detailed tests. For these tests special field designs are planned.

When field tests are to be conducted it is important that the field chosen be as nearly uniform in its fertility as is possible to obtain. All fields show a certain amount of variation with respect to the growth of plants. Even within the distance of a few meters it will be found that plants may grow much more vigorously in one spot than in another. For variety tests, each variety to be studied is grown in a small plot. We use plots consisting of three rows planted one-third of a meter apart and four and one-half meters long (Figure 1). These plots must be the same size and shape for each variety in the test and care must be exercised to see that each plot contains the same number of hills of rice. This is not always possible due to accidents and loss of plants but when the stand varies due to missing hills a record must be kept so that adjustments as to yielding ability of the different varieties may be made.

Owing to the fact, as stated above, that there is considerable variation in any field, it is not sufficient to have only one plot of each variety but each variety must be replicated several times. The plan followed is that of having one plot of each variety planted side by side in the field, and this is referred to as a block, or one replication. For best results it is desirable to have five or more replications of these blocks. In the majority of tests conducted in the course of our experiments we use six replications. In order to have a fair distribution of the varieties in each block or replication the location of each variety is determined by chance, or random arrangement. During the growing season careful cultivation must be practiced and the plots all treated as nearly alike as possible. This includes the matter of irrigation or the amount of water that is let onto the field from time to time.

At the end of the season the plots are harvested (Figure 2) and carried to the field house for drying (Figure 3). The yield of each row of a plot is kept separate so that special studies may be made with the results. Formerly, after conducting a variety test the agriculturist compared the yields by taking the average of the several plots of the same variety. This method was found to be unsatisfactory due to the fact that there is a considerable amount of variation throughout the field. If one had, say, three plots of each variety and obtained the average and then if he had four plots or five plots of the same variety in the same field it was found that the averages from the different numbers of plots varied, so it became evident that it would be desirable to have some way of expressing the final result more realistically.

Modern experimenters, recognizing the fact that there is a considerable amount of variation from plot to plot, have developed methods which can be used to evaluate this variation. No matter how carefully an experiment has been conducted one finds that the yields of the several plots of the same variety differ from one another. In fact, it is recognized that, if an experiment could be repeated on the same plot of ground in the same season, it would be most unusual to obtain the same yield from each plot as was obtained from the first test. There is always present the effect of uncontrollable factors which influence field experiments and many other studies of similar kind. A term, "the experimental error," has been adopted when referring to this general effect. Chance variation causes these results to be somewhat different and mathematical techniques that have been developed for the study of problems of chance or probability are applied in the study of results of field experiments.

Without going into the mathematics involved in the methods used for such studies, an illustration of the application will help to explain how field experiments can be evaluated. For example, if a variety study has been made with several different sorts of rice, one may find that variety A gives an average of 420 kilograms of rice per rai. The analysis of this test may lead to an experimental error of 20 kilograms. Then, instead of stating that the yield of A is exactly 420 kilograms, the result is often written as 420 ±20. This indicates that if the variety test were repeated under similar conditions the new mean may not be 420 but it would vary around 420 according to the limits of the standard error. That is, it can be anywhere from 400 to 440 and it may also fall beyond these limits, but not so frequently. On the basis of theory it would fall within the limits of the standard error 68 times out of 100 and would fall beyond the limits 32 times out of 100. In other words, the mean result obtained from an experiment is subject to variation and when comparing different varieties this must be taken into consideration. For example, suppose variety B gives an average of 450 kilograms per rai; may we conclude that B is a better-yielding variety than A? Roughly, in common practice, varieties are not considered to be different unless the difference is two to three times the value of the experimental error, and here this is not the case. In more careful studies certain refinements are applied but this illustration points out very briefly what we have in mind when we use the term "experimental error" as applied to biological experiments.

Another detail that needs to be added while discussing the method used for variety tests is that for more accurate results it is desirable to conduct variety tests on more than one field when possible, and certainly for three or four seasons at least, before making the final choice as to the best variety. Those sorts that are definitely inferior at the end of one or two seasons may be removed from the variety test but it may be worthwhile to save seed of each of these for possible further use.

The chief reason that it is desirable in the beginning of a program to conduct large-scale variety tests is that if some unusually good varieties are found, either from the varieties native to a country or among foreign varieties, seed of these good sorts may be multiplied and made available to the farmers, so that they may profit by growing the better-producing sorts until such time as these may be replaced by even better varieties obtained from the selection or hybridization programs.

The studies we have been able to conduct so far with varieties have involved observation and testing of something over 2,000 varieties from Thailand, as well as some 1500 varieties obtained from India, Indo-China, Indonesia, Taiwan, Japan, and the United States.

(2) Selection

While variety evaluation enables the plant breeder to obtain some useful sorts that may be substituted for the poorer varieties the farmers are growing, none of these varieties is likely to be completely satisfactory. So the next method the breeder may use is that of selection, By selection we mean that one goes into a field of plants and selects a large number of individual plants or heads and removes these from the field so that they may be studied further. With rice, since the farmer usually follows the practice of putting three or more plants in a hill, it is not possible to select plants, since the entire hill would have to be pulled up and the individual plants examined. This is not practical; so the plan that is followed in Thailand is that of selecting individual heads. For best results a large number of heads must be saved from a field or a fairly large number saved from many fields. It does not pay to begin a rice-selection program with only a few hundred selections; one needs thousands.

You may ask why it is desirable to make selections, and we may point out why this is so. Let us consider a field of ordinary rice. The field as you see it may be a very good field from which the farmer may expect a satisfactory yield or it may be an average or even a poor field. If the seed for this field has come from ordinary-by this we mean unselected-seed, then it is known that there are many, many different types of plants in the field so far as their yielding ability is concerned. The yield which the farmer gets is made up of the total of all the individual plants. If every plant in a field could be saved and given a yield trial in comparison with every other plant it would be found that there are a large number of poor-yielding plants and only a few perhaps that produce an unusually high yield, and the other plants would produce yields ranging all the way between the poorest and the best. Naturally, it is not possible to test all the plants from one field. If one were able to go into the field and find the best plant and multiply seed of it he would find that this seed would yield from a few percent to perhaps 25 or 30 percent more than the farmer is able to get from the mixture out of which this one plant came. Unfortunately, there is nothing to guide the plant breeder to this unusually good plant. He does not select plants affected by disease or which may have a week straw or are poor in other ways, but from the standpoint of yield there is nothing that will guide the breeder in choosing one plant over another. It is possible that he may find an unusually good plant with a large head well filled with rice kernels, but he does not know whether this is due to a very favorable spot in the field, that is, whether this plant is good due to its nature, by which we mean heredity, or to nurture, which is its environment.

Nature and nurture, heredity and environment, by operating together produce the final result. If a plant possesses good characters, such as cause high production, disease resistance, and other useful qualities, and is grown in a favorable environment the result will be a good quantity of grain. On the other hand, if a plant does not possess these characters it may produce well only when the environment is most favorable, but it cannot transmit to its offspring the ability to produce this high yield. What is desired is a plant that has the nature, the heredity, to produce a high yield and can transmit this to its progeny.

When a large number of head selections has been obtained there are two ways the breeder may use these in his program. One way is to thresh the seed of all the heads together and sow a field the following season, and then make another lot of head selections from this field and continue this process for a few seasons. We refer to this method as mass selection. This method is limited as to what it may accomplish, but for special purposes, such as uniformity of maturity, height, and other similar characters, mass selection may be followed and some worthwhile results obtained. It was my pleasure to meet a farmer in Taiwan who had been practicing mass selection with rice for 35 years and he did have a good variety and furnished a considerable amount of seed to his neighbors at no extra cost to them. He stated that he merely wanted to be helpful to his neighbors and friends. It is not necessary to continue mass selection with crops like rice for as many years as this farmer did; usually four or five years is long enough.

The other method of handling selections is known as the individual-selection or pedigree method. With this method the seed of each head is kept separate and tested separately for one or more seasons until one is satisfied that it is or is not a desirable type. The crop produced from a single head is referred to technically as a "line," so when individual rice heads are selected and grown each head produces a line. These lines will differ greatly in type, maturity, production, and the like. Since special records of each head and its progeny are kept as long as it is being tested it is apparent that a large amount of record keeping is involved. The record should show the locality from which the selection was made and if possible the name of the farmer who owned the field, and if the variety is known by name this should also be recorded. Other information such as the type of rice, glutinous or nonglutinous, early, medium, or late, should also be noted.

Preparatory to conducting field tests the seed of each selection is put in a separate small envelope, and the number of the selection is recorded on the envelope (Figure 4). When transplanting is to be followed seed beds are prepared and the seed of each selection is placed on the beds. Sometimes the seed may be placed in thin paper envelopes and placed on the seed beds (Figure 5). It is important to have the different sorts far enough apart so that no mixture of seed may occur.

For testing these different heads in the field a short row or plot of each selection is sown or transplanted and the breeder will have as many plots as he has selections, often many thousands in one field (Figure 6). Efforts are made to have the same number of plants in each row. In order to have some common standard for comparison it is desirable to have a plot sown from a well-known variety located frequently throughout the test. We refer to these as our check plots and place them on every tenth plot. The check variety is changed in accordance with the type of rice, such as early, medium, or late. As time passes it is found that for each locality one type of maturity occurs more frequently, and then it is satisfactory in later tests to use one variety for check.

Planting plans are made, showing the number of each selection and in what row it is placed in the field. These plans are used during the growing season as the different selections are observed and records are made on maturity, straw stiffness, reaction to insects and diseases, and any other notes that will be of value to indicate which selections seem to possess unsual merit are also recorded.

After the plants have headed out so that it is possible to judge the different lines, those conducting the experiments study each row carefully and compare it with the check or standard. Those lines that appear to be outstanding are marked by placing a stake at the end of that row (Figure 7). All the lines in the field are observed carefully and the promising ones marked so that the seed from these may be harvested for testing another season. Before harvest time all the lines are studied again to make sure that all those marked for further study still seem to be outstanding, and to add some that may have been missed the first time. That is, a few that did not appear too promising at the time of the first study earlier in the season may later appear desirable. The heads from each selected row are harvested and threshed (Figures 8 and 9), and then stored where they will be protected from insect and rodent injury until time to prepare the seed for growing the next crop.

The selections saved from the first year are handled somewhat differently in the field tests the second year. Each selection is planted in larger plots or longer rows and each line is replicated in the same field. One row of each selection is placed in the field until all selections are planted; check rows of a standard sort are placed every tenth row as was done previously; then the entire series is repeated in the same field. Sometimes in order to gain further information regarding the performance of these new lines we grow a third replication on a different field. This also has the advantage of having the test growing in two different localities so that in case storms damage one field we might still have seed left from the other field for continuing the investigation. For example, the selections that were grown the first year at Bangkhen were repeated at Bangkhen the second year, having two replications of each line, and a third replication was grown at the Rangsit Experiment Station. A similar plan was followed for those selections grown at the Rangsit Station; the third replication was grown at Bangkhen. The different selections were studied, as before during the season and previous to harvest, and the more outstanding ones noted. The grain from each row was harvested separately and the yields determined by weight. Those that gave the best result were saved for testing the third year, when it was possible to have five replications of each line, and the practice of growing a check row every tenth row was followed. For the fourth year, 1954, some of the more outstanding lines are being grown in three-row plots similar to our regular veriety tests, while the remainder are being grown in single-row plots, using six replications in each case.

That selection does offer an opportunity to obtain better varieties that will produce larger yields without any change in cultural methods may be shown by numerous examples. At this point may be mentioned some results obtained in China from a cooperative plant-improvement project with which the author was associated for some time. A number of different kinds of crops were included in the program. The gain in yields of wheat ranged from 20-40 percent; rice 10-40; barley 21; millet 27-50; kaoliang 20-40; soybeans 45-70, and in one region 90 percent was obtained. One wheat selection that gave an increase of 40 percent in the region where the selection was made, Nanking, was moved to West China, and gave an increase of 24 percent over the farmer's varieties. In addition it produced 12 percent more flour than the sorts grown there. Such gains show the importance of plant selection, especially when work is begun in an unworked area. It may be pointed out that many of the improved varieties grown in different parts of the world today are the result of selection.

It is well to emphasize that selection as practiced with a crop like rice does not produce anything new. Selection merely sorts out some individuals from the many thousand kinds of plants that may be found growing in a field. For this reason the breeder will have a better opportunity to obtain some good sorts if he can select and test a very large number obtained from many different farms.

(3) Hybridization

Since selection does not produce anything new it may be of importance at times to produce new types of plants or a new variety of rice that may actually be different in one or more respects from any varieties presently available. This is done by following the third phase of our program, namely, hybridization or crossing. Crossing is used when it is apparent that new sorts must be produced that possess a certain combination of characters such as high yield, disease resistance, and stiff straw, which would make the new sorts more desirable than the ones being grown by the farmers. That is, one variety may be able to produce very high yields when a disease to which it is susceptible is not present. Another variety may not yield so well but it may be able to resist the effects of this particular disease. The breeder would like to have these characters, high yield and disease resistance, combined. He wants to add disease resistance to high yield. This can be likened to the work of a builder who places one stone or brick on another to erect a building. Crossing gives the plant breeder the opportunity of putting good characters together but it is well to point out that it is not so simple as adding one stone to another. The plant breeder may succeed in combining these characters in his first cross or he may not. Much will depend on the hereditary nature of the characters. He may find it necessary to make several crosses differing in these characteristics before he obtains the result desired. Or he may find it desirable to cross some of the plants obtained from the first cross with other different varieties possessing the desired characteristics

In setting up a new program for crop improvement the breeder usually begins his hybridization program after he has conducted variety evaluation and selection programs for a short while. These studies enable him to know what types are more desirable for the areas for which he is working and what varieties possess valuable characteristics that will be useful in a crossing program.

It may be important at this point to say a few words regarding the steps that are necessary in making these crosses. The illustration in figure 10 is a rice flower just before it has bloomed. The small ovary, from which under proper conditions will develop a rice kernel, is shown at the base of the flower. From it protrudes the two-parted brush-like stigma. Coming out from the base of the flower are six small filaments and on the end of each is borne a small, slightly elongated floral part, the anther. As these anthers develop they are filled with grains of pollen and when the anther reaches maturity it bursts along the sides and the pollen is liberated. Some of this pollen falls on the brush-like stigma and germinates, and what is known as a pollen tube develops which penetrates the ovary, and fertilization is effected. The embryo then begins to grow and in time a mature rice kernel is obtained. Under normal conditions the pollen matures and falls on the stigma before the glumes open. Thus the rice flower is usually self-pollinated. This is the reason why it is not possible, as a rule, to change the type of plants produced by a single head by selecting the best plant in a line and growing its progeny and continuing this process for several seasons. Due to the natural tendency of rice to be self-pollinated, it is not possible to change the nature of the line by selecting large or small plants within the line. So we refer to the line of plants produced by a single head of rice as a "pure line." This helps the plant breeder, for he may test many lines in the same field without fear of any great amount of mixing due to natural crossing.

When it is planned to cross different varieties of rice, one plant is chosen and designated the female parent. A number of flowers on this plant are opened and the anthers removed a short time before they reach maturity. A plant from the other variety which has been chosen for the cross, which we term the male parent, is used to furnish pollen. Just before the anthers reach maturity they are collected and if they are ready to burst are rubbed gently on the stigma of the flower which has been prepared by removing the anthers. Often the anthers will begin to open and the pollen may be dusted on the stigma. The outer portions of the flower, the glumes, are then gently pressed back into position. All the flowers so treated are covered with light glassine paper bags to protect the flowers and prevent stray pollen from reaching the stigma.

Experience has shown that one is not likely to obtain a well-developed seed from every flower that is crossed. One may obtain only about five percent of successful crosses or he may obtain a higher percentage. Weather conditions and the care with which the work is done and other factors operate to affect the result. So the breeder is forced to make a large number of pollinations in order to obtain a sufficient amount of seed.

The seed is sown and produce the first-generation plants. These plants contain in their hereditary complex the hereditable factors of both parents and they will all be alike. The seed from these first-generation plants is sown one seed to a hill in order to study the many different types of plants that may be obtained in the next generation. This is the second or segregating generation. Some of the plants of this second generation will produce pure types in the next, or third, generation. Others will segregate and give the same general mixture of plants that was obtained from the first generation. The breeder needs to select the more desirable plants from the second generation and grow the third and often the fourth and fifth generations before he can be certain that he has true-breeding sorts. This may sound as though one is dealing with a complex mixture of plants and that there is no way to determine what is actually happening. Studies in heredity, however, have shown that many plant characters tend to follow definite ratios in their inheritance. For example, in crosses between a variety of rice that normally produces a red kernel and another type that produces a white kernel, one obtains in the second generation more red-than white-kernel plants following the ratio of three red to one white. These results show that red predominates over white, and we use the term "dominant" to indicate this. With these results red is the dominant character and white is designated as the recessive character.

Some crosses between varieties that produce purple kernels with types that produce white kernels have resulted in a ratio of three purple-seeded plants to one white-seeded, and in another case a ratio of 12 purple : 3 red: 1 white was obtained. Crossed between early and late varieties have given different ratios. Some results have been obtained giving a ratio of 3 late : 1 early. Then in another case the ratio of 9 late : 7 early was found. In a third study it was found that earliness was dominant to lateness, giving a ratio of 3 early: 1 late. Crosses between plants that produce starchy kernels with those producing glutinous kernels gave a ratio of 3 starchy: 1 glutinous. A large number of other characters of rice have been studied and many different ratios have been determined. There are some characters, that do not follow such simple ratios and the analysis of their inheritance becomes more involved. However, in the hands of a well-trained plant breeder hybridization offers a valuable tool for the development of new varieties of plants, and a large number of useful varieties have been produced by using this method.

RESULTS

(1) From Variety Evaluation

We will now consider some of the facts we learn from variety evaluation studies. At the main rice experiment stations, Bangkhen, Rangsit, Kok Samrong, San Patong, Hantra, and Surin, we conduct variety trials in which we compare from 30 to 50 varieties in one experiment under as nearly the same conditions as it is possible to obtain. In these variety trials we include some of the standard varieties, that is, varieties that have been studied in the past by the Department of Agriculture and are recognized as standard varieties for at least certain areas in Thailand. In addition we use varieties that we obtain from farmers, agricultural officers, and from the annual rice exhibit which is held in Bangkok by the Ministry of Agriculture, so that altogether we have in these evaluation tests several hundred different varieties of rice.

As indicated earlier, our efforts in variety evaluation are directed toward finding the best-yielding varieties of high-quality rice that are already available. While the varieties used in most of these tests are those grown on Thai farms, it is of interest to see how much these differ in production when they are grown in the same test on one field. For example, at the Rangsit station in 1953 in one test of 39 varieties we find that the highest-yielding variety, Sam Ruang, produces at the rate of 533 kilograms per rai while the lowest, Leaung Nond, produces at the rate of 373 kilograms per rai. That is a difference of 160 kilograms. With the same 39 varieties grown at Bangkhen, the highest-yielding one, Puang Nak 28, gave 630 kilograms per rai while the lowest, Nang Tani, produced only 404, resulting in a difference of 226 kilograms per rai. It is important to get this information, but of course we recognize that a test for one year is not sufficient and these tests are conducted for more than one year, so that in the end it will be possible to furnish information to the farmers as to what varieties are best for a certain locality.

The results of testing a number of varieties at Bangkhen are presented in table 1. The average results for the two years, 1952 and 1953, are presented in the first part of the table and the results for the three years, 1951, 1952, and 1953, are presented in the second part. It will be noted that there is considerable range in yield for the two-year period, 1952 and 1953, between the highest-yielding variety, Puang Nak 28, and the lowest-yielding one, Nang Tani. The difference is 198 kilograms. If we look at the results in a slightly different manner we find that the total produced from two crops of Puang Nak 28 would be 1,164 kilograms and that it would take three crops of Nang Tani to equal approximately the same amount.

The results for the three years show that Khao Nang Mom yielded at the rate of 597 kilograms per rai while Nang Tani, the lowest-yielding variety, produced at the rate of 359 kilograms. Here the difference is 238 kilograms. In fact, it would take more than three crops of Nang Tani to produce as much as was obtained from two crops of Khao Nang Mom. Differences as large as this are of great importance from the standpoint of what the farmer is able to obtain from using better varieties as compared with what he may harvest if he used the poor-yielding varieties.

The same varieties were grown at the Rangsit Experiment Station for the same years. The data are presented in table 2. In the Rangsit area the yields per rai are much lower than those obtained at Bangkhen. This is a general situation, for that area is recognized as an area that produces a relatively low yield of rice per rai. While the two stations are not very far apart geographically,

Table 1. Yields in Kilograms per Rai for Some Varieties Tested at Bangkhen in Randomized Blocks with Six Replications of Each Variety

Results for Two Years 1952-1953		Results for Three Years 1951-1952-1953	
Variety	Yield kgs/rai	Variety	Yield kgs/rai
Puang Nak 28	582	Khao Nang Mom	597
Khao Nang Mom	577	Khao Ta Hang	591
Khao Ta Hang	560	Leaung Rahang	539
Leaung Nual	550	Puang Nak 16	529
Puang Wai	536	Khao Prasert	522
Leaung Rahang	528	Leaung Ruang Hak	521
Khao La-or	526	Nam Dok Mai	521
Khao Suphan	517	Pin Tong 19	518
Pin Tong 18	504	Khao Umpai	518
Sam Ruang	503	Bang Phra	505
Khao Umpai	503	Kraya Chuey	505
Leaung Ruang Hak	502	Puang Pradoo	501
Khao Prasert	502	Khao Savuey	495
Nam Dok Mai	498	Leaung Nond	493
Bang Phra	496	Leaung On 23	481
Khao Keow 33	496	Khao Puang	479
Khao Savuey	494	Sam Ruang	473
Puang Pradoo	492	Chek Kradod	466
Khao Klong Sip	491	Khao Pudas	454
Leaung Nond	488	Pin Keow 9	452
Kraya Chuey	488	Khao Toklong	426
Khao Puang	460	Nang Tani	359
Chek Kradod	460		
Khao Pudas	450		
Pin Keew 9	436		
Leaung On 23	435		
Khao Toelong	407		
Nang Tani	384		

it is important to note that, because of the difference in environment, there is not always a close relation between the yields obtained from the same varieties grown at the two stations. Although close correlation is not found each year between the yields of the same varieties grown at Bangkhen and Rangsit, correlation is usually found between the yields of the varieties at each station from season to season. The results for two years show that Khao Suphan gave the highest yield, 388 kilograms per rai, while Leaung Nond, the lowest-yielding one, gave only 300 kilograms. For the three years the variety Khao Ta Hang gave the highest average yield of 366 kilograms per rai, with Leaung Ruang Hak giving the lowest yield of 288 kilograms per rai.

In northern Thailand near Chiengmai we conducted variety tests using for the most part varieties that are grown in the northern part of the Kingdom. At San Patong we found that of a total of 41 varieties the highest-yielding one produced 637 kilograms per rai while the lowest produced 303, giving a difference of 334 kilograms. These results are from the nonglutinous type of rice.

Three variety tests using the same 41 varieties were grown at San Patong, San Sai, and Doi Saket in 1953 and the average results for 34 of these varieties for the three tests are presented in table 3. It will be seen that the highest-yielding variety, Chinese 380, gave 662 kilograms per rai, while the lowest-yielding sort, Khao Ruang, gave 286. At this rate it would take more than four crops of Khao Ruang to equal two crops of Chinese 380. When these and similar studies have been continued for another season or so it will then be possible to give the farmers a considerable amount of definite information as to what varieties it will be profitable for them to grow and which ones they might well give up growing and replace with some of the better-yielding sorts. In this way production of rice will be increased on the same land without any decided change in general cultural conditions. It will merely mean the substitution of good-yielding varieties for mediocre or poor-yielding kinds.

Table 2. Yields in Kilograms per Rai for Some Varieties Tested at Rangsit in Randomized Blocks with Six Replications of Each Variety

Results for Two Years 1952-1953		Results for Three Years 1951-1952-1953	
Variety	Yield kgs/rai	Variety	Yield kgs/rai
Khao Suphan	388	Khao Ta Hang	366
Nam Dok Mai	386	Khao Savuey	363
Khao Ta Hang	382	Nam Dok Mai	362
Sam Ruang	381	Pin Tong 18	357
Pin Tong 18	380	Sam Ruang	352
Khao Savuey	379	Puang Nak 16	342
Khao Klong Sip	369	Khao Todlong	339
Khao Puang	359	Khao Prasert	339
Pin Keow 9	358	Chek Kradod	334
Leaung Rahang	357	Khao Umpai	334
Puang Nak 28	357	Khao Puang	333
Bang Phra	356	Nang Tani	331
Nang Tani	355	Leaung Rahang	328
Khao Prasert	353	Bang Phra	328
Chek Kradod	352	Pin Keow 9	326
Khao Keow 33	351	Khao Nang Mom	326
Khao Nang Mom	350	Khao Pudas	321
Leaung Nual	346	Kraya Chuey	318
Puang Wai	345	Puang Pradoo	307
Khao La-or	342	Leaung On 23	302
Khao Todlong	339	Leaung Nond	289
Kraya Chuey	339	Leaung Ruang Hak	288
Khao Umpai	339		
Leaung On 23	331		
Khao Pudas	325		
Poang Pradoo	320		
Leaung Ruang Hak	305		
Leaung Nond	300		

Among the varieties studied, as was stated above, we include the prize-winning sorts shown at the annual rice exhibit. At this exhibit prizes are awarded on the quality and appearance of the rice. Nothing is known about the productive ability of the different varieties. This last year, with a variety test of a number of these prize winners conducted at Rangsit and Bangkhen we find that one variety, Si Nual, averaged from the two tests 519 kilograms per rai, while Leaung On, one of the poorer–yielding ones, averaged only 340, giving a difference of 179 kilograms. Thus it is evident that while different varieties may produce high–quality rice certain of these have the ability to produce more rice per rai than others.

Earlier it was stated that in these studies we also compare varieties from other countries as to their ability to produce under conditions in Thailand. Among a large number of varieties received from the United States Department of Agriculture there were many that came originally from China. Some of these in early tests have appeared very promising indeed. In the Chiengmai area in 1953 we tested the yielding ability of 41 different kinds of rice at three different locations, as stated above, and the results obtained at all three localities show that four of these Chinese varieties yielded as follows: 662, 655, 643, and 629 kilograms per rai, while in the same test the Leaung Yai, which is very popular in that part of Thailand, yielded at the rate of 540 kilograms per rai, thus giving a difference of over 100 kilograms per rai. (Table 3) If these newly introduced varieties continue to produce higher than the best of the farmer's varieties that are grown in northern Thailand it will be desirable to multiply the seed and get it into the farmers' hands as quickly as possible, providing the quality is satisfactory.

In addition to the variety trials conducted at the different stations–and there were a total of 21 such trials grown this last season – another type of test, which we call regional trials, is conducted. These regional trials are placed on the fields of farmers who are willing to cooperate. Usually about 15 varieties for the tests are furnished from our experiment stations depending on

Table 3. The Average Yields in Kilograms per Rai from Three Identical Variety TestsConducted in 1953 at San Patong, Doi Saket, and San Sai in Northern Thailand

Variety	Yield kgs/Rai
Chinese 380	662
Chinese 298	655
Chinese 345	643
Chinese 311	629
Leaung Yai Selection 42	617
Eeaung Yai Selection 34	612
Leaung Yai Selection 10	604
Chinese 365	600
Leaung On	575
Leaung Pin-tong	548
Chinese 333	544
Muang Pon	543
Leaung Yai	540
Haiti 17	538
Lampang	535
Leaung Pan-tong	520
Nang Mol	518
Rak Pai	514
Leb Chang	510
Luang Savuey	497
Thong Raya-dam	475
Seta (Cita)	475
British Guiana 559	470
Lon Yung	463
Muang Pai	450
Champa Da	407
Hom Durian	406
Haiti 20	383
Krish Pasom	371
Khao Keow	374
Khao Ta-oo	356
Leaung Thong-suk	316
Pin Keow	296
Kao Ruang	286

where the tests are to be conducted, whether in the Central Plain or in other areas, and the agricultural agent in charge of these experiments is asked to select four or five of the varieties that are looked upon as good ones in his community, so that we have 20 varieties in most tests. These are grown in replicated plots so that small differences in soil fertility which are experienced from spot to spot in the field may not unduly influence our interpretation of the final results. These experiments are labeled so that farmers and others passing by them as they go through the country may know what is being done. In this way we hope to interest the farmers in our program. This last season we had about 55 such regional variety tests and they furnished some very interesting facts. In one locality, at Muang, near Nakorn Nayok, the highest–yielding sort produced 487 kilograms per rai while the lowest–yielding one--which in that test was a local variety obtained from one of the farmer–produced only 316 kilograms per rai. This difference of 171 kilograms is something that the farmers need to know about. In another test at Nan we find that the highest–yielding variety gave more than twice as much as the lowest–yielding sort which, again, was one obtained from one of the farmers.

One of the points we have in mind in conducting these tests is to find out whether the varieties we have had under test and which do well in some localities will also do well in other localities. We also want to find out whether there may be some local varieties which we have not yet obtained in our collection that may be high yielding and perhaps in some cases higher yielding than the varieties we send to a particular location. That occurs sometimes. For example, in one test conducted at Nakorn Sawan a local variety gave the highest yield of all 20 varieties in the test. This of course is important to learn because we are endeavoring to find the best–producing varieties of rice for Thailand.

In this connection, it may be pointed out that in 24 regional tests conducted on different farms of the Central Plain the variety Khao Ta Hang ranked either first, second, third, or fourth 17 times, and Khao Nang Mom ranked as well in 11 out of the 24 tests. On the other hand, the variety Khao Ta-oo ranked either 18th, 19th, or 20th in 15 out of the 24 tests. These results show definitely that some varieties have the ability to yield well in a number of localities while others do not possess this ability.

When speaking of the yields obtained it must be made clear that these yields per rai are not definite except for the particular experiment and that soil and other factors cause variation, with the result that if a test were conducted on the same field another season one would not expect the varieties to give the same yields as were obtained the first season, This means that in conducting tests the investigator must grow them under different conditions for more than one season. When this is done he finds that in the end certain varieties tend to be good producers season after season while others do not. He will also find that some varieties vary much more from season to season than do others. These factors must be taken into consideration when recommending varieties for the farmers' use.

(2) From Selection

We may now consider what is being learned from the extensive selection program that we have under way. It has been pointed out that when attempting to improve a crop like rice by individual plant or head selection it is important that the plant breeder have a large number of selections for testing. Part of the instruction during our first short course in 1950 was on the importance of improving crops through selection and plant breeding and the details of making and handling selections were discussed fully. Toward the end of the course we called for volunteers from the group to help us in making a large number of head selections, as we had already determined that this should be done, and a large number of men volunteered. We then gave them further instruction after the regular short course was over, and asked each man to visit, if possible, 20 farms in his locality and to make from 100 to 200 selections from each farm or field visited. These men did their work exceedingly well and selections were obtained from 978 farms in 35 different localities. A total of about 120,000 different head selections was made. A record was made of the locality and farm from which each lot of selections was made. The record also indicated whether they were obtained from early, medium, or late types and whether they were of the floating or nonfloating type.

Due to shattering of seed and other losses we had left for testing in 1951 over 114,000 of these heads. They were grouped according to the locality from which they came and tested at certain of our main stations. For example, the selections made from the central part of Thailand were tested at Bangkhen and Rangsit, with the exception of the deep-water or floating varieties, which were tested at the deep-water station at Hantra near Ayuthia. Those selections made in the North and Northeast were tested in the Chiengmai region.

As explained earlier, the more promising selections are saved each year to be continued in further tests the following year. Of a total of over 114,000 selections grown in 1951 there were 22,553 saved for testing in 1952. Thus it will be seen that about one-fifth of the selections were continued in the 1952 tests. At the end of the 1952 season over 10,000 were saved for the 1953 yield comparisons. Nearly 3800 of these selections are still under test in 1954.

Certain facts stand out clearly when all the results at the different stations are studied; for example, it is found that certain areas tend to give better varieties, and more selections from these better sorts are continued in the tests from year to year. It is also found, however, that while certain areas furnish good varieties there may be a few poor types found in the same area so that, while from some of the varieties good selections are obtained, yet from some other sorts grown in the same area only a very few selections are worth continuing in the test. From some varieties one obtains a number of high-yielding strains while from others there are few—often none—that are good enough to be continued year after year. Some data obtained from the selections grown at Kok Samrong in 1952 will illustrate this. These results are presented in table 4. In the upper part of the table are selections that are producing satisfactorily. In the first column the selection number is presented. A word of explanation will help in pointing out how these records mentioned earlier are kept. For example, the first number in the first column is 20-29-30. The number 20 refers to the locality from which the selections were made; the number 29 refers to the field in that locality; and 30 indicates the number of the selection made from that field still remaining in the test. Thus, 20-29-30 means that selection number 30 from field 29 which grew in locality 20 represents the first result in this table. All the selections are numbered in a similar manner.

The data are presented in this way: following the selection number we have in column 2 the yield of the check variety with which the new selection is compared and in the third column is the yield of the selection. For example, for the first selection the check yield is 388 and the variety yield is 587. Taking the difference, we find that the gain of the selection over the check is 199 kilograms per rai. It will be noted that all the selections from this variety show substantial gains over the check. On observing the data presented in the lower part of table 4, it will be seen that some of the selections yield somewhat better than the check but five of them yield lower. In work of this kind such results are to be expected, since it is recognized that not all the selections one makes from the farmers' fields will be superior to the varieties used as check. These yield comparisons must be conducted in order to find

Table 4. Yields of Rice Selections Obtained from Three Replications at Kok Samrong in 1952 Yields are given in kilograms per rai.

Selection Number	Average Yield: Check	Average Yield: Selection	Gain or Loss compared with check
This variety furnished promising selections :			
20-29-30	388	587	199
20-29-35	387	690	303
20-29-37	391	549	158
20-29-38	397	529	132
20-29-42	402	611	209
20-29-46	410	645	235
20-29-47	417	543	126
20-29-56	422	601	179
20-29-57	429	649	220
This variety furnished no outstanding selections:			
4-1-119	525	556	31
4-1-120	522	587	65
4-1-121	525	537	12
4-1-125	534	530	-4
4-1-126	538	464	-74
4-1-128	539	501	-38
4-1-130	542	459	-83
4-1-133	544	466	-78
4-1-135	545	525	-20

those which are superior and those which are inferior to the check varieties. The data in the lower part of the table further emphasize what was stated above, that is, that certain localities and certain varieties tend to furnish poor-yielding selections, while from other localities and varieties we obtain good selections.

Some results obtained from comparing selections with the check for two seasons, 1952 and 1953, are presented in table 5. The data are arranged as in table 4 but in this case we have the average results for two seasons rather than for only one season. It will be seen that the selections from location 20, field 29, some of which were included in table 4, show very good gains over the check variety. In the lower part of the table are some data presented from a series of selections tested at Bangkhen for the two seasons and some of these yielded much better than the check.

While some of these selections do show large increases in yield over the check variety, it is too early to draw definite conclusions as to which one or ones of these will be best. Experience with similar work has indicated that some of these selections will not continue to give the large increases over the check such as are shown in table 5. Tests must be continued for at least two or three more seasons before we can be absolutely certain which ones of these will tend to give large yields season after season. While at this stage it is not possible to be definite, experience with this kind of breeding and testing work justifies us in the belief that we will obtain some selections that will be worthy of multiplication and distribution to the farmers. If any of these or other selections in our studies should give as much as five-to ten-percent increase in yield this would mean a considerable gain, not only to the farmers but in the total amount of rice produced in Thailand. For example, assuming the production of Thailand to be about 7,000,000 tons of rice a year, we find that even a five-percent increase would mean an additional 350,000 tons annually.

Table 5. The Average Yields of Rice Selections Grown at Kok Samrong and at Bangkhen in 1952 and 1953 Yields are given in kilograms per rai.

Selection Number	Average Yield		Gain
	Check	Selection	
Kok Samrong:			
20-29-9	364	583	219
20-29-17	366	563	197
20-29-18	369	550	181
20-29-20	371	472	101
20-29-28	373	507	134
20-29-30	377	530	153
20-29-35	384	583	199
20-29-37	393	513	120
20-29-38	402	491	89
20-29-42	409	555	146
Bangkhen:			
8-16-9	362	487	125
8-16-22	370	514	144
8-16-23	376	462	86
8-16-28	358	507	149
8-16-42	328	508	180
8-16-45	321	617	296
8-16-51	315	530	215
8-16-53	320	441	121
8-16-54	331	493	162
8-16-72	379	481	102

A further example of the results that may be expected from selection may be shown from some studies on selections made near Chiengmai. In 1948, 1000 selections were made from the Leaung Yai variety mentioned earlier and these were grown in 1949. Each year the poorer ones were discarded, and only the better sorts continued. Only three of these remained for testing in 1953. This last season, in the three variety tests grown near Chiengmai (Table 3) we find that the variety from which these selections were made yielded 540 kilograms per rai while the best selection, No. 42, from this variety yielded 617 kilograms per rai, a difference of about 14 percent.

The plant breeder does not depend upon one lot of selections; he knows he must make new collections of many thousands of heads every two or three years. With this in mind, in 1952 another large collection of heads was made from farmers' fields and a total of over 90,000 individual heads was obtained. These were tested for the first time in 1953. We have something over 20,000 selections from this second lot being tested in 1954 in replicated plots located at our main stations. It is evident that with selection work of this kind facilities are needed so that adequate yield tests may be conducted in a number of different parts of the Kingdom. This work will be continued and expanded and it is expected that other large collections of individual heads will be made in the future.

(3) From Hybridization

When the rice-improvement program was being planned it was agreed that hybridization should be stressed as an important phase of the project. The improvement of plants by hybridization is a slower process than is selection but much may be accomplished by this method when properly followed. There are some who believe that hybridization offers the opportunity to produce greater increases in yield than does selection. This may or may not be true depending on the type of crosses made and for what purpose. When a disease proves to be so serious that yields are greatly reduced then larger yields may be obtained by making crosses between a high - yielding but disease-susceptible sort with one that is disease-ersistant. However, the yield of the new variety may be no higher than that of the susceptible parent when no disease is present. As already pointed out, selection has resulted in large increases in yield with many different crops.

Just before our arrival in Thailand the possibilities of a large-scale crossing project were discussed at the meeting of the International Rice Commission held at Rangoon, Burma in February, 1950. As a result a large-scale program was inaugurated under the sponsorship of the Food and Agriculture Organization of the United Nations. The plan as adopted was to confine the work to crossing varieties of japonica with varieties of indica. The varieties grown in Thailand are nearly all of the indica type. Varieties of japonica are grown in Japan, China, Korea, Taiwan, and some other parts of the world. One of the important objectives in making these crosses is to combine the high yield and stiff straw of the best varieties of japonica with good varieties of indica so that new types possessing stiff straw and good quality and capable of yielding well may be obtained. It was thought that those new varieties might stand up well and produce high yields with heavy applications of fertilizer. In this way it would be possible to produce more rice per unit of land and not lose in quality due to the crop lodging as it nears maturity.

The plan agreed upon was that the work would be located at the Central Rice Research Institute at Cuttack, India, as that station had the facilities needed and graciously offered to undertake the work. Each country that was willing to participate was asked to send to Cuttack a few of the best indica varieties resulting from previous research. That station arranged to obtain a number of good japonica varieties to be used for crossing, The crosses were made by the plant breeders of that station who were well acquainted with the methods involved. It was also agreed that the first-generation plants would be grown at Cuttack. The seed from the plants is then sent to the several cooperating countries to be grown under the direction of their rice breeders.

The first crosses were made in 1950 and in 1952 a large amount of seed from first-generation plants was made available for our program here in Thailand. The second generation of these hybrids was grown in 1952. Since that time our efforts with hybridization have been confined to the growing and study of the material made available under this cooperative program. From the first lot of seed received from 15 different crosses and grown in 1952 about 35,000 plants were selected for growing the third generation in 1953. In 1953 another lot of seed from first-generation plants from a different lot of crosses was received from Cuttack and we grew a large number of plants from this material.

For the 1954 season we have about 17,000 plants from the third generation to grow a fourth generation and over 10,000 plants from the second generation to grow a third generation. It will be another season or two before types are found that are desirable and are true-breeding in their nature. These will then be tested by the same method used for testing the selections. This will mean that it will be some time yet—at least four or five seasons-before we will know whether valuable types have resulted from these crosses.

Another lot of seed from other crosses and backcrosses has been received for growing a new lot of plants in 1954. Other crosses will be made from time to time using types grown in Thailand along with varieties obtained from other countries. Work of this sort must continue and expand. The breeder is always hoping to produce better and better varieties.

CONCLUSION

You may ask how this is going to help the farmer and what can be done to enable him to obtain seed of any of these new sorts that may be developed. This is an important part of our program and we are making plans to this end. It will be necessary to add to our staff a specialist who is trained and experienced in seed multiplication, inspection, and distribution. After experiments have demonstrated that a variety, a line selection, or a selection from one of our hybrids is superior in yield and quality, small fields will be sown with seed of this variety as a first step in multiplication of seed. From these small fields quantities of seed will be made available to good farmers who are willing to take part in the program and who will give special attention to make certain that the new seed is kept free from all mixtures of other rice. From these farmers' fields more seed will be obtained from which a much larger area may be grown, and thus seed will be ready to distribute to the farmers who want the new variety. In practically all cases it is expected that demonstration field tests will be made in many localities with the new varieties and local sorts, so that farmers may know first-hand whether they will want seed of the new sort. No farmer will be forced to take a new variety unless he is convinced that it will enable him to produce more rice per rai. It will be necessary to conduct demonstrations, to educate through field meetings and in other ways, so as to acquaint the farmers with the advantages of the new sorts developed. In this way it is hoped that Thailand's rice production may be increased to the extent necessary to take care of all the needs for rice consumption at home and the amount necessary for world trade. This is the aim of our program.

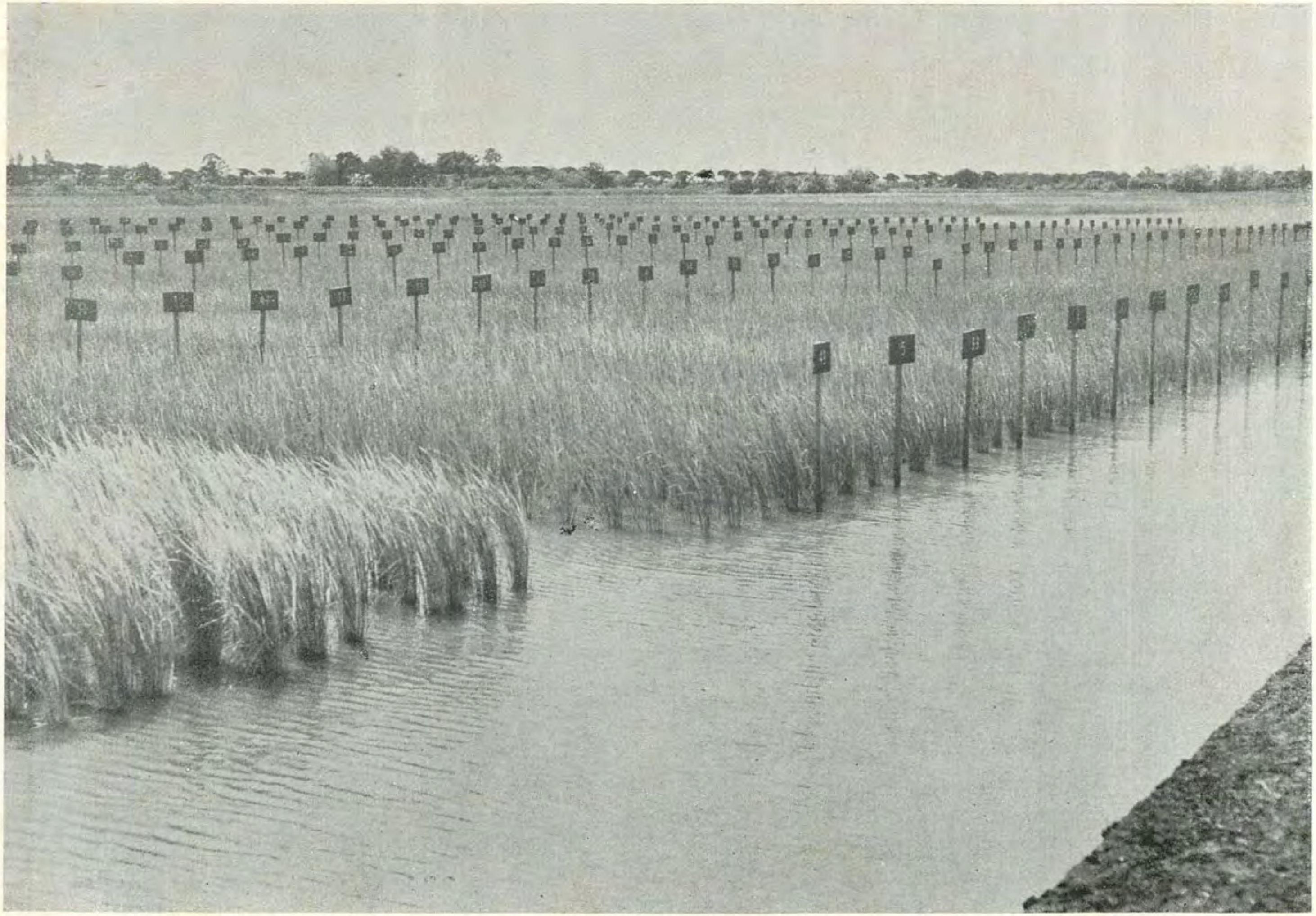

Figure 1. View of a variety test. A stake showing the variety number is placed at the end of each plot.

Figure 2. Harvesting a variety test at Bangkhen.

Figure 3. Taking the samples and bundles of rice to the laboratory for threshing and storing.

Figure 4. Preparing packets of seed from the selections for sowing on seed beds.

Figure 5. Placing the packets of seed from the selections on the seed beds.

Figure 6. View of the work of transplanting, together with the bundles of seedlings arranged along the dike.

Figure 7. Placing a stake at the end of a row that has been chosen for further testing.

Figure 8. Harvesting heads from a selected row.

Figure 9. Showing one method of threshing the heads from each selected row.

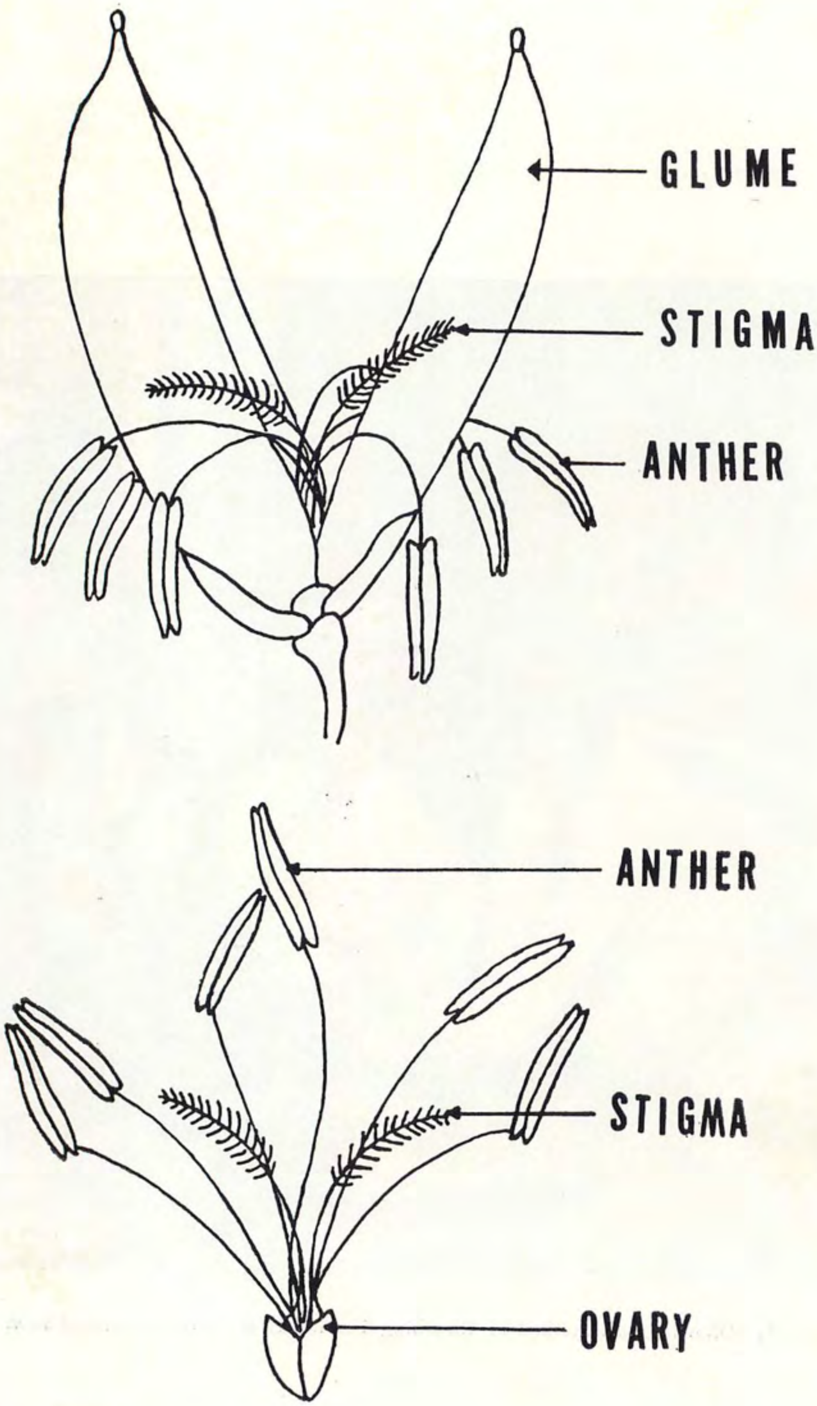

FIG 10

Figure 10. Diagram of a rice flower previous to blooming, showing the essential floral parts.