CHINESE-AMERICAN
JOINT COMMISSION ON RURAL RECONSTRUCTION

Plant Industry Series No. 15

RICE IMPROVEMENT IN TAIWAN

TAIPEI, TAIWAN, CHINA
1st Printing: MAY 1959
2nd Printing: MAY 1960
3rd Printing: AUGUST 1961

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FOREWORD

This report is a compilation of papers prepared by the JCRR specialists since 1957. It is intended to bring together in one volume reports concerning the various phases of rice improvement work in Taiwan, which together are responsible for raising the total rice production of this Island from a prewar maximum of 1,402,414 M.T. in 1938 and a postwar minimum of 638,828 M.T. in 1945 to 1,894,127 M.T. in 1958 in terms of brown rice.

Papers No. 1, 4, 6, 7, 8, 9, 10, and 11 have been published in No. 3 (September 1957) and No. 4 (December 1957) of Volume 6 and No. 1 (March 1958) and No. 4 (December 1958) of Volume 7 of the International Rice Commission Newsletter of the FAO Regional Office for Asia and the Far East in Bangkok, Thailand. Concurrence for reprinting these papers has been obtained from Mr. C. W. Chang, Executive Secretary of the FAO International Rice Commission. Papers No. 1, 6 and 9 have been brought up to date, while the rest of the above mentioned reports remain unchanged as they were published before.

Paper No. 3 has been published in New Series No. 21 of the Journal of the Agricultural Association of China, Taipei, March 1958. Papers No. 2 and 5 are recent papers.

H. T. Chang
Chief
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May 1959

CONTENTS

FACTORS CONTRIBUTING TO RICE PRODUCTION INCREASE IN TAIWAN

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Rice is the most important crop of Taiwan, for in addition to being the staple food of the local populace, it is the second largest earner of foreign exchange, has by far the largest acreage among all crops, and its price constitutes the backbone of the whole price structure. Since the termination of the Second World War, rural reconstruction has become the central part of the economic development program of Taiwan; and to increase rice production has always been a primary objective of the agricultural program. The success of the efforts made toward boosting rice production is borne out by the fact that the acreage, production, and yield per hectare of rice in Taiwan in postwar years have all exceeded their respective prewar records.

Table 1. Acreage, Production and Yield of Rice in Taiwan

Year	Acreage ha.	Production M.T. (Brown rice)	Yield per ha. kg. (Brown rice)
1935-1939 av.	653,878	1,339,494	2,052
Prewar record	681,548 (1936)	1,402,414 (1938)	2,242 (1938)
1945	502,018	638,823	1,273
1946	564,016	894,021	1,585
1947	677,557	999,012	1,474
1948	717,744	1,068,421	1,489
1949	747,675	1,214,523	1,624
1950	770,262	1,421,486	1,845
1951	789,075	1,484,792	1,882
1952	785,729	1,570,115	1,998
1953	778,384	1,641,557	2,109
1954	776,660	1,695,106	2,183
1955	750,739	1,614,953	2,151
1956	783,629	1,789,829	2,284
1957	783,276	1,839,009	2,348
1958	778,189	1,894,127	2,434

From Table 1 we can see that there was a rapid increase in rice acreage from 1945 to 1948. Thus in 1948, only three years after the war ended, the rice acreage had already surpassed the prewar record acreage. Such rapid expansion of area was brought about by a sharp increase in demand for rice at that time. Not only did the sudden influx of population from Mainland China impose a heavy demand on local rice supply, but the local populace, once freed from the colonial and wartime restrictions, showed a marked tendency to eat more rice. The yield per hectare of rice during those years was, however, very low, as a result of the disrepair of irrigation facilities, the lack of chemical fertilizers, the disruption of supply of improved seeds, etc. By 1951, the expansion of rice acreage had reached an all time high of 789,075 hectares, being about 100,000 hectares more than the prewar record. Such expansion of rice acreage has apparently brought some of the rice fields on to marginal lands, notably those without reliable irrigation facilities. The frequency of drought hazards in these areas and the low production therefrom account at least partly for the rather slow recovery of the island's average per hectare yield of rice, notwithstanding the significant technical improvements made in other phases of rice production.

The yield per hectare of rice began to increase more sharply after 1949, and the increase has continued ever since. By 1956, it eventually surpassed the highest prewar record. The total rice production surpassed the prewar record as early as 1950, and continued to climb in the following years although the acreage had remained static after 1951. It may be said that from 1945 to 1948, the increase in rice production in Taiwan was due to the expansion of planting areas; from 1949 to 1951, it was due to the increase in both acreage and yield, and from 1951 to 1958, it was solely due to the continuous rise of yield per hectare.

Such steady improvement is due to many interrelated factors, e.g. the improvement of irrigation, the increase of the use of chemical fertilizer, the rehabilitation of the seed multiplication system, the improvement of pest control methods and cultural practices. All these factors are interrelated, additive, and mutually complementary. It is difficult to tell exactly which factor contributed most. But if each of the above mentioned factors were a pearl, the land reform would be a thread of silk, stringing the pearls together to form an impressive necklace.

The aim of this article is to summarize briefly the manner in which these various factors have contributed to the increase of rice production, and the efforts currently made for further improvement. More detailed accounts of these subjects are given in other papers appearing in this same issue.

I. Land Reform

The land reform program in Taiwan was carried out in three different phases. The first phase involved reduction of the land rental paid by tenant farmers to land owners from a customary 50 percent or more to 37.5 percent or less of the value of the crop. The land rent reduction program was inaugurated in 1949, with the primary objective of improving the living of the tenant farmers and discouraging the holding of land by big landlords, thus setting the stage for sale of land by the latter to the former in later years. 302,277 farm families signed 396,002 new contracts with land owners under this program, involving 256,948 hectares of land. The second phase was related to the sale of the public land by the Government in 1951 at a price equivalent to 250 percent of the value of the main crop yields payable in ten years by semi-annual installments. At the end of 1953, 63,021 hectares of public lands had been sold to a total of 121,953 farm families. This phase of the program further served to elevate the social status of the tenant farmers and made it clear to every one, including the big land owners, the determination and sincerity of the Government to help tenants own the land which they till. The third and final phase of the land-to-the-tiller program was authorized by the Government early in 1953 and completed in one year's time. Under this program, the Government bought land from absentee land holders and distribute it to tenant farmers. 70 percent of the payment to land owners by the Government was made in the form of interest bearing land bonds redeemable in ten years, and 30 percent in stocks of Government owned corporations which manufacture cement, paper and pulp and textile, and process agricultural products and others. The resale price of the land to tenant farmers was calculated on the basis of 250 percent of the value of the annual main crops payable in 20 semi-annual installments in kind. Before the price was fully paid, an interest of 4 percent per annum was payable by the new owners on the outstanding portion of land price. Up to the end of 1953, a total of 143,568 hectares had been purchased and resold by the Government to 194,823 tenant families.

The land reform program is at present almost completed. Before it was started in 1949, 38 percent of the total privately owned farm land was under tenancy. After the reform, the area under tenancy was reduced to 14 percent of the total private farm land. By 1955, the number of owner-farmer families in Taiwan had increased to 56 percent of the total number of farm families in the province, and the number of tenant families and farm hands had dropped to 17 percent and 5 percent respectively, the remaining 22 percent being part-owner-farmer families.

The effect of the land reform on the agricultural improvement program cannot be measured quantitatively. More important than any statistical figures can express, the successful implementation of the program has given the farmers a stimulus to improve their crop, their home and their living. The agricultural extension workers have been aware of such spiritual enlightenment on the part of the tenant farmers, reflected by the eagerness with which they adopt better seeds, insecticides, implements, cultural methods and more fertilizers, and solicit Government assistance in the improvement of irrigation and drainage.

Equally important in an intangible way the land reform program has won for the Government and its workers the confidence of the farmers. The simple logic is that a Government which helps farmers obtain land has no reason to teach them wrong methods in farming. If farmers' lack of genuine interest for making improvement and their lack of confidence in agricultural extension workers were the two greatest obstacles to a successful agricultural extension program, the land reform removed both of them in one stroke. It is not a mere coincidence that the per hectare yield of rice started to rise steadily since 1949, the year when the first phase of land reform was initiated.

II. Seed Improvement

One of the earliest efforts made in Taiwan after the War in rice improvement was to strengthen the rice breeding and rehabilitate the rice seed multiplication system. Achievement in breeding is evidenced by the gradual waning in popularity of the variety "Taichung 65" in recent years. In 1941, this variety alone occupied more than 65 percent of the total area of Ponlai (*Japonica* typ) rice in both spring and fall planted crops. In 1956, its area dropped to 25 percent, being replaced gradually by new Ponlai varieties developed after the War. The rice seed multiplication system not only enabled the growers of the Ponlai varieties to renew their seeds once in every three crops, but also made it possible for the acreage of Ponlai rice to expand continuously. By 1956, it reached an all time high of 450,000 hectares, comprising 57 percent of the total rice acreage. Since under favorable conditions, Ponlai varieties yield from 10 to 20 percent higher than native *Indica* varieties, it is natural that the expansion of Ponlai rice acreage will result in an increase in the average rice yield.

III. Use of Chemical Fertilizers and Manure

The gradual increase in the use of chemical fertilizers on rice in postwar years is shown in the following table:

Table 2. Rates of Chemical Fertilizers Allocated per Hectare of Rice in Taiwan (In Terms of Nutrient Elements)

Year	Per hectare allocation rate (kg.)		
	N	P_2O_5	K_2O
1937-1939 average	70.0	24.6	7.9
Prewar record for N (1938)	77.8	(21.7)	(5.7)
1945	0.3	0.6	0.2
1946	1.5	—	—
1947	13.8	9.5	—
1948	17.6	6.3	—
1949	23.3	7.8	—
1950	51.6	14.0	—
1951	58.6	11.8	7.3
1952	66.0	24.1	9.8
1953	67.0	27.6	11.1
1954	83.4[1]	29.2	12.0
1955	83.7[1]	33.3	13.8
1956	85.3[1]	33.7	14.3
1957	87.2[1]	33.6	16.4
1958	90.0[1]	34.9	18.6
Optimum rate based on experiments	80.0	40.0	40.0

It can be seen from the above table that the present rate of application of chemical fertilizers on rice has surpassed the maximum rate applied before the war. The rate of nitrogen has already reached the optimum, though that of phosphorus and potassium still has some room for increase.

The Government also encouraged the use of compost manure on rice and other crops. Since 1949, cement has been provided to farmers as a subsidy toward the building of compost shelters, with farmers themselves paying for other building materials and labour cost. From 1949 to 1956, a total of 102,027 compost shelters were built by farmers with such subsidy. It is estimated that 2,500,000 M.T. of compost manure are produced yearly from these shelters. The total annual production of compost manure of Taiwan is around 7,000,000 M.T., the bulk of which is being used in rice fields. The farmers generally apply 6,000 kg. of compost manure to each hectare of spring planted rice, and 4,000 kg. to the fall planted rice. The recommendation of the Government is to use up to 9,000 kg. per hectare per crop.

1 The optimum rate of application (80 kg. N per ha.) is the rate at which the increase in crop yield per additional unit of fertilizer applied is the largest. However, in the consideration of increasing rice production of the Island as a whole, application up to 120 kg. nitrogen per hectare is still profitable.

The compost is made mostly of rice straw, sugarcane leaves, other plant refuse and hog manure.

Sesbania sesban is the most widely grown green manure crop in rice fields, especially as a winter crop in southern Taiwan. Soybean and field pea are also grown to some extent in southern and central Taiwan, respectively, for both picking the pod and green manuring. But until recently, there had been no suitable leguminous green manure crop to be recommended for northern Taiwan, because the wet and cool winter there prevents most green manure crops from making a satisfactory growth during the period between the harvest of the fall rice in November and the transplanting of spring rice in March. Since 1955, however, experiments on *Astragalus* planted two weeks to 20 days before the harvesting of the fall rice crop have yielded an average of 20,000 kg. of green stuff per hectare. It is expected that the planting of *Astragalus* in northern Taiwan as a paddy field winter green manure crop will spread rapidly, and will help increase the rice yield over some 100,000 hectares of land in this area.

IV. Pest Control

The contribution of pest control to the increase of rice production in recent years in Taiwan is prominent. The acceptance of new pesticides by the farmers is especially noteworthy. Since the introduction of the first litre of Parathion (Folidol E-605) for testing in 1952, the use of Parathion and other organo-phosphorous compounds for the control of rice borer has quickly been established in rural Taiwan as a routine practice in rice culture. For the fall rice crop of 1955 and the spring crop of 1956, 45,000 litres of Parathion were bought by farmers and applied over some 65,000 hectares of rice. Hence three private factories were set up during the last three years to manufacture pesticides of the organo-phosphoric and chlorinated hydrocarbon groups from imported materials. A fourth factory, owned by the Government, has added the making of these modern pesticides to its original business of manufacturing DDT and BHC. Since 1956, the control of rice insects has become completely commercialized, with farmers buying their own sprayers and pesticides.

3,360 M.T. of locally made 1 or 1.5 percent BHC powder were used during the fall of 1955 and the spring of 1956 over 113,000 hectares of rice field for the control of other rice insects. Another even more widely practised measure is the soaking of rice seed before planting in 0.1 percent solution of organic mercury compounds for the control of rice diseases. Annually, 100,000 lbs. of these compounds were used up by farmers in Taiwan for treating seeds, covering about 287,000 hectares of rice fields.

V. Improvement of Farm Machinery

Many types of farm implements and machines are used in Taiwan for rice production, but mostly have been in use for many years. Significant developments which have definitely contributed or will most certainly contribute to the increase of rice production in Taiwan are enumerated below:

(1) Before 1953, there was only one government operated pilot plant which turned out sprayers on an experimental basis. Sprayers and dusters used before this were mostly imported from Japan, and the number imported was small, as chemical spraying for control of rice insects and diseases was not widely practised. Since the successful demonstration and extension of the use of Parathion and Endrin for the control of rice borers, the demand for sprayers rapidly increased. During the past six years, more than a dozen private factories have been established to manufacture sprayers and dusters, including some power sprayers. Rice growers are now buying more than 10,000 sprayers a year.

(2) Introduction, experimentation and demonstration of small power tillers have been undertaken during the past five years. The program was prompted by the shortage of an estimated 100,000 head of draft cattle in Taiwan in the face of expanding cultivated land area and tight crop rotation schedules. Extensive experimentation on the performance and the cost of operation of 2.5 HP to 3.5 HP tractive and rotary type power tillers has demonstrated that this type of machine would be a good substitute for water buffaloes in Taiwan.

VI. Expansion and Improvement of Irrigation Facilities

Although Table 1 shows that there has been no increase in rice acreage in Taiwan after 1951, it does not mean that the effort to improve irrigation facilities has stopped, as may be seen from Table 3.

Table 3. Areas of New Irrigation and Improved Irrigation[1]

Year	Area of land with new irrigation facilities (ha.)	Area of land with improved irrigation (ha.)
1953	11,753	7,425
1954	7,336	49,858
1955	7,298	36,144
1956	7,369	23,658
1957	3,933	36,786
1958	4,384	100,562

[1] Area given here is in terms of crop area, i.e., if a one-hectare piece of land is planted twice in a year, it is counted as two hectares.

This means that while on the one hand new lands have been brought under irrigation each year and the irrigation on some lands has been made more dependable, on the other hand some marginal lands have been retired from rice production. In one southern area (Tainan), the extension of a special cultural system developed for planting sugarcane on heavy-clay, rain-fed single-crop rice field has met with some success. In a northern area (Miaoli), a new variety of soybean has produced more than a poor crop of fall planted rice in rain-fed fields. The area under this soybean variety is expected to increase rapidly in northern and eastern Taiwan in the near future where irrigation facilities are lacking.

It is now obvious that, although the rice planting area of Taiwan has not increased since 1951, there has been a steady improvement in irrigation facilities, thereby contributing definitely to the increase of rice per hectare yield in recent years. In addition, the provision of better irrigation enables farmers to change from the planting of native rice varieties to the higher yielding Ponlai varieties, to make more efficient use of chemical fertilizers, and to further increase the double cropping index of the land.

VII. Prospects of Further Rice Production Increase

The population of Taiwan is at present about ten millions and the rate of increase is over 3 percent, or more than 300,000 persons per annum. The present rice consumption is about 150 kg. of brown rice per capita per year. Therefore 45,000 more metric tons of rice is needed each year for feeding the increased population. At the present hectare yield, 20,000 additional hectares of land is needed each year for growing the needed additional 45,000 M.T. of rice. Since available arable land is limited, further raising the yield per hectare is not only feasible, but imperative. Under the Second Four-Year Plan for Economic Development of Taiwan, it is planned that by 1960 the rice acreage will be increased to 830,000 hectares, yield per hectare to 2,470 kg. of brown rice per hectare per crop, and the total production to 2,050,000 metric tons of brown rice. The following are some of the technical aspects of the plan to reach these goals:

(1) Seed improvement — Since 1956, five new promising rice varieties have been released for extension. The new emphasis placed on the rice breeding work by all experiment stations is to obtain varieties resistant to rice blast disease and lodging, and of early maturity. The former two characters will enable us to elevate the rate of fertilizer application so as to further bring up the rice yield per hectare; while the latter will facilitate the extension of winter crops following the two rice crops on the same piece of land.

(2) More efficient use of chemical fertilizers — The per hectare rate of chemical fertilizer application is not expected to make any substantial gain until new varieties resistant to rice blast disease and non-lodging under heavy N application (above 120 kg. of N per ha.) are obtained. The efficiency in the use of chemical fertilizers on rice in some areas, however, will be improved, following further improvement in irrigation (e.g. Shihmen Dam) and soil property. The latter will be made possible by the extension of new green manure crops or the use of more other organic manure (e.g. compost, filter cakes from sugar mills, etc.). A program for composting city refuse for farm use is being promoted to supplement the application of farm produced compost manure.

Thus far, chemical fertilizers have been allocated to rice farms at fixed amounts for each hectare. The accumulated data on soil and fertilizer studies are not yet sufficient to provide a basis for recommending the rates of chemical fertilizer application to individual farms. Soil testing methods are being studied. It is hoped that practical means may soon be developed to determine the fertilizer needs of individual farms. The present allocation system should eventually give way to free marketing, with the bulk of the chemical fertilizers to be consumed marketed directly by local industries to farmers. Meanwhile the farmers must be sufficiently educated to appreciate the value of using proper rate of fertilizers adapted to the soil conditions of their own farms. Such objectives, however, may not be fully realized in the immediate future.

(3) Field rodent and granary pest control — After two years of laboratory and field studies, various methods of controlling field rats have been tested. It has been found that baits made of 0.5 kg. of 0.5% Warfarin, 9.5 kg. of brown rice, traces of peanut oil, sugar and salt, and deposited in bamboo stations placed at the rate of 15 to a hectare in winter when the food in the field is scarce, have proved effective in destroying most of the rats in the baited area. An island-wide baiting campaign for rat eradication conducted in the winter of 1957 and the early spring of 1958 brought in 6,900,000 tails cut off from dead rats found in the field, and is estimated to have actually killed four times as many rats. Continuous program will be conducted to keep the rat population at a low level. The next step to further reduce the loss of rice would be the granary pest control. A demonstration project has been started in 1958 by spraying the rice warehouses with 25% DDT emulsion and mixing paddy with Lindane at 2.5 ppm.

(4) Extension of small power tillers — Long range planning for the extension of the small power tillers includes giving encouragement to local factories not only to manufacture machines similar to foreign makes, but to improve and modify the

attachments so that they will be better adapted to local needs; training technicians and extension workers who in turn will educate the farmers and render their services; arranging for stable fuel supplies and rural repair service; and providing credit to help farmers buy the tillers. Six manufacturers, all private concerns, have started to make the tillers. The program is well underway.

(5) Further improvement of irrigation — According to the estimate of hydraulic engineers, there are yet 60,000 hectares of dryland in Taiwan which could be turned into double rice crop field, and 60,000 hectares into single rice crop field; in addition, there are also 100,000 hectares of single rice crop fields which could be turned into double crop rice fields by construction of new irrigation projects or by improvement of the existing systems of irrigation. However, irrigation projects of lower cost and easier engineering have been mostly completed during the recent years. For further development, the engineering aspects will become more and more difficult and the cost of construction higher and higher.

Such major projects as the Shihmen Reservoir and the systematic development of the underground water resources in southern Taiwan have already been started. The adoption of the rotational method of irrigation will contribute substantially to a fuller utilization of the water resources.

THE RICE BREEDING PROGRAM AND ITS RECENT DEVELOPMENT IN TAIWAN

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I. Introduction

In the early days of Taiwan, the rice varieties were mostly of the ***Indica*** type. During the Japanese occupation, efforts had been made by the Japanese agriculturists to improve the local rice varieties. Japanese rice varieties were then introduced to Taiwan for planting. These introduced rice varieties of the ***Japonica*** type are locally known as Ponlai rice. Owing to its better quality, higher yield, shorter growing period, and non-sensitiveness to photoperiod, the Ponlai rice began to gain a firm footing on the Island. Among the early introduced Ponlai rice, Nakamaru was the leading variety. Its acreage in Taiwan once reached 106,689 ha. before 1926. Through local hybridization work, new varieties gradually came into being, among which "Taichung 65" was the most prominent one ever produced. It was an offspring of a cross between Kameji and Shinriki, developed by the Taichung District Agricultural Improvement Station in 1929. Because of its good quality, high yield and wide adaptability, it replaced Nakamaru as well as the native ***Indica*** type of varieties, rapidly to become the most widely planted rice variety in Taiwan.

During the post-war years, rice breeding work has been carried out by all the District Agricultural Improvement Stations; and considerable progress has been made especially on Ponlai rice, including round glutinous rice. New varieties have been released from all district stations and are favorably accepted by farmers in their respective areas. Meanwhile, new varieties better adaptable to localized areas have gradually replaced the acreage originally planted to Taichung 65. In 1941, the acreage of Taichung 65 was 118,692 ha. (or 69.45% of the total acreage) in the first rice crop or spring crop and 119,704 ha. (65.5% of the total acreage) in the second rice crop or fall crop, while in 1958, it dropped to 48,681 ha. and 48,834 ha., being 21.1% and 18.86% respectively of the total Ponlai rice acreage. Among the existing Ponlai rice varieties, 20 varieties are being most widely planted by farmers.

The post-war government policy, until recently, has been one to extend the acreage of Ponlai rice at the expense of native rice because the former is of better quality, higher yield, and of higher export value. For this reason, rice improvement work and seed multiplication have been concentrated on Ponlai rice, while such work on the native and upland rice have been rather neglected.

II. Rice Breeding Program in Taiwan

A. Breeding Stations

Rice breeding work is carried out by the Taiwan Agricultural Research Institute and all the seven District Agricultural Improvement Stations. The names and locations of the organizations engaged in rice improvement program are listed as follows:

Organization	Location	Breeding Programs Conducted
1. Taipei District Agricultural Improvement Station (Taipei DAIS)	Taipei (Northern Taiwan)	Ponlai rice
2. Hsinchu DAIS	Hsinchu (Northern Taiwan)	Ponlai rice
3. Taichung DAIS	Taichung (Central Taiwan)	Ponlai rice, native rice, glutinous rice, blast resistance
4. Tainan DAIS	Tainan (Southern Taiwan)	Ponlai rice, upland rice
5. Kaohsiung DAIS	Pingtung(Southern Taiwan)	Ponlai rice
6. Taitung DAIS	Taitung(Eastern Taiwan)	Ponlai rice
7. Hualien DAIS	Hualien(Eastern Taiwan)	Ponlai rice
8. Taiwan Agricultural Research Institute (TARI)	Taipei (Northern Taiwan)	Ponlai rice, inter-species cross between *Japonica* and *Indica* rices, Genetic and Cytogenetic studies
9. Chiayi Agricultural Experiment Station, TARI	Chiayi (Central and Southern Taiwan)	Blast resistance of Ponlai rice

B. Purposes of Rice Breeding in Taiwan

The main purposes of rice breeding in Taiwan may be summarized as follows:

1. To breed blast resistant varieties:

Rice blast is one of the main diseases which annually cause considerable losses in Taiwan. Particularly in the first rice crop, the disease is very prevalent in the Ilan, Chiayi, Kaohsiung and eastern Taiwan areas. The breeding of blast resistant variety, therefore, is one of the most primary aims in rice breeding.

2. To breed varieties with high yielding capacity:

Breeding of varieties with high yield is the universal aim of all breeding programs. Under the circumstance of limited arable land and steadily increasing population in Taiwan, it has special and practical significance.

3. To breed varieties with good milling and table quality:

The bulk of rice produced here in Taiwan is for domestic consumption, but about 10% of it is exported to other countries, chiefly, Japan. In the recent years, the competition in the world rice market has become much keener than a few years ago, and the need for Taiwan to produce rice of higher quality is more pressing. So, to strive for the factors of good milling and table quality has become an important aim of the future rice breeding program.

4. To breed varieties of wide adaptability:

Wide adaptability is a very important character to be taken account of in rice varieties. Among the rice varieties now being grown in Taiwan, "Taichung 65" is so far still the most widely adaptable one. Although some of the new varieties released in the recent years have proven superior to "Taichung 65" in yield, yet their superiority varies in each given district. The extension of these varieties has been effective in raising the yield of rice, but has also resulted in a larger number of extension varieties than before, each covering a smaller area. Emphasis is therefore to be placed on wide adaptability in rice breeding, with the hope that the varieties under extension may be reduced.

5. To breed varieties of shorter growing period:

One of the superiorities of the Ponlai rice lies in its shorter growing period. In the recent years, more and more farmers have adopted cropping system under which a summer crop, a winter crop or both are planted in between the spring (or the first rice crop) and the fall (or the second rice crop) rice crops in order to get more out of the limited acreage of arable land. This could be illustrated by the winter soybean crop, which is planted after the second rice crop in the Kaohsiung area, and the summer planting of melons and winter planting of wheat in the Taichung area, both of which being planted in between the two rice crops. With this extremely tight cropping system, rice varieties of shorter growing period naturally have definite advantages.

6. To breed varieties with stiff straw and responsive to heavy fertilization:

In the last ten years, the rate of fertilizer application on rice crop has been increasing considerably. The rate of fertilizer application in 1958 was N-90 kg., P_2O_5-35 kg. and K_2O-18.6 kg. per hectare. To apply more nitrogen fertilizer would induce the plant to lodge or an increased infestation of rice blast disease, so to breed new varieties which could tolerate heavy application of fertilizer without succumbing to lodging and rice blast becomes one of the most important aims in the rice breeding program in Taiwan.

C. Materials for Rice Breeding in Taiwan

The breeding materials commonly used in Taiwan are the native *Indica* type varieties, the local rice varieties grown by the aborigines in mountain areas, the Japanese rice varieties and the locally bred Ponlai rice varieties. In the recent years, rice varieties introduced from the mainland of China and those from southeast Asian countries are added to the breeding stock for making crosses. In some stations, rice varieties brought from the United States are also being used as breeding material.

D. Procedures of Rice Improvement in Taiwan

The breeding of rice varieties is usually carried out in two ways:

1. Hybridization — commonly used for Ponlai native and upland rice breeding.
2. Pure line selection — inclusively used for improving native rice and upland rice.

The procedures of which are summarized as follows:

1. Hybridization:

Crossing is usually made between native and Ponlai rice varieties, and, in most instances, multiple cross is used. The F_1 plants of the crosses are mostly sterile, so only the fertile plants are selected. The F_2 and F_3 strains possessing desirable characters of both parental materials are selected. From F_3 to F_5, selection is continued to discard all segregated plants. Fixed strains will be chosen from F_6 for the preliminary yield test.

a. Preliminary yield test

The preliminary yield test is divided into two groups. One group is applied with a normal rate of fertilization, while the other is treated with a double rate of fertilization. The field layout is in 2- to 3-row-plot, randomized block with two to three replications. Field notes on the following will be taken: heading, maturity, degree of infection of blast and other diseases, height of plant, tillering, length of head, awn, shape of kernel and number of kernels per head. The preliminary yield test will be continued for four crop seasons. The offspring from a cross is sometimes crossed with other varieties, so in many cases, the parental stock consists of more than two varieties.

b. Advanced test

The strains selected from the preliminary test are put into the advanced test, in which 5-row-plot, randomized arrangement is adopted with four replications. After four crop seasons in the advanced test, the desirable strains will be selected by the breeding station for entering into either one of the following two tests.

c. District regional test

The strains released from the advanced test of the breeding station will be recommended by the station to the Rice Improvement Conference called semi-annually by the Taiwan Provincial Department of Agriculture and Forestry. The function of the conference is to determine the varieties to be included in the district regional test, provincial regional test, demonstration farms and the foundation seed farms. After the varieties are approved by the said conference, they will be included in the district regional test, in which 5-row-plot, randomized block with four replications, will be followed. The number of varieties in the district regional test does not usually exceed 16 in number.

The number of tests within each district is to be decided and recommended by the respective District Agricultural Improvement Station and approved by the Rice Improvement Conference, but the total number of places of the district regional test in the whole province of Taiwan stays around 50.

Every two years, considerations will be made to replace partly or wholly the varieties used in the district regional tests.

d. Provincial regional test

From the advanced test, promising varieties which show possibilities of wide adaptability may be picked out for provincial regional test which is conducted by the Taiwan Agricultural Research Institute to find out their adaptability on a province-wide basis. The recommendation is to be made by the breeding station and approved by the Rice Improvement Conference of the Taiwan Provincial Department of Agriculture and Forestry. Under the provincial regional test, 5-row-plot, randomized arrangement with five replications, will be used. The varieties in the provincial regional test are usually from 16 to 20. The test is to be conducted at not more than ten places scattered in the whole province. Consideration is to be made to replace partly or wholly the varieties with newer and more promising varieties in every three years.

The varieties bred by other stations but showing superiority in the provincial regional test at any station are to be included into the district regional test carried on by the District Agricultural Improvement Stations along with varieties selected from their own advanced tests as described in the foregoing paragraph.

e. Demonstration

Promising varieties come out from the district regional test will be put into the demonstration farms within the district for demonstration purpose before starting seed multiplication and extension.

f. Multiplication

Varieties, after being demonstrated in demonstration plots for a year, may be multiplied through the three levels of seed farms, i.e. the foundation, stock and extension seed farms, to produce seeds for extension.

2. Pure line selection:

This is carried out among the adaptable varieties. In the beginning, head selection is practised. The heads selected will be put into the head row test, in which each head is planted in a row of 1 m. long. Direct sowing method is used. The selected rows will be put into the 2-rod-row test for further screening and selection. In 2-rod-row test, the plants will be spaced 25 cm. and 20 cm. between rows and hills. Each row is 4 m. long, consisting of 20 hills. Five plants will be planted in a hill. Every fifth row is a check. The strains selected from 2-rod-row test will be further screened in the 5-rod-row and 10-rod-row tests, in both of which the same design as in 2-rod-row test is used. Strains chosen from 10-rod-row test will be tested in the advanced test. In the advanced test, 5-row-plot, randomized arrangement with 6 replications, will be used. The spacing and length of row are the same as that in 2-rod-row test. The test will usually be continued for two years, and the desirable strains will be released for district regional test, demonstration, seed multiplication and extension.

It is to be noted that breeding procedures used are conventional. Only the coordination between the district regional tests and the provincial regional test is a special feature adapted to the organizational relationship between the District Agricultural Improvement Stations and the Taiwan Agricultural Research Institute. This coordination system was established by organizing a Rice Improvement Conference under Provincial Department of Agriculture and Forestry since the spring of 1956. In this conference, all plant breeders in the various district stations are invited to attend for exchange of information on breeding materials, discussion of breeding results and screening of the recommended varieties to be included into the district regional test, provincial regional test, demonstration farm and foundation seed farms. Under this closely coordinated plan, the promising varieties emerged from the advanced tests of the various breeding stations may be included for further test (either in district or in provincial regional test), and the less desirable varieties may be discarded. Furthermore, a uniform breeding program may be obtained.

Aside from the hybridization and pure line selection method described above, backcross method is frequently used in the course of breeding of disease resistant varieties, particularly those resistant to rice blast.

In addition to the conventional breeding methods described in the foregoing paragraph, the application of irradiation on rice seeds for induced mutation has also been applied since 1955 as a new tool in the rice breeding program in Taiwan.

E. Recent Development of Rice Breeding in Taiwan

1. Breeding for blast resistance:

As the blast disease is the most persistent and destructive disease of rice in Taiwan, particularly in the first rice crop, causing an annual loss estimated not less than 5% of the total production, emphasis has been placed on the breeding of blast resistant varieties in the rice varietal improvement program. Furthermore, the susceptibility of the existing Ponlai rice varieties to this disease is limiting the expansion of Ponlai rice acreage and the increase of application of N fertilizer on rice.

Systematic breeding work for blast resistance has been started since 1950. Crosses between Ponlai rice varieties (*Japonica* type), Ponlai rice and native rice varieties (*Indica* type), Ponlai rice and mountain rice varieties (originally introduced from Malaya and the Philippines) and Ponlai rice and glutinous rice varieties have been made at various agricultural stations in Taiwan. The varieties selected to make crosses possess either desirable agronomic characters or resistant character to blast. The "Taichung 65", being the most popular variety in Taiwan, noted as a high yielder of wide adaptability and producing grains of good quality, was, therefore, most extensively chosen as the parental material in making crosses.

In the methods of breeding, pedigree, bulk and backcrosses are employed. Two or all three methods may be used in different generations after a cross is made. Furthermore, backcrosses are frequently made with Taichung 65 as recurrent parent. In inducing the infestation of blast disease on the progenies, at first, only artificial inoculation method was used during the seedling stage. Later, it was found that the response of the variety to blast in the growing season differed from that in the seedling stage. Therefore, from 1952 to 1954, certain spots near the hillside of Tungshih, Taichung Prefecture, where development of blast disease was very favorable, were chosen to set up experiment fields on which the progenies were planted for the observation of resistance to blast. Besides the favorable natural environment to the blast infestation, very heavy applications of nitrogenous fertilizer (160 kg. of nitrogen per hectare) was made to the experimental plots to make the condition even more favorable to blast development.

In making observation of the leaf blast, 12 classes of disease development in leaf blast phase are established, varying from "no diseased leaf surface" to complete succumb of the entire plant. These standards are being used to rate the degree of leaf blast development on rice plant.

Since the first crop of 1956, a number of established varieties were planted in areas at four localities where blast disease was prevalent to observe the reaction from blast disease. The results obtained from 1956-1958 revealed that rice varieties show great deal of difference in resistance with respect to variety, locality and year.

The physiological strains of the causal organism have been studied since 1957 for determining the presence of such strains.

Irradiation of Ponlai rice seeds with X-ray, Cobalt 60 and thermal neutrons have also been made to induce mutants which may be resistant to rice blast. Among the treated progenies, a few are found to be quite resistant. The preliminary results are encouraging, and observation and further tests are still underway.

The varieties relatively resistant to blast disease developed in Taiwan are listed as follows:

Variety	Parental stock	Degree of resistance to blast[1]
Chia-nung 242	(Hsinchu 4 × Taichung 150) × (Taipei 7 × Tainung 45)	0.2-5%
Taichung 178	Taichung Glu. 46 × Yoshino	11%
Taichung 179	Kwangfu 401 × Kwangfu 1	5%
Kaohsiung-yu 71	(Chianan 2 × Ladang Pae-boeboe) × Kaohsiung 18	5%

1. Percentage indicating diseased leaf surface.

2. Application of irradiation treatment for induced mutants:

Irradiation of rice seeds with X-ray and Cobalt 60 for induced mutation was started in 1955 in Taiwan. Again in 1957, seeds of five Ponlai rice varieties were sent to the Brookhaven National Laboratory, Long Island, New York, USA, for irradiation treatment by X-ray (20,000r and 25,000r) and thermal neutrons (15 hours and 20 hours). Treated seeds were sent back to Taiwan for experimentation. Among the treated progenies, disease resistant (several are found resistant to blast, two strains being resistant to Helminthosporium and a few others resistant to Corticium sheath rot), early maturing (five to ten days earlier than the untreated varieties), and of stiff straw and large panicle strains are found.

To acquire induced desirable mutants by applying irradiation seems to be quite encouraging, particularly in the breeding for disease resistant strains, although the results are not yet conclusive.

3. Breeding of promising native (*Indica*) rice varieties:

The improvement work on native rice was started in 1949. Five crosses were made between the local breeding stocks by the Taichung District Agricultural Improvement Station. In 1957, a new promising rice variety, Taichung Native No.

1, was developed. This variety, though an *Indica* rice, has many desirable characters. Differing from other *Indica* varieties in Taiwan, it is non-sensitive to photoperiod, so it can be successfully planted in both the spring and fall crop. It is of stiff straw, responsive to fertilizer application and also a good yielder. Its agronomic characters may be summarized as follows:

The agronomic characters of Taichung Native No. 1

Parentage	Presence of awn	Days from transplanting to heading	No. of ears	Height of culm (cm.)	No. of kernels per panicle	Paddy yield (kg.)
Dwarf Wu-jin × Tsai Yuan Chung	Awnless	91 (spring crop)	19	83.8	85.9	5,645
		67 (fall crop)	18.6	84.3	84.3	4,997

It is predicted that this variety will become more and more popular in regions where native rice is grown.

III. Conclusion

In summarizing the recent progress made in rice breeding in Taiwan, it may be stated that the popular Ponlai rice varieties released in the earlier period have been largely replaced by varieties bred in the post-war period. The acreage of "Taichung 65" in the first and second crop of the past few years dropped considerably. Among the new varieties recently developed, Chia-nung 242, a cross of Chia-nung-yu 65 and Chia-nung-yu 123, released by the Chiayi Agricultural Experiment Station has been found rather promising in Taichung, Tainan and areas in eastern Taiwan for its blast resistance, high yield and wide adaptability. Kaohsiung 45 and Kaohsiung 53 have made very good performance in the Kaohsiung area, while Hsinchu 55 and Hsinchu 56 have shown good results in the Hsinchu area, and Taipei 127 and Taipei 177 in the Taipei area. These varieties are being planted in the demonstration farms in various districts for demonstration and extension.

The new varieties to be developed in the future would be varieties of early maturity, of good quality and of good yielding capacity, highly resistant to blast and tolerant to heavy fertilization without lodging, so that it would be able to fit into the tight cropping schedule now being practised in Taiwan. With the recent development of breeding technique as well as the application of irradiation treatment on crop seeds together with the more thorough genetic studies on rice and expansion of breeding stock, new varieties bearing the desirable characters will be developed in the future.

A table showing the varieties released from the various stations and approved by the Rice Improvement Conference of the Provincial Department of Agriculture and Forestry for seed production in 1958-1959 is given in the following table.

The Characteristics of the Ponlai Rice Varieties Multiplied in Foundation Seed Farms in Taiwan in 1959

Name of variety	Breeding station	Year cross was made	Year selected	Parental material	Days from transplanting to heading and (yield)		Distinct characters
					1st crop	2nd crop	
Taipei 127	Taipei DAIS 1/	2/ II, 1936	II, 1941	Taichung 65 × Tsing-kao-an 3/	85 (3,561) 4/	65 (3,402)	Adaptable to heavy fertilization. Fairly resistant to diseases. Medium bearing. Apicule pale brown in color.
Taipei 177	-ditto-	II, 1936	II, 1941	Hwang-chien 3/ × Asahi	86 (3,216)	63 (3,369)	Fairly susceptible to diseases. Apicule pale brown.
Taipei 301	-ditto-	II, 1936	I, 1941	Taichung 65 × Tsing-kao-an	87 (3,004)	64 (3,372)	Adaptable to heavy fertilization. Fairly resistant to diseases. Apicule pale brown in color.
Hsinchu 55	Hsinchu DAIS	I, 1939	I, 1943	Tainung 44 × Chianan 2	89 (3,567)	68 (3,345)	Resistant to disease. Good table quality. Heavy bearing. Awnless. Short grain. Stiff straw.
Hsinchu 56	-ditto-	I, 1939	I, 1943	Tainung 44 × Chianan 2	89 (3,561)	69 (3,135)	Fairly resistant to disease. Medium quality. Medium bearing. Awnless. Stiff straw.
Taichung 65	Taichung DAIS	II, 1923	1929	Kameji × Shinriki	79 (4,665)	68 (3,976)	Medium stalk. Stiff straw. Large head. Heavy bearing. Yellow glume. Apicule dark brown color. Medium maturing. Good table quality with wide adaptability.
Taichung 150	-ditto-	1930	1938	[(NC4×Japanese sp.)×Italian sp.] × Taichung 65	75 (4,503)	63 (3,792)	High stalk. Medium tillering. Large head. Early maturing. Green apicule. Fairly resistant to diseases.

(To be continued)

Table (cont'd)

Name of variety	Breeding station	Year cross was made	Year selected	Parental material	Days from transplanting to heading and (yield)		Distinct characters
					1st crop	2nd crop	
Taichung 155	Taichung DAIS	II, 1935	II, 1939	Taichung 115 × Taichung 121	76 (4,643)	63 (3,675)	Fairly resistant to diseases. Good yield.
Taichung 160	-ditto-	I, 1938	II, 1941	Taichung 114 × Kinkoho	84 (4,674)	67 (3,800)	Apicule dark purple. Short grain. Awnless. Grows better in the 1st crop.
Taichung 162	-ditto-	I, 1936	II, 1941	Kameji × Taichung special 6	87 (4,506)	64 (3,998)	Adaptable to heavy fertilization. Susceptible to disease. Long head. Awnless. Dark purple apicule.
Taichung 170	-ditto-	II, 1943	I, 1946	Taichung 150 × Nungling 1	85 (4,528)	78 (3,911)	Apicule colorless. Long grain. Awnless. Grows better in the 2nd crop.
Chianan 2	Tainan DAIS	II, 1935	I, 1938	(Uluan glutinous × Mitsi) × Taichung 65	85 (4,494)	77 (3,564)	Adaptable to heavy fertilization. Resistant to diseases. Heavy bearing. Good table quality.
Chianan 8	-ditto-	II, 1935	I, 1938	-ditto-	82 (5,178)	74 (4,215)	Medium stalk, head and tillering. Heavy bearing. Good quality. Fairly resistant to diseases. Pale purple apicule.
Chianung 242	Chiayi Expt.Sta., TARI	I, 1946	II, 1948	Chia-nung-yu 65 × Chia-nung-yu 63	82 (5,029)	62 (3,556)	Strongly resistant to blast. Adaptable to heavy fertilization. Heavy bearing. Awnless. Long head.

(To be continued)

Table (cont'd)

Name of variety	Breeding station	Year cross was made	Year selected	Parental material	Days from transplanting to heading and (yield)		Distinct characters
					1st crop	2nd crop	
Kao-hsiung 10	Kao-hsiung DAIS	I, 1930	I, 1933	Kaielou Iikoku × Kaohsiung 6	95 (4,020)	68 (3,157)	Adaptable to heavy fertilization. Resistant to disease. Long head. Heavy bearing. Reddish brown apicule. Short awn.
Kao-hsiung 18	-ditto-	I, 1939	II, 1941	Kaohsiung 10 × Taichung 114	95 (4,780)	68 (3,850)	High stalk. Medium tillering. Green apicule. Long head. Medium bearing. Short awn.
Kao-hsiung 22	-ditto-	II, 1946	I, 1949	Kaohsiung 18 × Taichung 158	93 (4,476)	69 (4,246)	Very long head. Heavy bearing. Resistant to diseases. Grows well in fertile soil. Stiff straw. Broad leaf blade.
Kao-hsiung 24	-ditto-	II, 1946	I, 1949	-ditto-	94 (4,884)	69 (4,210)	Very resistant to blast. Very long head. Heavy bearing. Resistant to diseases. Grows well in fertile soil. Stiff straw. Broad leaf blade.
Kao-hsiung 27	-ditto-	II, 1946	I, 1949	Chianan 3 × Kaohsiung 18	94 (4,931)	69 (3,957)	Resistant to diseases. Rather long head. Heavy bearing.
Kao-hsiung 53	-ditto-	I, 1949	II, 1951	Kwangfu 401 × Taichung 65	93 (4,927)	60 (4,024)	Resistant to blast. Apicule reddish brown. Awnless. Round kernel. Good quality. Wide adaptability.

1/ DAIS—District Agricultural Improvement Station

2/ I—Spring crop; II—Fall crop

3/ Native rice (*Indica* type)

4/ Figure in bracket—Yield of paddy in kg/ha.

PRELIMINARY REPORT ON RICE BREEDING FOR BLAST DISEASE RESISTANCE IN TAIWAN[1]

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I. The Rice Blast Disease Problem in Taiwan

The blast is the most persistent and destructive disease of rice in Taiwan, particularly in the first crop. It causes more damage than all other diseases combined. The annual loss is estimated to be not less than 5% of the total production. Seed treatment, which helps a great deal in preventing the start of the disease, does not control it completely as the pathogene that lives over winter in the diseased straw and wild hosts may start the disease. Application of chemicals such as ceresan-lime for controlling the disease already developed in field is not yet a satisfactory method, because the time of application, phytotoxicity to native varieties (*Indica* type) and cost of application are still problems in Taiwan. Rice varieties show wide range of susceptibility to the disease. The breeding of rice for blast resistance is the most logical and fundamental approach to the solution of the problem. Among the extension varieties in Taiwan, the Ponlai rice (*Japonica* type) is more susceptible than the native rice, while the former is of better yield and quality. The breeding of Ponlai rice with resistance to blast is most ideal under conditions in Taiwan.

Systematic breeding work for blast resistance has been started since 1950. Crosses with various combinations of parental stocks, backcrosses, selection and regional test of varietal resistance have been made. This paper summarizes the work in the past few years and presents problems that have arisen in the course of the studies.

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II. Breeding of Resistant Varieties through Hybridization

A. Materials

Since 1950, crosses of 34 combinations have been made between 29 parental varieties belonging to 4 rice groups in the Taichung District Agricultural Improvement Station.

First group (Ponlai × Ponlai varieties) contains 8 combinations: Taichung 65 × Kwangfu 1, Taichung 150 × Kwangfu 1, Taichung 150 × Kungchuan, Kwangfu 401 × Kwangfu 1, Kwangfu 401 × Chianan 8, Kwangfu 401 × Kaohsiung 18, Tainung 45 × K2 and Kwangfu 401 × S 6.

Second group (Ponlai × Native varieties) contains 7 combinations: Taichung 65 × Pei-ku-chu, Taichung 65 × Pei-me-fen, Taichung 65 × Tie-cha-oo-chien, Taichung 65 × Yi-kung-pao, Taichung 65 × Tur-ku-tsao, Taichung 150 × Pei-me-fen and Taichung 150 × Tur-ku-tsao.

Third group (Ponlai × Mountain varieties) contains 6 combinations: Taichung 65 × Cutsugulcul, Taichung 65 × Montana, Taichung 65 × Bayaibatos, Taichung 65 × Baishotsulu, Taichung 65 × Nabohai and Kwangfu 401 × Cutsugulcul.

Fourth group (Ponlai × glutinous varieties) contains 13 combinations: Taichung 65 × Taichung glu. 46, Taichung 65 × Taichung Yu glu. 26, Taichung 65 × Taichung Yu glu. 29, Taichung 65 × Salt Resist. glu., Taichung 65 × Hung-chia glu., Taichung 65 × Kiangsi Late, Taichung 150 × Taichung glu. 46, Taichung 150 × Taichung Yu glu. 26, Taichung 150 × Taichung Yu glu. 29, Kwangfu 401 × Hung-chiaglu., Taichung glu. 46 × Shinriki, Taichung glu. 46 × Chi-yi 1 and Taichung glu. 46 × Taichung Sp. 6.

The varieties selected possess either desirable agronomic characters or resistance to blast. The "Taichung 65" is the most popular variety, noted for its higher yield and good quality grains. It was, therefore, more extensively used as parental material in the crosses. Other varieties are highly resistant. The mountain varieties are supposed to have originated from Malaya and the Philippines and may have different genetic constituents. Some of the glutinous varieties such as Taichung Yu 26 and 29 are also very resistant to blast.

B. Methods of testing disease resistance

Resistance of the progenies from the above crosses was tested in fields near hillsides where development of blast disease was more favorable. Very heavy application of nitrogen fertilizer (160 kg. of N per hectare and top dressings during tillering stage) was made. In addition, the fields were frequently drained to keep them as dry as possible. The disease developed in the fields was so severe that only resistant varieties could survive. Varieties such as Taichung 65 succumbed entirely. Two crops were planted each year, but disease development was more severe in the first crop. Resistance to leaf blast as well as "neck blast" phases was observed and recorded.

Degree of disease development in leaf blast phase is classified into 12 steps based upon the percentage of leaf surface covered by lesions and number of leaves killed in different stages.

% Diseased leaf surface	0%	0.2%	0.5%	1%	2%	5%	11%	25%	55%	80%	100%	120%[1]
Disease index number	0	1	2	3	4	5	6	7	8	8.5	8.8	9

Note: 1. Complete killing of the leaves and lesion extend to leaf sheaths.

C. Methods of breeding

Pedigree, bulk and backcross were employed. In pedigree methods, 2,000 individuals were saved in F_2. Separate lines were established since F_3. Number of lines selected in succeeding generations were based upon the performance in respect to disease resistance and agronomic characters. Twenty individuals were planted for each line.

In bulk methods, 2,000-3,000 individuals were used from F_3 to F_6. Selections were made in F_6 to establish separate lines in F_7 for further testing and selection.

Backcrosses were frequently made with Taichung 65 as recurrent parent. It could be made continuously for a number of generations or alternately with selfing. Forty to fifty seeds were obtained in each backcross.

Two or all of the above three methods may be used separately or in combination after a cross is made.

D. Results

Three Ponlai varieties have been developed and are in early stages of extension. 10 highly resistant, 9 moderately resistant lines in homozygous state for advance test, another 19 lines of high resistance and 13 lines of moderate resistance have been selected but not yet in pure state.

Table 1. The genetical background and resistance to blast of some of the outstanding selections

Selections	Parental stock	Degree of resistance to blast, (Taichung testing field)
Highly resistant selections		
Taichung native 1[1]	Tie-cha-oo-chien×Tsai-yuan-chung	0.2%
Taichung early 12	Taichung 65×Kan-to 52	0.2%
Taichung early 13	Taichung 65×Kan-to 52	0.2%
Taichung early 17	Taichung 65×Kan-to 55	0.2%
Taichung early 18	Taichung 65×Kan-to 55	0.2%
Taichung early 20	Taichung 65×Kan-to 55	0
Taichung early 21	Taichung 65×Kan-to 55	0
Taichung early 22	Taichung 65×Kan-to 55	0.2%
Taichung early 23	Taichung 65×Kan-to 55	0
Taichung early 27	Taichung 65×Kan-to 55	0.2%
Taichung early 29	Taichung 65×Kan-to 55	0.2%
Moderately resistant selections		
Taichung 178[2]	Taichung glu. 46×Yosino	11 %
Taichung 179[2]	Kwangfu 401×Kwangfu 1	5 %
Taichung stock 31	Taichung glu. 46×Shinriki	5 %
Taichung stock 33	Taichung glu. 46×Shinriki	11 %
Taichung stock 30	Taichung 65×Taichung glu. 26	11 %
Taichung 171[2]	Tainung 45×K2	0.2~11 %[3]
Susceptible check		
Taichung 65	Kamegi×Shinriki	100 %
Taichung Sp. 6	Selection from Asahi (owned)	100 %

Note: 1. An *Indica* type, in very early stage of extension.
2. Ponlai or *Japonica* type, in early stage of extension.
3. Reactions found different in varying with localities and years.

E. Resistant varieties developed in Chiayi and Kaohsiung Station

In the general rice breeding program in the Chiayi Branch Station of TARI and the Kaohsiung District Agricultural Improvement Station, special attention has also been given to the resistance of varieties to blast disease. Selections were made from fields where blast disease was severe.

Table 2. The varieties released for general extension

Varieties	Parental stocks	Degree of resistance to blast
Varieties developed from Chiayi Station		
Kwangfu 1	Tainung 45×K2	0.2~25%
Chia-nung Yu 242	(Hsinchu 4×Taichung 150)×(Taipei 7×Tainung 45)	0.2~ 5%
Chia-nung Yu 280	(K2×Tainung 45)×(Taichung Yu 12×Cheu-we-tze)	0~11%
Varieties developed from Kaohsiung Station		
Kaohsiung Yu 70	(Chianan 2×Ladang Pae Boeboe)× Kaohsiung 18	5%[1]
Kaohsiung Yu 71	(Chianan 2×Ladang Pae Boeboe)× Kaohsiung 18	5%[1]
Kaohsiung Yu 72	(Chianan 2×Ladang Pae Boeboe)× Kaohsiung 18	5%[1]
Kaohsiung Yu 73	(Chianan 2×Ladang Pae Boeboe)× Kaohsiung 18	5%[1]

Note: 1. Tested in Kaohsiung only.

III. Resistant Varieties Obtained Through Irradiation

Seed of variety Taichung 65 has been treated with X-ray and Cobalt 60 in the hope that artificial mutation will produce varieties of blast resistance but retaining all good agronomical characters.

Forty seeds were treated by X-ray with 20,000 γ. They were multiplied in bulk in the first and second generation. 3,200 heads were selected as separate lines in the third generation. Thirty plants in each line were planted in the disease field. One line has been observed to be resistant. Further observation and test will be made to determine the resistance and other characters.

2,200 seeds were treated by Cobalt 60 with 12,000 γ. 2,000 heads, one from each plant, were selected from the first generation. 5,000 seeds were planted for the second generation in the disease field. Among the 5,000 plants, 6 plants have been noticed to be resistant. Further observation and test will be made.

In all the selected resistant plants, general agronomical characters are very similar to those of Taichung 65 but with disease index number about 4 or 2% leaf lesion. If further studies on the resistance and other characters prove to be true, the use of radio-active material for inducing blast resistance in rice may be a short way to success.

In the course of the study, it is also noticed that two lines are more susceptible to *Helminthosporium* leaf spot and two lines resistant to it; a few lines indicate resistance to *Corticium* sheath rot.

IV. Variation of Resistance Among Varieties, Localities and Years

Since the first crop of 1956, a number of established varieties (40 in 1956, 20 in 1957) were planted in the disease field in 4 localities from northern to southern part of Taiwan (40 plants to a row, two to three replicates) to observe the reaction to the blast disease. The methods of inducing and classifying the disease as described above are used. The results of the two years (first crop only) are presented as follows:

Table 3. Varietal resistance to blast disease in different localities in Taiwan

Variety	Taipei		Taichung		Chiayi		Pingtung	
	1956	1957	1956	1957	1956	1957	1956	1957
Taichung Sp. 6 (J)[1]	8[2]	8	8	9.0	6	9.0	8.0	7
Taichung 65 (J)	9	8	8	8.8	7	8.8	8.0	8
Taichung 171 (J)	4	2	5	6.0	1	3.0	4.0	1
Taichung line test 33 (J)	3	3	6	8.0	1	5.0	5.0	1
Kwangfu 1 (J)	3	2	7	7.0	5	3.0	8.5	1
Chianan 2 (J)	0	4	5	8.8	5	8.0	7.0	6
Chia-nung Yu 242 (J)	4	2	4	5.0	1	3.0	5.0	4
Chia-nung Yu 280 (J)	4	2	5	3.0	0	1.0	6.0	1
Kaohsiung 22 (J)	7	6	6	8.0	3	3.0	6.0	5
Kaohsiung 24 (J)	8	7	6	8.8	1	8.5	7.0	7
Bai-ki-tou (J)	0	3	0	1.8	0	2.0	5.0	2
Pei-me-fen (I)	0	2	0	1.0	1	1.0	5.0	1
Oo-chien (I)	5	2	0	1.0	0	1.0	6.0	2
Kaohsiung Ta-li-ching-u (I)	2	2	1	1.0	1	1.0	6.0	2
Bayaibatos (M)	6	2	6	3.0	2	2.0	5.0	1
Natabasne (M)	6	2	1	1.0	1	2.0	5.0	1
Natala (M)	6	6	7	5.0	1	5.0	5.0	3
Cutsugulcul (M)	7	4	8	9.0	1	1.0	5.0	2
Kanto 51 (J)	2	2	7	1.0	1	1.0	4.0	1
Pi No. 1 (J)	7	2	0	1.0	0	3.0	5.0	1

Note: 1. (J) *Japonica* type, (I) *Indica* type, (M) Mountain varieties.
2. Disease index number, refer to the description under II, B above.

The above experiments revealed several interesting and important points in connection with the breeding program for blast resistance.

While it is very evident that varieties show a great deal of difference in resistance, it also shows that resistance also varies with localities and years. They may be illustrated by some of the varieties in the following tables:

Table 4. Table showing resistance varying with locality

Variety	Chiayi	Taichung
Taichung 65	100.0[1,2]	100.0
Taichung 171	1.0	11.0
Kwangfu 1	1.0	25.0
Taichung line test 33	5.0	55.0
Kaohsiung 22	1.0	55.0
Natala	5.0[2]	5.0
Cutsugulcul	0.2	120.0
Chianan 2	55.0	100.0
Pi No. 1	1.0	0.2
Chia-nung Yu 242	1.0	5.0

Note: 1. Data of 1957, showing % of disease.
2. Varieties showing consistent reaction in resistance.

Table 5. Table showing resistance varying with year

Varieties	Taichung		Kaohsiung		Chiayi		Taipei	
	1956	1957	1956	1957	1956	1957	1956	1957
Taichung 65	55.0	100.0	55[1]	55.0	25.0	100.0	120	55.0
Chianan 2	5.0	100.0			5.0	55.0	0	2.0
Bayaibatos	11.0	1.0						
Kanto 51	25.0	5.0						
Natala	25.0	5.0			0.2	5.0		
Kaohsiung 24	11.0	100.0	25[1]	25.0	0.2	80.0		
Kwangfu 1	25.0[1]	25.0	80	0.2	5.0	1.0		
Cutsugulcul	55.0	120.0					25	2.0
Natabasne	0.2[1]	0.2					11	0.5
Chia-nung Yu 280			11	0.2				
Pei-me-fen			5	0.5	0.2[1]	0.2		
Oo-chien 2			11	0.5				
Kaohsiung 22					0.1[1]	1.0		
Kaohsiung Ta-li-chung-u					0.2[1]	0.2		
Taichung Sp. 6							55[1]	55.0
Taichung line test 33							1[1]	1.0
Bai-ki-tou							0	1.0
Pi No. 1							25	0.5

Note: 1. Varieties showing consistent reaction in resistance.

V. Discussion

A. Breeding materials

Rice varieties show wide range of difference in resistance to blast disease. None, however, have been found to be immune from the disease. More lines and some with higher degree of resistance are found in varieties of the native rice than the Ponlai varieties. The use of the resistance of either type, for developing a new variety, has disadvantages or limitations. When a highly resistant native variety is crossed with a Ponlai variety, the lower quality and yield and other undesirable characters of the native variety usually associate with the resistant progenies. When a resistant Ponlai variety is crossed with a Ponlai variety, the resistance in the progenies never reach a very high degree. Most of the varieties that have been developed this way are only moderately resistant. Judging from the many crosses that have been made and the appearance of the progenies, the resistance is controlled by one pair (or more) of genes which is not completely dominant. Linkage of resistance with other undesirable characters is found in the native variety. Sterility occurred in crosses between native rice and Ponlai rice, often causing abnormal distribution of the frequency of the resistant progenies. For these reasons, a cross stock (Taichung cross stock No. 1) has been selected from the numerous progenies of the many crosses. It is highly and consistently resistant to blast in varying years and localities and is in good compatibility with Ponlai rice but is low in yield. This material is used as source of resistance in the future crosses.

B. Breeding methods

From the past experience there is little hope of obtaining ideal new resistant varieties by selecting the progenies from direct or simple crosses. Under present condition in Taiwan, the variety Taichung 65 can be considered a standard variety except for its susceptibility to blast. (It would be ideal, of course, if the variety could mature still earlier to fit into rotation in many areas and have more kernels per ear to attain still higher yield.) To introduce resistance from other varieties and repeat backcrossing to Taichung 65 seems most logical. However, the introduction of resistance directly from the existing varieties in Taiwan may not be easy for the reasons briefly stated above. A "synthetic" cross stock was therefore selected among the progenies of various crosses. This cross stock (Taichung cross stock No. 1) was a selection from Taichung 65 × mountain variety reaching homozygous state and possessing high resistance and good compatibility with Taichung 65. Three successive backcrossings to Taichung 65 have been made and highly resistant progenies have been selected. It is hoped that all the good characters of Taichung 65 may be retained and high resistance introduced. Varieties from the bulk selection possess other desirable characters which may also be used for f ture cross.

Variety Taichung 65 treated with X-ray and Cobalt 60 for inducing resistant mutant gives very encouraging results, though not yet conclusive. Large number of seeds should be used in the future. Radiation may prove to be the short way to develop resistance.

C. Factors affecting resistance

The most difficult problem encountered at present in this study is the inconsistency in reaction to resistance by most of the varieties in varying localities and years. This can hardly be explained by the different degrees of disease development in various localities or different years, because some showed the same reaction, others reacted in reverse directions in the same locality or year. The change of resistance is also reported from many of the early developed varieties. For instance, variety Chiayi late 2 was known to be resistant when it was developed, now it is completely susceptible. Varieties Kaohsiung 10 and 18 were also known to be resistant many years ago, now No. 18 has lost completely the resistance and No. 10 only very low resistance. A breeding program would have only limited value, if the cause or causes of the variation were not to be understood.

It is well known that the development of blast disease is greatly affected by environmental conditions. Uniform conditions and high degree of disease development should be maintained throughout the testing fields.

The presence of physiological strains of the causal fungus may also be suspected. Separate study has been started in 1957 for determining the presence of such physiological strains.

Study on the mechanism of resistance would also help to understand the problem.

D. Resistance to neck blast

No high resistance against neck blast was found in both the native and Ponlai varieties. Records indicate that late maturing varieties developed less disease than the early ones. Infection was almost confined to the period one week before and after heading. Chances of escaping infection are often very great. Data on resistance obtained from naturally infested field are therefore not reliable. This was shown in the past records that the percentage of infection would be very high in one year while very low in another. Methods of artificial inoculation at susceptible period should be employed in order to determine more accurately the degree of resistance.

VI. Conclusion

A. Great difference in resistance to blast disease was found in rice varieties. Highly resistant varieties are found mostly in native varieties, Taiwan mountain varieties and a few in Ponlai rice. No varieties was found immune from the disease.

B. Some of the varieties developed in Taiwan so far are only moderately resistant. They include: Kwangfu 1, Chia-nung Yu 242, Taichung 171, Taichung 178 and Taichung 179.

C. The resistance seems to be governed by one pair (or more) of genes which is not completely dominant. The resistant gene (or genes) in the highly resistant native variety is found to be in link with that of other undesirable characters. Sterility occurs between cross of native variety and Ponlai rice. Detailed genetical analysis should be made in order to device better methods of breeding.

D. In breeding program, it seems advisable to introduce first the resistance to Ponlai rice, select the highly resistant strain and improve the agronomic characters by backcrossing to standard variety.

E. The use of radiation for inducing mutation of resistance to a standard variety may prove to be a short way to develop resistant variety.

F. As varieties show inconsistency in reaction to disease resistance in varying localities and years, detailed studies are deemed necessary to be made on the causes of the variation such as the possible presence of physiological strains of the fungus, the effect of environmental factors and the mechanism of resistance.

G. No variety was found to be highly resistant to neck blast. Infection of neck blast takes place only within a limited length of time. Methods of artificial inoculation at proper time should be employed.

H. *Uniform and high degree of disease development should be maintained in* the testing field.

THE SYSTEM OF RICE SEED MULTIPLICATION AND EXTENSION IN TAIWAN

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I. Background

The sub-tropical climate of Taiwan plus a rather well-developed irrigation system makes it possible to produce two crops of rice annually in most areas. Rice varieties in Taiwan fall into two broad groups, namely: the lowland and the upland rice. The lowland rice which accounts for 94 percent of the total acreage can be further classified into three types, namely: Ponlai rice (*Japonica* type), native rice (*Indica* type) and glutinous rice (both *Japonica* and *Indica* types). Among the three types of lowland rice, Ponlai rice acreage is the largest, accounting for 55 percent of the total lowland rice acreage; native rice ranks second, with an acreage amounting to 42 percent of the total; and glutinous rice the third, accounting for 3 percent. The Ponlai rice is, in fact, a common name for all the improved varieties, which were derived either from the intercrossing of the introduced Japanese varieties, or from the latter's crossing with the native rice varieties in Taiwan. It outyields the native rice by 10-20 percent and also has a better milling quality. Since its first introduction into Taiwan in 1922, its acreage has been expanding steadily, reaching 100,000 ha. in 1926, 200,000 ha. in 1933 and 450,000 ha. in 1956. As a result, the rice production of Taiwan has increased immensely. In 1921, it was slightly over 700,000 M.T. But in 1930, it topped 1,000,000 M.T.; in 1950, it reached 1,400,000 M.T.; and in 1956, 1,800,000 M.T., or 2.5 times the 1921 figures. The most important factors contributing to the success are the breeding, multiplication and extension of the improved rice varieties.

II. Seed Multiplication and Extension System

Seed rice is multiplied by three steps: the foundation seed, the stock seed and the extension seed. The general practice is to renew the seed once every three crop seasons. Since the same Ponlai rice can be grown both in the first and second season of the year, it takes only one and a half years to complete the renewal. The foundation seed farms are operated by seven district agricultural improvement stations, one for each of the seven rice producing regions of the Island. There are 160 stock seed farms, either run by local government organizations or by farmers' associations, but mostly by contract farmers; and about 4,000 extension seed farms, operated entirely by contract farmers, one farm for every village on the Island.

The acreage of land devoted to seed propagation and the amount of seed to be produced by the various seed farms in each crop season are determined by the amount required for seed renewal for 1/3 of the total acreage under Ponlai rice on the Island. The general guiding principle is that the seed produced from one unit of a foundation seed farm should be sufficient for planting 25 units of stock seed farms, and the seed produced from one unit of a stock seed farm for planting 40 units of extension seed farms. Thus the total acreage of seed farms required for the multiplication of the foundation, stock and extension seeds for each crop season is about 4 ha., 94 ha. and 3,750 ha. respectively. The average size of a seed farm is around 0.5 ha.

The foundation seeds are distributed to the stock seed farms free, while the stock seeds are purchased by different counties or municipal governments and distributed to the extension seed farms free. The extension seeds are bartered for farmers' seeds either at the ratio of 1:1, or at a premium up to 20 percent.

III. Management and Inspection of Seed Farms

Care is required in the management of the seed farms of different levels in order to ensure the purity and trueness of the rice plants to the variety characteristics. In foundation seed farms, the one-plant-per-hill method is practised, and the seedlings are transplanted in straight rows with regular intervals between rows and hills (24 cm. x 21 cm. on the average) to facilitate observations, operations, weedings and roguings. Every hill in the field is closely inspected. Four to five roguings are carried out from tillering to dough stage. The expected rate of seed production is set at a low level of 1,500 kg. per hectare, which is sufficient for planting 25 ha. of stock seed farms at the rate of 60 kg. per ha. for Ponlai rice. The operation of stock and extension seed farms is similar to that of the foundation seed farms, except that four to six plants are transplanted per hill and the roguing is done three to four times in each crop. The expected yield of rice from the stock and extension seed farms is no less than 2,400 kg. per ha. Each hectare of the extension seed farms should produce enough seed for planting 40 ha. of rice fields in the following crop season.

The foundation seed farms are under the care of the rice breeders of the district agricultural improvement stations, while the stock and extension seed farms are supervised by the technicians from township offices during the heading and dough stages. If a mixture is found, it must be removed before the field can be accepted. Blast infection must be less than 5 percent. Such other factors as heading, grain uniformity and ripening conditions are also closely checked.

IV. The Role Played by Extension Seed Growers in the Whole System

From the above discussion, it can be seen that rice seed is largely multiplied by the contract farmers. If it were not for the active participation of these individual growers, it would have been impossible to carry out the system of seed multiplication and extension in Taiwan on such an extensive scale. An extension seed grower must be a member of a local farmers' association and a farm operator owning a farm of not less than 0.7 ha., with some education, having years of experience in rice culture and enjoying good reputation in his own community. The location of his farm should not be far away from a highway. Once chosen by the township office, the farmer usually carries on the job of seed multiplication for several years. It is not unusual to find a seed grower with ten to fifteen years of service record. Their farms are well managed and they take pains to keep the field crop pure and true to the variety characteristics. No doubt, they have to put in additional labor. Some of them may get paid for by collecting 10-20 percent premium in the bartering of pure seeds for ordinary ones. Most of them, however, decline to accept the premium for the reason that the other farmers to whom the seed is sold are either their relatives or friends and it would appear to them improper to make a profit out of the deal. Most of them, therefore, operate the seed farms on a non-profit basis.

The concerned government agencies have tried to keep up the spirit of these volunteer seed farmers by all possible means, such as distributing to them free posters, pamphlets and other publications concerning rice and agricultural improvement, holding contests on the management of extension seed farms, etc. Certificates and prizes are awarded to the winners. Winners of the first prize in local districts may be given free tickets to go to Taipei on the Farmers' Day to attend a reception given by the Commissioner of the Department of Agriculture and Forestry or some other high officials of the provincial government. Besides, the Department, during the past six years with the assistance of the Joint Commission on Rural Reconstruction, has appropriated a large sum of fund to help seed growers construct 6,110 concrete drying floors, 971 bowl-type storage huts, and 783 metal bins. Most of the seed growers have received free radio sets and cash subsidies for the upkeep of their compost shelters.

V. The Organization and Operation of the Seed Multiplication System

Varieties to be multiplied and the amount of seed produced are first decided upon in township meetings, at which village chiefs, small unit chiefs, directors of township farmers' associations, seed growers and township officers all participate. The decision reached is then referred to the county and provincial meetings for approval. It is the policy of the government to limit the number of the improved varieties planted in any one region not to exceed more than four or five in order to facilitate the maintenance of seed purity. The total number of the improved varieties multiplied in 1957 in Taiwan was 21. The meetings at the different organizational levels are held twice a year, before the planting of a rice crop. The provincial meeting also passes its final judgement on the kind or kinds of materials to be used in the province-wide and district-wide tests, as well as in variety demonstration plots.

The overall plan prepared by the Provincial Department of Agriculture and Forestry covers not only the acreage to be planted for the year, but also the amount of seed to be produced for each variety at each type of seed farms. After being adopted, the plan is further detailed to specify the exact responsibilities of the county and township governments and the individual seed growers.

VI. Conclusion

The rice seed multiplication and extension system was established thirty-five years ago. In the early stage, emphasis was placed on recruiting more seed growers, but little was done to establish the seed farms. Before the outbreak of World War II, only the seven foundation seed farms operated by the government and six stock seed farms by the farmers' associations were provided with the necessary facilities, while all the extension seed farms were sadly neglected. As a result of the War, the acreage under Ponlai rice dropped from the prewar record of 400,855 ha. to 196,036 ha. in 1946.

After the War, the Provincial Department of Agriculture and Forestry took vigorous steps to revitalize the whole system of seed multiplication and extension, with the financial and technical assistance of the Joint Commission on Rural Reconstruction. It provides the necessary leadership, together with travel expenses and transportation facilities for its supervisors. In the meantime, it gives encouragement to all the individual seed growers as mentioned before. As a result of several years' continuous effort, Ponlai rice seed is now multiplied in sufficient quantities in each crop season for seed renewal on 150,000 hectares, or 1/3 of its present acreage.

Since Ponlai rice outyields the native rice by 10-20 percent, the expansion of its acreage is an important factor contributing to the steady rise in hectare yield in Taiwan.

RICE SEED CERTIFICATION SYSTEM IN TAIWAN

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I. Introduction

In Taiwan, there are two main paddy rice groups under cultivation, i. e., the Ponlai rice group (*Japonica* type) and the native rice group (*Indica* type). The Ponlai rice is a common name for the improved varieties of the *Japonica* type including both the purely-bred varieties introduced from Japan and the offsprings from the inter-crossing of the introduced Japanese varieties or from their crossing with the native rice in Taiwan. The Ponlai rice is of stiff straw, short and round kernel, non-sensitive to day length, responsive to fertilizer, early maturing and a high yielder, so it is favorably accepted by the farmers.

Although there are 127 established Ponlai rice varieties for the spring crop (or the lst rice crop) and 131 varieties for the fall crop (or the 2nd rice crop), only 20 varieties are being widely planted in both the spring and fall crops. It has been the policy of the Government to encourage the farmers to plant Ponlai rice in place of the native rice. The extension of irrigation facilities, chemical fertilizers and pesticides to farmers has decisively helped the expansion of its acreage in the recent years. In 1958, the Ponlai rice acreage was 460,596 ha., being 59.2% of the total rice acreage (778,189 ha.). Its production reached 1,185,342 M.T. of hulled rice (brown rice) which was 62.6% of the total production (1,894,127 M.T.) of brown rice. The acreage and production of the *Indica* rice of the two crops in the same year were 274,508 ha. (35.3% of the total) and 644,262 M.T. (34% of the total) respectively.

The Ponlai Rice Seed Certification System was inaugurated in Taiwan in 1957. The year before, when the First Far East Seed Improvement Conference (FESIC) sponsored by the International Cooperation Administration (ICA) was held in Taipei, Taiwan, much discussions were made on how to develop the seed technology (seed processing, seed analysis, seed storage and seed marketing) in the Far East Asian countries. The resolutions made in the FESIC may be summarized as follows:

A. ICA/Washington be requested to make arrangements with some leading organizations on seed technology to offer special courses on seed technology to trainees from FESIC countries.

B. FESIC countries should take necessary actions on the establishment of a seed laboratory as the first step towards the development of seed technology.

C. ICA/Washington be requested, at appropriate time, to set up a seed technology training centre in FESIC area to offer training courses, conduct researches and furnish information and services toward seed technology.

Pursuant to the policies set forth in the said seed conference, the Chinese Government in Taiwan has approved the recommendations made by the Agricultural Association of China (an organization of Chinese agricultural research workers and educationists) to establish the seed certification system of rice and other farm crops and to set up two seed laboratories in Taiwan, one in the National Taiwan University for research and training purposes and another under the Taiwan Provincial Department of Agriculture and Forestry (PDAF) to administer actual seed certification program.

Subsequently, with the technical and financial assistance from the Joint Commission on Rural Reconstruction (JCRR), seed standards and procedures were stipulated and adopted by the PDAF and the Ponlai Rice Seed Certification System was inaugurated in Taiwan in 1957.

II. Ponlai Rice Seed Certification Standards

The certification standards of Ponlai rice seed consist of two phases, i.e., field standards and seed standards, which are to be observed respectively in field inspection and in laboratory analysis. The field and laboratory certifying standards for different seed farms are listed in the following table:

Ponlai Rice Seed Certification Standards

(1)Field standards:

Factor	Maximum permitted in each class of seed farm		
	Foundation	Stock	Extension
Other varieties	None	None	None
Barnyard grass	None	None	None
Objectionable weeds	None	None	10 plants per 1,000 sq. m.
Disease affecting quality of seed or transmissible through planting stock	None	None	None

(2) Laboratory standards:

Factor	Standards for each class of seed farm		
	Foundation	Stock	Extension
Pure seeds (minimum)	99.8%	99.5%	99%
Inert matter (maximum)	0.2%	0.5%	1%
Other varieties (maximum)	None	None	25 seeds per kilo
Barnyard grass (maximum)	None	None	5 seeds per kilo
Weed seeds	None	None	2 seeds per kilo
Germination (minimum)	90% (1st crop) 85% (2nd crop)	90% (1st crop) 85% (2nd crop) 80% (Intermediate crop)	90% (1st crop) 85% (2nd crop) 80% (Intermediate crop)
Moisture content (maximum)	13%	13%	13%
Weight of 1,000 kernels (minimum)	See the following table		

The weight of 1,000 kernels will be determined in all the three classes of seed farms according to varieties and localities. The following table gives the standard weight of 1,000 kernels of different varieties under seed production at different localities:

Locality	Variety	Weight of 1,000 kernels (gm.)
Taipei area	Taipei 127	24.5
	Taipei 177	26.1
	Taipei 301	24.7
	Taichung 65	25.9
Hsinchu area	Hsinchu 55	22.0
	Hsinchu 56	22.5
	Taichung 65	25.0
	Taichung 155	24.0
	Kaohsiung 24	25.0
Taichung area	Taichung 65	25.2
	Taichung 150	25.1
	Taichung 155	28.2
	Taichung 160	25.9
	Taichung 162	24.6
	Taichung 170	23.5
Tainan area	Chianan 2	23.8
	Chianan 8	25.0
	Taichung 65	26.3
	Kaohsiung 24	26.6
Kaohsiung area	Kaohsiung 10	25.8
	Kaohsiung 18	25.0
	Kaohsiung 22	26.2
	Kaohsiung 27	25.1
	Kaohsiung 53	24.7
	Chianan 8	24.9
	Taichung 65	26.7

Taitung area	Chianan 2 Chianan 8 Chianung 242	24.0 24.7 25.3
Hualien area	Chianan 8 Kaohsiung 24	24.0 24.0

In addition to field inspection and laboratory analysis, the storage inspection is also needed to determine: (1) whether the storage facilities are sufficient; (2) whether proper care has been taken to clean the storage before seeds are stored; (3) whether the storage facilities are adequate to prevent rats and insects; (4) whether the storage facilities are affected by outside humidity; and (5) whether the germination percentage is affected by long period of storage; etc.

III. Operation of the Seed Certification System

The certification of rice seeds includes the field inspection, storage inspection and laboratory analysis. The field inspection covers all classes of seed farms, while the storage inspection and laboratory analysis cover all the foundation seed farms, stock seed farms and so far only a part of the extension seed farms. In 1957, only 113 extension seed farms were sampled at random to undergo laboratory analysis. From 1958 to 1959, one third of the extension seed farms has been scheduled to undergo laboratory analysis.

In making field inspection, inspectors will be dispatched to the seed farm from full heading stage to dough stage to carry out field inspection work. The foundation seed farms, stock seed farms and extension seed farms will be inspected by inspectors respectively from the Taiwan Agricultural Research Institute (TARI), District Agricultural Improvement Stations (DAIS)/Prefectural Governments and the township offices with the assistance of DAIS.

In making laboratory analysis, the TARI will dispatch personnel to the DAIS to take seed samples (2 kg. each) from foundation seed farms and bring them back to its laboratory for seed analysis. For the stock seeds, the DAIS will dispatch personnel to take seed samples and bring them back to the station for seed analysis. If a sample is found up to the standard, the respective seed farm will be informed and tags will be issued (white tags for foundation seed farm and purple tags for stock seed farm) to indicate that these seeds are certified according to government regulations. For the extension seeds, no tags will be issued to the operators. Instead, a notice, certifying the name of the operators, name of the variety, amount of seeds produced and quality of seeds, will be posted at some public place in the township.

The results of seed certification of the three classes of seed farms in the 1st and 2nd crops of 1958 are given as follows:

Kinds of seed farms	Field inspection		Laboratory analysis		Storage inspection	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
(1) Foundation seed farm						
No. of seed farm inspected	6	7	6	7	6	7
No. of seed farm complying with the standards	6	7	5	6	6	7
No. of seed farm disqualified	0	0	1[1]	1[2]	0	0
(2) Stock seed farm						
No. of seed farm inspected	73	111	46	95	57	95
No. of seed farm complying with the standards	57	95	33	73	57	95
No. of seed farm disqualified	16	16	13	22	0	0
(3) Extension seed farm						
No. of seed farm inspected	2,260	2,952	520	1,560	0	0
No. of seed farm complying with the standards	1,963	2,496	264	998	0	0
No. of seed farm disqualified	297	456	256	562	0	0

1. *In the 1st crop, 24 varieties were examined, 2 found disqualified.*
2. *In the 2nd crop, 30 varieties were examined, 1 found disqualified.*

IV. Concluding Remarks

The certification of Ponlai rice (*Japonica* type) seeds in Taiwan was inaugurated only in 1957. Since then to date, the field inspection and storage inspection have been carried out to cover all the three levels of seed farms. Laboratory analysis is conducted on all the foundation and stock seeds, however, it covers only one third of the extension seeds. The reasons why not all the extension seed farms are included for laboratory analysis are: (1) the vast number of extension seed farms, totalling over 5,000 in two crop seasons; (2) the limited number of trained personnel at various stations to conduct laboratory analysis on seeds; and (3) the shortness of time between the 1st and the 2nd rice crops in some areas.

There is, at present, only one seed laboratory already in operation established under the National Taiwan University with its function mainly devoted to the training of personnel and the conducting of research works on seed standards, methods of seed analysis and other projects along seed technology. The regulatory seed laboratory under the PDAF is now under construction and is expected to be completed sometime in July 1959. After its completion, with the assistance of the seven DAISs, each possessing a minimum set of equipment, the certification work on Ponlai rice seeds will be expanded gradually with the ultimate goal to cover all the extension seeds in Taiwan in the not too distant future.

FERTILIZER USE IN RICE PRODUCTION IN TAIWAN

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I. Economic Significance of Fertilizer Use in Rice Production

Rice production plays a most important role in the economy of Taiwan. The total planting acreage of both the spring and fall crops of rice reached 778,189 ha. in 1958, producing 1,894,127 M. T. of brown rice at the average yield of 2,434 kg. per hectare per crop. Not less than three million people, representing about 33 percent of the Island population, are directly engaged in rice growing. Rice not only supports about ten million people but also is the second important item on the list of export of Taiwan's products.

Rice production in Taiwan depends heavily on fertilizer use. In the recent years 400,000 to 500,000 M. T. of chemical fertilizers were annually used for this crop. Rice consumes about 80 percent of all the fertilizers used on the Island. Nearly 20 million U.S. dollars was spent annually for importing chemical fertilizers for rice production. Approximately 640 kg. of fertilizers is now applied to each hectare of paddy field and constitutes about 20 percent of the total production cost. Either from the viewpoint of the national economy or the farmers' economy, the efficient use of chemical fertilizers is of paramount importance to rice production.

II. Effects of Fertilizers on Rice Production

Chemical fertilizers have been used on rice in Taiwan for more than thirty years. In 1938, the total quantity of fertilizers used for rice production was 389,334 M. T., and the yield of brown rice was 2,242 kg./ha. But in 1945, on account of World War II, the fertilizer consumption on rice dropped to 1,958 M. T., and the yield also decreased to 1,273 kg./ha. Taking the period of 1935-39 as peak years when the average annual consumption of fertilizers on rice was 359,433 M.T., and 1944-48 as lean years when the average was 41,308 M.T., the comparison between the two periods reveals that the average annual production of brown rice had dropped from 1,339,494 M.T. to 933,641 M.T., and that the average yield per ha. of 1944-48 was 26 percent less than that of 1935-39.

From the field experiments made on the first crop of Ponlai rice, the yields of plot with 24 years of continuous application of NPK fertilizers and plot of non-application of fertilizers is 2,581 kg./ha. against 1,117 kg./ha., indicating a 56.7% reduction in yield due to non-application of fertilizers.

The results of the rice fertilizer experiments conducted in more than one hundred localities show that, by applying nitrogen up to 120 kg./ha., the yield can be profitably increased. Taking 120 kg./ha. of nitrogen as a standard rate of application, 8.7 to 10.2 kg. of paddy for the first crop can be increased by each additional kg. of nitrogen applied, and 6.1 to 7.1 kg. for the second crop, the percentage of increased production being 37-57 % and 29-34 %, respectively. Phosphate and potash fertilizers have little responses in rice production. However, in some particular areas, a fairly good effect from these fertilizers is significantly shown, especially when potash fertilizer is applied to the second crop.

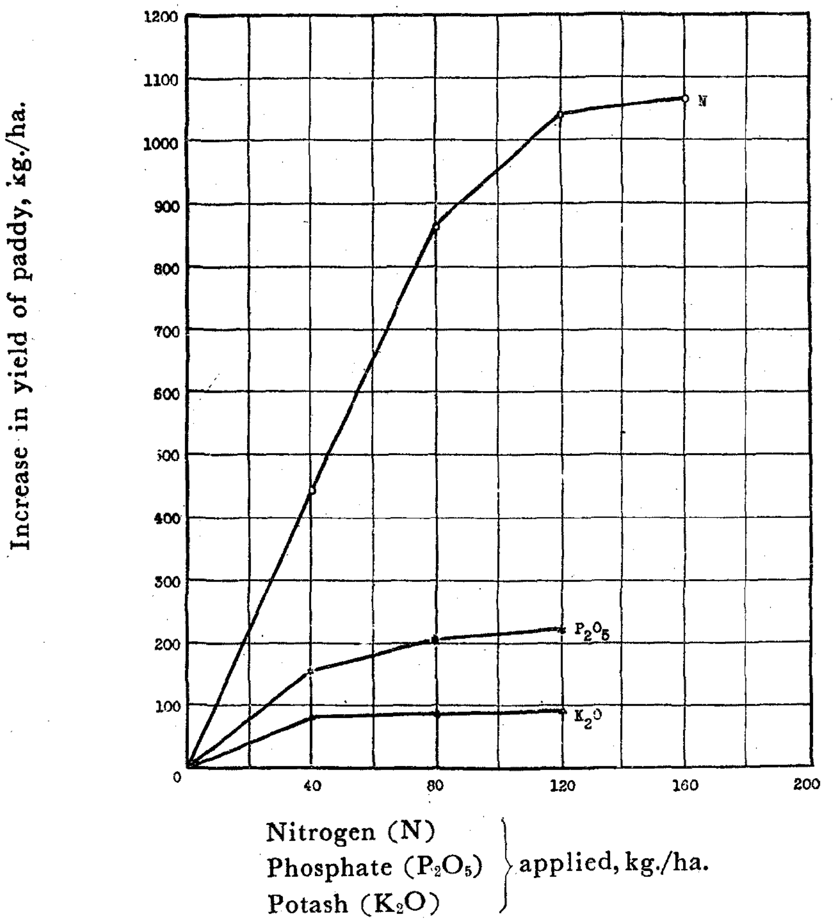
A summary of data and response curves for the first rice crop is shown below:

Table 1. Average Results of Fertilizer Experiments Conducted Between 1929-1942 at 104 Localities in Taiwan, China

(Limited to 1st crop each year and paddy yields and fertilizers applied all in kg./ha.)

N with adequate P_2O_5 and K_2O (80 kg./ha. each)			P_2O_5 with adequate N and K_2O (80 kg./ha. each)			K_2O with adequate N and P_2O_5 (80 kg./ha. each)		
N level	Yield	Increase over control	P_2O_5 level	Yield	Increase over control	K_2O level	Yield	Increase over control
0	2,848		0	3,512		0	3,632	
40	3,291	443	40	3,668	156	40	3,716	84
80	3,719	871	80	3,719	207	80	3,719	87
120	3,889	1,041	120	3,738	226	120	3,723	91
160	3,923	1,075						

Chart 1. Graphic Representation of the Data Presented in Table 1



III. Recent Efforts Made to Increase the Efficient Use of Fertilizers

Although the use of chemical fertilizers has become very popular among the farmers of Taiwan, misconception and misapplications are not uncommon. For instance, rice farmers are not thoroughly acquainted with the use of balanced N-P-K, the three major elements required for crop growth. They take it for granted that all chemical fertilizers should turn leaves green as ammonium sulphate does. Any fertilizer that has no such visible effects is considered poor. Therefore, farmers are much less ready to accept the use of phosphate and potash fertilizers. When phosphate and potash fertilizers are used, they are always applied as top dressing instead of being applied as a base manure. In order to disseminate knowledge on the most efficient use of fertilizers, the Provincial Food Bureau and the Provincial Department of Agriculture and Forestry, with the technical and financial assistance of the Joint Commission on Rural Reconstruction, have been carrying out an island-wide program on fertilizer education and demonstration since 1951. The main activities in this program are outlined as follows:

A. Holding training classes on fertilizer application:

Training classes are held in each township to educate the farmers on the proper application of fertilizers. During the period of fertilizer distribution, discussion meetings are held for the village chiefs, who are informed of the characteristics of the various kinds of fertilizers, their methods of application and the procedure of their distribution, and are requested to transmit this information to the farmers.

B. Setting up fertilizer demonstration plots:

Field demonstrations on the effectiveness of fertilizer use and methods of application are sponsored by the provincial agencies and supervised by the township farmers' associations. Farmers in the neighborhood are invited to see the demonstration plots twice in the rice growing and harvesting periods. More than a thousand demonstrations are conducted throughout the Island for each crop of rice.

C. Publicity through radio and other means:

The Provincial Food Bureau, which handles fertilizer distribution, prepares articles in simple language on the methods of fertilizer application and the procedure of their distribution and sends them out through the Provincial Information Office to all broadcasting stations in the province for publicity through their radio programs. These materials are also sent to the Harvest, a bi-weekly farmers' journal published by JCRR and widely circulated among the farmers for public information. The local Food Offices also conduct publicity campaigns by sending trucks equipped with loud-speakers to the villages at proper times to remind the farmers of the timely procurement of fertilizers and the proper methods of fertilization.

D. Other educational means:

While drawing fertilizers from the warehouses of the farmers' associations, farmers usually have to wait for a considerable length of time before they are able to clear with the delivery procedures. The farmers' association staff always takes advantage of such hours to educate the farmers in an on-the-spot manner, regarding the names, characteristics, and methods of application of the fertilizers distributed.

Through all these educational means, remarkable progress has been made on the wise use of the three major fertilizer nutrients for rice production. Along with other phases of agricultural improvement, the use of chemical fertilizers has made a significant contribution toward the continuous increase in rice yield, as indicated in the table below.

Table 2. Consumption of Fertilizer Nutrients for Rice Crops

Year	N		P_2O_5		K_2O		Yield of brown rice	
	Kg./ha.	Index	Kg./ha.	Index	Kg./ha.	Index	Kg./ha.	Index
1951	58.6	100	11.8	100	7.3	100	1,882	100
1952	66.0	113	24.1	204	9.8	134	1,998	106
1953	67.0	114	27.6	234	11.1	152	2,109	112
1954	83.4	142	29.2	247	12.0	164	2,183	116
1955	83.7	143	33.3	282	13.8	189	2,151[1]	114
1956	85.3	146	33.7	286	14.3	196	2,284	121
1957	87.2	149	33.6	286	16.4	225	2,348	125
1958	90.0	154	34.9	296	18.6	255	2,434	129

1. Effect of the unusual drought in the first crop season.

IV. Experiment and Research Work on Fertilizer Use for Rice

Two kinds of fertilizer research are now being undertaken by the Taiwan Agricultural Research Institute: fertility studies on paddy soils and field experiments.

In 1953 and 1955, 173 N-P-K fertilizer experiments on rice with $3 \times 3 \times 3$ confounding design were conducted in various places according to the main soil groups of Taiwan. The results obtained show that, for all soil groups, the response of nitrogen is the most significant. An application of 80-120 kg. of N per ha. for the first crop and 60-80 kg. of N per ha. for the second crop is recommended. The alluvial soil originated from sandstone and shale or slate always gives more significant response than the latosol. Most Taiwan soils, as a result of the manuring system, are not seriously deficient in phosphorus and potash. However, on the lateritic soil, the two nutrients, P_2O_5 and K_2O, have more significant response than on other soils. The general recommendation for them is 40 kg./ha. each.

Calcium ammonium nitrate (nitrochalk) and urea will soon be manufactured in quantities in Taiwan. Methods of applying them on paddy have been studied. The response of rice to nitrochalk applied as a base manure is definitely inferior to ammonium sulphate. Late applications of nitrochalk as a top dressing may raise the paddy yield more than its application as a base manure. Better results, however, may be obtained by supplying one half or one-third of nitrogen from ammonium sulphate as a base manure and the rest from nitrochalk as top dressing. The nitrochalk is applied about 40 to 60 days after transplanting the first rice crop and 30 to 50 days after transplanting the second crop.

When urea is to be used as a base manure on paddy land, a thorough mixing with the surfaced soil is advisable. In soils of light texture, field should be drained before application. Flooding three or four days after application appears to be profitable. Urea also can be applied once or twice as top dressing prior to weeding.

The relative availability of superphosphate, fused phosphate and Reno rock phosphate was tested on some representative soils, including lateritic soils, slate alluvial soils and shale and sandstone alluvial soils. It was found that superphosphate is in general superior to the other two phosphate carriers in all kinds of soils. Fused phosphate and rock phosphate are much less available than superphosphate on neutral soils; while on acid soils, their availability is almost comparable to that of superphosphate.

Liming acid paddy soils was also tested. The experimental results reveal that the effect of lime on rice is related to the status of soil fertility. On very fertile soils or soils receiving sufficient fertilizers, the rice crop has not shown as much response to lime as on the infertile soils, or soils receiving only organic manures. Soils low in pH value, which are generally of poor fertility, usually have good response to lime. It is recommended that three tons per hectare of lime be applied to the first crop of rice as base dressing.

DISEASES AND INSECT PESTS OF RICE IN TAIWAN AND THEIR CONTROL

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I. Rice Diseases

Over 40 diseases of rice have been recorded in Taiwan. Among them, the blast, sheath and stem rots, the elongation disease, and the sesame leaf spot are common. Economically, the blast disease, which causes more damage than all other diseases combined is most serious. Brief notes are given below on some of the more important diseases and some of the work that has been carried on in the past few years.

A. Rice Blast

1. Seasonal development and losses: The disease is most prevalent in the first rice crop and seldom bothers the second crop. It appears to be most destructive to the leaves at the tillering stage during late March through early May. The continual rains during the heading stage (consequently lowering of the temperature) may also cause serious outbreaks of neck-rot. Fields below hills with cooler irrigation water are much more liable to the disease attack than those on the plain.

Damage from the disease in individual fields varies from a very slight to a complete loss. Acreage reported to have suffered from severe attacks (over 50% loss) amounts to 40,000 to 50,000 ha. in the past few years. In 1953 and 1954, when continual rains occurred during the heading stage of the first crop, the neck-rot wiped out the crop almost completely in many thousands of hectares in the south. The annual loss due to the disease is estimated to be not less than 5% of the total rice crop.

2. Sources of infection and the effect of environmental factors: While the disease is chiefly seed borne, wild hosts and the diseased refuse of the previous crop may also serve as sources of infection in Taiwan.

The disease is greatly affected by environmental factors. Relatively low temperature (average daily temperature 20-25°C) and high humidity favor its development. This is clearly indicated by the fact that the disease is much more serious in the first crop of rice than in the second in Taiwan and the fact that fields below hills with cooler irrigation water develop more disease. In many areas, no susceptible varieties of rice can be planted in the first crop for the reason that the environmental factors favor the disease development. It is also interesting to note that the disease is very destructive in the temperate zone, such as in Japan, less so in the sub-tropical countries and diminishes in intensity toward the tropics.

The disease is very sensitive to the application of fertilizers. The nitrogenous fertilizer favors its development, especially when it is applied alone. Heavy applications of nitrogenous fertilizers (150 kg. of N per ha.) in fields near hill sides or in areas with cooler climate will always induce serious outbreaks of the disease. Under these conditions, susceptible varieties will be killed completely before heading. One may notice that the disease often develops in a corner of a field where a manure pit was located without spreading to the other parts of the field because of the nutritional differences. The amount of nitrogenous fertilizers used may often determine the degree of the disease development.

3. Chemical control: A program of seed treatment by soaking rice seed in a solution of organic mercury compound (1/20,000 active ingredient) was launched in 1950. Since the Ponlai rice is most susceptible, the program was started with it in the first crop. Now it has been extended to include native varieties and the second crop as well. Nearly 100,000 pounds of the chemicals are used annually. Treated seeds are sufficient to plant over 300,000 ha. Besides the large wooden tubs or earthen jars generally available on all farms, small brick and cement ponds are constructed for community use. The desired length of time for soaking the seed is six hours; however, for practical extension purposes, one hour is recommended.

Applications of chemicals in diseased fields have been introduced, especially of ceresan-lime dust which has proved to be very successful in Japan. However, the following problems will have to be solved: (a) time of application, (b) reduction of chemical injuries to native varieties, and (c) lowering of the cost of application.

Spore trap stations were established in 1956 at various localities throughout the Island to determine the seasonal development or the dissemination of the spores. The accumulation of such information may help determine the proper time of applying fungicides.

4. Varietal resistance: Generally speaking, the Ponlai rice is more susceptible to the disease than the native rice. Nearly 1,000 varieties, including both Ponlai

and native types, have been tested for their resistance to the blast disease in the past few years. The breeding stock varieties were tested in the greenhouse for leaf blast with artificial inoculation, while the extension varieties were tested in the field to determine both the leaf and neck phases of the disease.

Of the varieties tested, over 170 show high degree of resistance. However, the resistance varies greatly from locality to locality. Most of the varieties that showed resistance in the northern and central parts of the Island became susceptible in the south. Particularly noticeable is the variety Bai-ki-tou, which was almost immune in all three testing stations in northern and central Taiwan, became quite susceptible in the south. A collection of 40 varieties, including the resistant, intermediate and susceptible, were planted in different stations from the north to the south in 1956 to verify their resistance or susceptibility. The variation in resistance in the four localities is very evident in most of the varieties with the exception of a few most susceptible varieties.

The resistance of rice varieties to the blast also varies from year to year. This has been noticed in tests during the past few years and also in tests of the older varieties, which showed resistance in the early years but have become susceptible at present.

Among the extension varieties, now considered more resistant are: Kwangfu 1, Kaohsiung 22, Kaohsiung 27, and the newly developed Chia-nung-yu 242, Kaohsiung-yu 73 and Taichung 179 of the Ponlai group, and Pei-me-fen, Pei-ko-chu, Neekung-po, Tsai-yuan-chung and the newly developed Taichung Native 1 of the native type. The most common variety Taichung 65 (*Japonica* type) is very susceptible.

5. Breeding rice for blast disease resistance: Crosses between Ponlai and native varieties, resistant and susceptible, Ponlai and upland rice, and Ponlai and glutinous rice with a total of 30 combinations have been made since 1950 in the hope to develop resistant varieties of the Ponlai type with good qualities. Progenies were planted in testing fields where all the susceptible "check" varieties succumbed. Backcrosses were made to the variety Taichung 65 which is a very good variety except that it is susceptible to blast. Up to now 12 varieties have been selected for the advanced test, 70-80 lines in homozygous state with desirable characters and over 350 lines in F_5 to F_7 generations have also been selected for further observations and backcrossing. Taichung 171 and 179 were once intended for release. Further tests, however, showed that the two varieties varied in their resistance from year to year in the same locality, as well as in different localities. Available data are insufficient to indicate as to whether this is due to different physiologic races of the fungus, the effect of environmental conditions, or some other reasons. Studies on

the physiological races of the fungus were started in 1957.

B. Banded Sclerotial Disease

A group of sclerotia-forming fungi attacks rice. Among them, ***Corticium sasakii*** (Sharai) Matsu, ***Rhizoctonia oryzae*** Ryker et Gooch, ***Helminthosporium sigmoideum*** Cov. var. ***irregulare*** Cralley et Tullis are more common, particularly ***C. sasakii***, which is often referred to as banded sclerotial disease and has been reported to cause serious damage in the past two years in the south of the Island.

The disease is more common during the second crop season when the temperature is high. It appears first in the field as scattered spots which gradually increase to large areas. The affected plants show large, pale brown, or grayish lesions with undulation, well defined margin on the leaf-sheaths. These plants often become blighted before they reach maturity, or the ears do not fill well. Hot weather and abundance of nitrogenous fertilizers favor the development of the disease.

The small sclerotia of the fungus survive in stubble and float on irrigation water. These sclerotia spread the disease from crop to crop and from field to field.

Chemical control of the disease has been tried without success. Varietal differences in resistance to the disease have also been noticed, but no definite conclusion can be made at the moment.

C. Helminthosporium Leaf Spot

Leaf spot caused by ***Cochliobolus Miyabeanus*** (Ito et Kur.) Dickson is very common in Taiwan. However, severe damage has seldom occurred under normal conditions.

Fertilizers are reported to affect the development of the disease as well as the type of lesions. More numerous small lesions are developed in the fields where the application of nitrogenous fertilizers is low. This is in contrast to blast disease which is favored by nitrogenous fertilizers. The individual lesions may become larger in fields where potassium is insufficient.

Varieties show considerable differences in resistance to the disease. About 100 varieties, including both Ponlai and native types, were planted for observations in 1953 and 1954.

The disease is also seed-borne, and seed treatment with chemicals may help reduce its incidence.

D. Elongation Disease

The disease is caused by ***Gibberella fujikuroi*** (Saw.) Wr. Infected seedlings show abnormal elongation of leaves with light green colour, most conspicuous in the seedbed. Diseased seedlings seldom grow beyond the seedling stage and soon die. The disease is seed-borne and is effectively controlled by seed treatment with organic mercury compounds. As a large scale seed treatment program has been implemented, the once prevalent disease no longer poses a problem at the present time.

II. Insect Pests of Rice

Insect pests cause much damage to the rice crop in Taiwan. The loss is estimated at 15-20 percent of the total production. More than 30 species of insects have been recorded. Major losses are caused by rice stem borers, rice leaf hoppers, spiny beetles, rice leaf beetles, rice leaf rollers and rice black bugs. Among them the rice stem borers are the most persistent and important. A considerable amount of work has been done in the past few years on the control of these insects. The following are brief accounts on the six groups of major insect pests in Taiwan.

A. Rice Stem Borers

1. Species and their damage: Three species of rice stem borers are found in Taiwan. They are: ***Schoenobius incertellus*** Walker, ***Chilo simplex*** Butler, and ***Sesamia inferens*** Walker. Among these, ***Schoenobius incertellus*** is the most predominant one.

Rice stem borers cause severe damage both at the tillering and heading stages of growth. The larvae bore into the young plants and kill the central young leaves and growing points, resulting in a "dead heart" of the plants, which never grow any further but put forth more tillers. The new tillers may be attacked successively and the plants may never head. During the heading stage, the borers cut off the basal part of the stalk, causing the death of the entire head which appears as an empty or "white ear". Damage in individual fields is often as heavy as 20-40 percent. Fields with 80-90 percent "white ears" have been observed.

The loss from the stem borers—the biggest single enemy of rice production in Taiwan—is estimated at 10 percent of the total production for average years.

2. Seasonal and regional development: Depending on the temperature of the year, the rice stem borer (***Schoenobius incertellus***) develops four or five generations in the northern Taiwan and five or six generations in the south. Each rice crop is subject to the attack of two generations of the borers. Because of the warm and dry weather prevailing during the winter in the south, the population is much heavier than that in the north.

On account of the differences in weather conditions and cropping systems, the regional development of the stem borer in Taiwan may fall into three patterns. In northern and central Taiwan, the population of the borer begins to increase in May, reaches the maximum in June, and drops in July when the first crop is harvested. It begins to increase again in August and September and reaches a peak in October. The larvae live over the winter in stubbles left after the harvest of the second crop. In the Chiayi-Tainan area in the south, the adult moth may be trapped by light all the year round. It begins to become abundant in February and March, increasing gradually and reaching the maximum in June. In this area, the so-called "intermediate rice crop", which is planted in between the regular first and second crops, offers food to the borers. The population therefore never drops as in other regions but steadily increases to extremely high density until October. The damage from the borers in this region is therefore particularly heavy. After the harvest of the second crop, the population begins to drop. In other areas of the south, the population increases early in January when a part of the rice crop is already planted, reaching the maximum at the end of May or early June when the crop is mature and partly harvested. The population in July and August is very low, because of the long absence of food supply after the harvest of the first crop. It begins to increase again in September and October but never is as high as in the first crop. In all regions, the different generations of the borers generally overlap one another and are hardly distinguishable.

3. Parasites of the stem borers. Two species of larval parasites, ***Cremastus Shirakii*** Sonan and ***Horogenes lineatus*** Townes et Merino, and three species of egg parasites, ***Telenomus dignus*** (Gahan), ***Trichogramma japonica*** Ashmead and ***Tetrastichus schoenobii*** Ferriere, have been identified recently. Surveys made during the year show the percentage of larval parasites to be varying from none in March and April to 15 percent in June and 5-8 percent in other months. ***Horogenes lineatus*** is more common than ***Cremastus shirakii***. The three species of Hymenopterous egg parasites vary from 15 to 45 percent during the year. Among them, ***Telenomus dignus*** is the most common, being 80 percent of the total. No serious study has yet been made to utilize these parasites for the control of stem borers.

4. Control measures. Since 1952, many of the newly developed insecticides have been tested and used in Taiwan for the control of stem borers. The first successful test was made in 1952 with "Folidol E-605", an ethyl parathion preparation by Bayer Company of West Germany. In the following year, Endrin also was proved effective. Since then, other preparations of ethyl parathion, methyl parathion, EPN, systox, metasystox, dipterex, chlorothion, diazinon, malathion, gusathion, specially emulsified lindane, dieldrin, etc., have been tested. After considering the

effectiveness and the degree of toxicity of these chemicals, parathion, endrin, diazinon and gusathion are now recommended for general use.

Field control of stem borers started in 1953. About 3,000 ha. of rice were treated with Folidol for demonstrations. About 30,000 ha. were sprayed by farmers in 1954, and 50,000 ha. in 1955. In 1957, 100,000 to 150,000 ha. may be covered if the insects become as serious as in the past few years.

Information on the development of stem borers is collected for use in the field control program. Studies have been made on rice stubble and light traps. Beginning in December, rice stubble is collected, split and examined at intervals of ten days until it is plowed under in preparation for planting in the next spring. Numbers of larvae, pupae and emerging moths, alive or dead, are recorded. This study gives information on the density of over-winter population, approximate time of moth development in the spring, etc. and serves to forecast the development of the borers. Light traps have been set up in each county to detect the development of the moths throughout the year. Daily records are taken and reports are made every ten days to the authorities concerned. This information is then used to guide the farmers to apply the chemicals at the proper moment. One interesting fact may be mentioned here from the light trap studies is that the great majority of the female moths trapped by light have already laid their eggs. This points out the little value of using light-traps as an effective measure for controlling the stem borers in Taiwan.

B. Rice Leaf-hoppers

This group includes two Fulgorids and three Jassids: ***Nilaparvata lugens*** Stal., ***Sogata furcifera*** Horvath, ***Nephotettix bipunctatus cincticeps*** Uhler, ***Deltocephalus dorsalis*** Motschulsky and ***Empoasca subrufa*** Melichar. The former three cause more damage to rice in Taiwan than the other two. These leaf-hoppers develop six to ten generations a year in Taiwan and are present all the year round. The population increases in dry seasons, especially during August and September when the temperature is high. The damage is not noticeable when the population is low but is very destructive when the population increases suddenly. The leaves of grown plants may turn yellow and die in large patches. The infestation often occurs in large areas.

These insects can be effectively controlled by dusting 1 percent BHC powder, except ***Nephotettix bipuntatus cincticeps*** which requires 3 percent. Field control of these insects was started in Taiwan in 1951 together with other rice insects. Recently 3,000-3,500 tons of the chemicals have been used annually.

C. Rice Hispa (spiny) Beetle

The rice Hispa beetle, ***Hispa similis*** Uhmann, develops three generations a year in Taiwan. The adult lives over-winter among weeds and in soil in uncultivated land. The insect appears first in March, but heavy infestations occur in the second generation during the time when the first crop of rice is approaching maturity and the second crop is just planted. The newly transplanted second crop is often severely damaged.

Severe outbreaks occurred during 1951-1953, when the spring seasons were wet. Large scale field control has been practised since then by the use of 10 percent DDT dust or 1 percent BHC dust.

D. Rice Lema Beetle (Leaf-beetle)

The Lema beetle, *Lema oryzae* Kuwayama, has one generation a year. The over-wintered adults begin to appear in February or March, laying their eggs in seedbeds or on young rice plants. The larvae live 2-4 weeks, becoming adult in May or June. Then the adult insects begin to hibernate. The damage from the insect usually occurs when the rice plant is still young.

The beetle may be controlled by the use of DDT and BHC dust as mentioned above.

E. Rice Black Bug

The black bug, *Scotinophara lurida* Burmeister, develops five generations a year in Taiwan. The adult lives over-winter in hillside or uncultivated land, and flies around only after dark. The insects live together on the lower part of rice plants near the water-surface in the daytime, moving to the upper part in the night.

Considerable damage has been done by the insect in many areas during the past few years. It can be controlled by 1.5 percent BHC dust. Recent studies show that dieldrin controls the insect more effectively.

F. Rice Leaf Rollers

The leaf rollers mentioned here refer to two species, *Cnaphalocrocis medinalis* Guenee and *Parnara guttata* Bremer. They develop four to six generations a year in Taiwan. Rolled or folded leaves are eventually destroyed. These insects can be controlled by BHC dust.

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RICE CULTURE IMPLEMENTS AND FACILITIES IN TAIWAN

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It is often said that, when tillage begins, other arts follow. However, it is the farm implement which started the art of tillage. Farm implements in Taiwan, especially those used for rice culture, are a rich inheritance from the mainland of China. Our statistics show that in Taiwan about 77 percent of the rice culture implements are directly inherited from the China mainland, 15 percent acquired from foreign countries, and about 8 percent developed locally. In this paper, the rice culture implements used in Taiwan will be briefly described according to the sequence of rice growing operations. A summarized report of the recent experiments on the improvement of some of these implements and facilities will also be given.

I. Farm Implements Popularly Used in Rice Culture in Taiwan

A. Implements for Paddy Field Preparations

1. Plow. As in most of the Oriental countries, there is the time honoured animal drawn plow. The Taiwan plow is always drawn by one animal, never by a team. The indigenous plow is identical to those used in mainland provinces, which belongs to the long bottom type. Its total weight ranges from 11 to 16 kg. It plows an average depth of 10 cm. and is not very effective in turning furrow slices. This type of plow can plow about 0.2 ha. per day, and sometimes up to 0.3 ha. per day under very favourable conditions. During the years of Japanese occupation, quite a few improved plows were introduced into Taiwan, such as the Isono type, Takakita type, Takechi type, Fukami type, etc. All of them have gone through a number of modifications and changes before becoming acceptable to the farmers in Taiwan. Therefore,

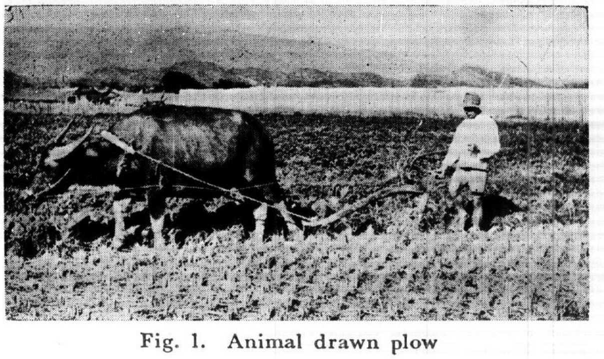

Fig. 1. Animal drawn plow

they are now manufactured in Taiwan to meet the local demand. These improved plows all belong to the short bottom type, and, therefore, are somewhat harder to operate. They weigh from 11 to 26 kg. a piece, will plow an average depth of 15 cm., and turn furrow slices better, but their working efficiency per day is about the same as the indigenous plow.

2. Comb harrow. This is a single row long spike (about 30 cm.) comb-shaped harrow and generally has 7 to 13 teeth evenly placed over a working width of 1.2 m. It is used in the paddy field right after plowing to break the clods and level the land. It can work about one hectare in one day. Bamboo pieces are sometimes fastened to the spikes and make it an almost solid board for moving earth from high spots to depressed spots. A levelling pole may also be attached to the harrow for the final levelling of the paddy field.

Fig. 2. Comb harrow

3. Knife tooth harrow. Knife tooth harrow has wooden frame of 35 cm. in length and 1.2 m. to 1.7 m. in width. Its 13 to 19 tooth blades are generally made of cast iron, and are arranged in two rows fixed underneath the frame. In gravelly fields, wrought iron blades are used, and, where the soil is very sandy, wooden or bamboo blades are also used, though not very popularly. Its total weight is around 17 to 19 kg. which is not heavy enough for a good penetration. Therefore, while using the knife tooth harrow in the field, the farmer usually stands on the frame to increase its weight and consequently raise its penetrability and land levelling ability. This harrow can also work one hectare of land in one day.

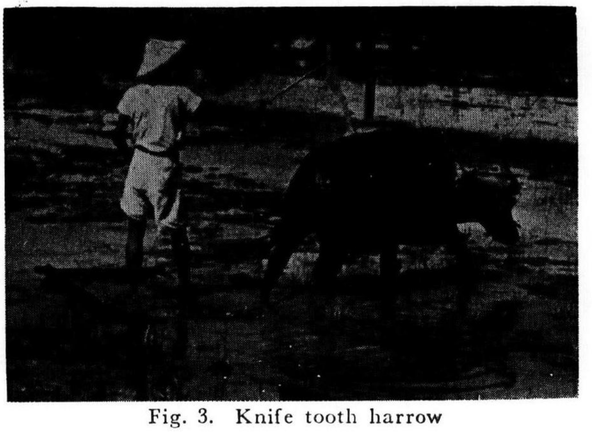

Fig. 3. Knife tooth harrow

4. Paddy field pulverizing roller. This implement not only pulverizes the soil and mixes plant residues into the soil but also performs the field levelling job. Its frame is 60–90 cm. × 1.6–2.7m. in size, and the roller is usually engraved into seven or eight longitudinal blades of 8 to 10 cm. or so in pitch from a whole piece of timber. Recently iron blades also have been used. The total weight of the roller

varies from 26 to 48 kg. This implement is the last one used to complete the paddy field preparations.

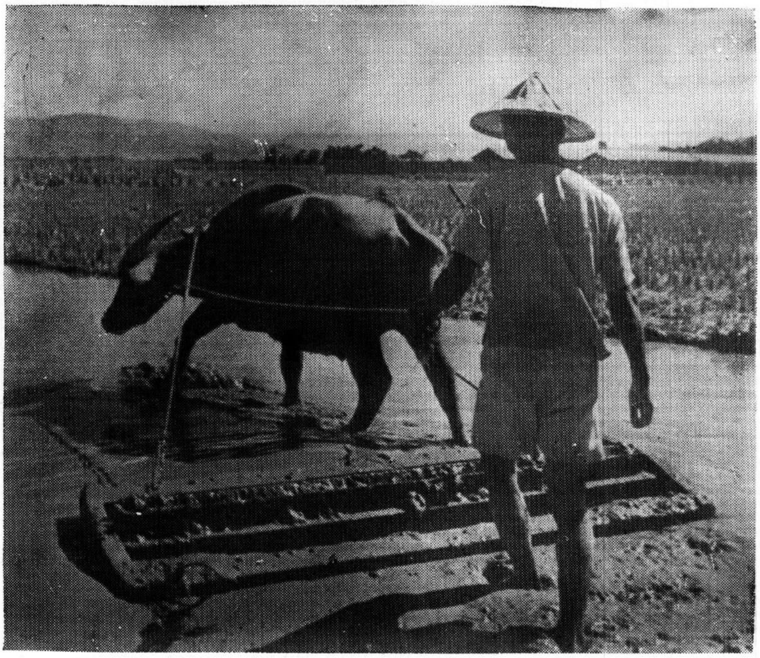

Fig. 4. Paddy field pulverizing roller

5. Paddy seedbed trowel. This is made of wood, similar to but larger than the mason's trowel. This tool is only used in smoothing paddy seedbeds, but not in big fields.

B. Equipment for Seed Selection and Disinfection

1. Winnower. Paddy grain that will be used for seed will have to go through the winnower two or three times. The winnower is made of wood. A revolving fan inside is cranked by hand to produce air blast for removing chaff, straw, dust and unripe grains from the good grains. Plain bearings are usually used in the revolving mechanism. It is only in recent years that ball bearings have been adopted by winnower manufacturers. On an average, 180 hectoliters of paddy may be cleaned by a winnower (on one run basis).

2. Disinfection tub. It is a common practice in Taiwan for farmers to soak their rice seeds in a solution of organic mercury compounds before sowing for the control of the rice blast disease. Any kind of tub may be used, if it is not inconvenient for such an operation. However, bigger tubs are used because the local farmers' associations usually provide such tubs for public use. Along the side of river streams and near the villages, people usually build disinfection ponds which

serve the same purpose.

C. Implements for Seeding and Transplanting

1. Rice direct planting machine. This machine is of the hill drop type, ordinarily made of sheet metal, and consists of a seed box and, underneath the seed box, 10 to 20 tubing ducts extending to the ground level. It is operated by one person. Check row hills of rice are thus sowed. This machine amazed the delegates from other countries attending the first Far East Seed Improvement Conference held in Taiwan in 1956. However, this is not a very popular machine because the direct planting method is very seldom practised in Taiwan.

2. Seedling spade, seedling sickle, seedling stool, seedling board, seedling bucket and carrier, seedling tub, seedling holder. These are used to spade up seedlings from the seedbed, cut off part of the seedling leaves, arrange seedlings in good order, shake off soil attached to the seedling roots and transport seedlings from the nursery to the main field. Their shapes can be visualized from their names.


Fig. 5. Check-row spacing marker

3. Check-row spacing marker. The marker is used to enable the farmers to set in seedlings in straight rows at desired spacing. There are two different types. The rod type, which was originally introduced from Japan, and the disk type, developed in Taiwan. After the disk type marker came on the market, it replaced almost completely the rod type marker. The disk type marker is usually made of wood and has some 13 disks of 18 cm. in diameter evenly spaced on a shaft of 2.8 to 3.0 m. long (The between disk spaces are usually set at 22 to 24 cm.). This marker has to be run on a well prepared paddy field lengthwise once and crosswise once to form check row marks for transplanting. More farmers use this implement in loamy or a little heavier soil, but less where the field is very sandy, because, on the sandy field, the marks will not be distinguished very clearly. The total weight of the disk type marker is around 11 kg., and its working rate is about 1 ha. per day. Marked rope is also used for check-row transplanting, although it is not very popular now.

4. Transplanting snapper (or thumb protector). It is usually made of sheet copper or bamboo, shaped after the human thumb. The farmer puts this gadget on his thumb, to separate seedlings into hills and to help stick seedlings into the soil.

D. Equipment for Applying Fertilizers and Manure

1. Fertilizer basket and fertilizer sack. Chemical fertilizers are put into either one of these two containers which is hung from the farmer's shoulder by a strap. The farmer takes a handful of the fertilizer from it, and broadcasts it by hand for top dressing.

2. Manure fork. This tool is used to spread manures on the paddy field before plowing starts, as compost manures are used only for basic application. Since Taiwan is short of steel, most of the forks used come from foreign countries, such as Japan.

E. Weeding and Intertilling Implements

1. Weed smoother. This is a very old implement popularly used on the mainland, but only in certain localities in southern Taiwan. It has a bamboo handle and a wooden board with nails or steel wire spikes underneath. At a glance, it looks like a wide hoe made of wood. With this implement, farmers do not have to kneel down in the paddy field to do weeding. The total weight is about 2 kg. and can weed 1/3 ha. of paddy field in one day.

2. Rotary paddy cultivator. This implement was originally imported from Japan, but it is now exclusively made in Taiwan. It has one or two rotors mounted onto a small boat-shaped framework and a handle for the farmer to push. The tilling rotor is about 10 cm. in diameter and 18 cm. in width, and has 15 to 21 teeth which are 5 to 6 cm. long, 2 to 3 cm. wide and usually curved backward. It is now used where the paddy soil is sandy and the paddy rice is planted in check-rows. This cultivator can work 0.3 to 0.4 ha. of paddy field per day.

Fig. 6. Rotary paddy cultivator

F. Irrigation Equipment

1. Water wheel. This is a stream-powered type of water lifting equipment to be used in places where the current of the stream is rapid and strong. Its efficiency is low, but since the power is cost-free, there are still a few in use in Taiwan. It is generally made of bamboo. The water lifting height is determined by the diameter

of the wheel. And the distance between the surface of the stream and the bank is the sole factor that determines the wheel size. One water wheel can ordinarily take care of one hectare.

2. Dragon pump. This is also another useful piece of equipment with a long history in China. Men step on its pedals to propel a train of water lifting vanes. This equipment can lift water from 0.5 to 3.5 m. high and has a capacity of 25 to 65 m^3. It is usually operated by 2 or 4 persons, and 80 to 120 pedallings per minute is the ordinary speed. It is a very laborious operation. Since the engine-powered centrifugal pumps came for use in Taiwan, the dragon pump has almost disappeared.

Fig. 7. Water wheel

3. Power pump. Engine or motor-powered pumps used in Taiwan are almost exclusively of the centrifugal type. Introduced into Taiwan some 30 years ago, they have been adopted quickly where gravitational irrigation is impossible. Deep water turbine pumps can also be seen in Taiwan, but they are seldom used in paddy fields.

G. Pest and Disease Control Implements

1. Sprayer. Various types of hand operating sprayers were introduced into Taiwan during the period of Japanese occupation. However, it is only during the last five years that the use of highly poisonous pesticides have made the sprayer indispensable equipment. With this increasing demand, local machinery works have started manufacturing sprayers. Some are now exported. As the

Fig. 8. Sprayer

hand sprayer is inefficient, Taiwan's farmers are now in active demand for power sprayers, and 1 to 2 h.p. types are becoming popular among them.

2. Duster. The hand crank type duster was introduced into Taiwan after the War. It did not become as popular as the sprayer because powder form insecticides can be handled by other simple equipment, or even by bare hands. A hand operating duster can cover about 0.5 ha. in a day.

Fig. 9. Duster

3. Worm scoop, worm catcher, worm comb. These are simple tools which the farmers can make in their homes to collect worms on leaves before the rice plants start heading, or to kill insects by shaking them down to the water during the growing period. They were used before chemical means of pest control were introduced.

H. Harvesting and Threshing Equipment and Drying Facilities

1. Sickle. The rice sickle is 10 to 12 cm. along the edge and 2 cm. wide. It is very light in weight, only 0.05 kg. when not fitted with a handle. The handle is made of wood and is about 20 to 30 cm. long. The human arm's pulling force is the only power that makes the sickle cut rice stalks. Therefore, the lighter the weight the better the sickle. One man with a sickle can reap 0.2 ha. of paddy in a day.

2. Pedal rice thresher. The revolving toothed cylinder type of rice thresher was originally introduced into Taiwan from Japan before the War, but has since been greatly modified by local manufacturers and now only the local products can be seen on the market. A two-man

Fig. 10. Pedal rice thresher

operated thresher can thresh 2,000 to 3,000 kg. of paddy per day. This thresher usually has a grain receiving box and is mounted on sleds so that the whole unit can be towed on the half dried or even wet paddy fields. Since the weather in Taiwan is usually wet in the harvest season, the sequence of the harvesting operations is to reap and thresh right in the field, transport the grain back to the farmstead, and then dry and clean the paddy in the courtyard or wherever the drying ground is available.

3. Rice threshing tub. This is a big round wooden tub of 1 to 1.2 m. in diameter and 55 cm. in height. An arched beating ladder (threshing ladder) is placed in the tub for the farmer to beat the rice heads against it. A screen is placed over and around the tub to prevent grains from flying outside the tub. Two men and one tub are capable of threshing about 1,200 kg. of paddy grain in a day. Since the introduction of the pedal rice thresher, threshing tubs have gradually been displaced.

4. Drying ground. Paddy grains are spread on the drying ground for sun drying. The old fashioned mud drying ground cannot provide a quickly available drying surface after the rain. Therefore, cement drying grounds are adopted by the farmers.

5. Grain rake, grain sweeper, grain scraper. These are the tools that spread, turn and collect grains during the course of drying on the drying ground. They are exclusively made of wood.

I. Cleaning Equipment and Processing Facilities

1. Winnower (Already stated in Section B).

2. Rice hulling and polishing plant. This equipment is not kept in the farmers' home, but managed by the local farmers' association, which is usually located in a village market and renders services to all farmers in the area. This type of installation in rural Taiwan usually has a hulling and milling capacity of 2 to 4 tons per hour and requires a prime mover of 7 to 12 h.p.

3. Rice cleaning sieve. It has a funnel, a framework, and a copper wire screen which is placed at about 36° inclination. It is popularly used for separating brown rice from the paddy after hulling.

4. Bamboo thread rice sieve, copper wire rice screen. These are usually pan-shaped hand operated equipment used for cleaning purposes.

J. Storage Facilities

1. Bowl type storage hut. This is for outdoor paddy storage. The wall is

made of bamboo and adobe, the bottom of wood, and it has a straw thatched top. The total height of this type of hut is 3 m., with a diameter of 2.5 m. The whole structure is lifted 15 to 30 cm. above the ground to keep it dry. Storage capacity per hut ranges from 2,000 to 6,000 kg. of paddy.

Fig. 11. Bowl type storage hut and drying ground

2. Grain storing bamboo bin. This bin is made of bamboo mats and adobe. It is about 2 m. in height, 1 m. in width and 2 to 4 m. in length. It is raised from the ground by legs to keep the stored grain dry.

3. Grain storing bamboo mat. This is a simple bamboo mat of 5m. x 2m. in size. It is rolled up to a convenient diameter, tied with rope and placed on a wooden board to store grains.

4. Warehouse. The warehouse is operated by the local farmers' association, as mentioned before. It is built of wood or brick walls, wooden or cement floor and tile roof. The usual capacity is 360 metric tons. Paddy is stored in bulk instead of in sacks. Bamboo mats made into chimney like ducts are usually placed in the center for ventilating purposes.

II. Effects Made to Improve Rice Equipment in Taiwan

A. Mechanization of Paddy Farms

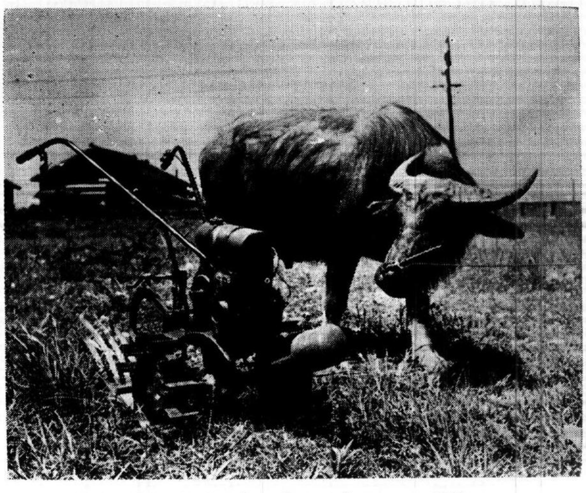

Fig. 12. Introduction of power tiller

In view of the difficulties in increasing the number of draft cattle, the Joint Commission on Rural Reconstruction (JCRR) has been trying for some time to adopt power machinery for rice production. In early 1955, JCRR purchased a Japanese type and a U.S. type power tiller for trial purposes. On the strength of the success of the test, 13 more

Merry Tillers of 2.5 h.p. each were imported in 1956 and were placed in 13 selected agricultural experiment stations on the Island for the following purposes:

1. To find out how to utilize power tillers and their attachments under Taiwan's conditions; and

2. To find out the differences in working efficiency and economy between using power tillers and draft cattle.

The tests are necessarily limited to paddy field preparations. The result so far seems to be encouraging, as shown in the following table of comparison on one hectare of land:

	Merry Tiller	Water Buffalo
Plowing	18-25 hours	35-50 hours
Pulverizing and levelling	26-40 „	35-50 „
Grass reappearing after preparation	in two weeks	in one week
Cost of plowing alone	NT$ 200	NT$ 270

Up till September 1959 about 1,800 farmers have purchased the small power tillers and are generally satisfied with their operation. We are now experimenting on the attachments, such as sprayers and threshers, to see how the power of the tiller's engine can be fully utilized. The success of the project depends on the following factors:

1. Ability to produce locally and cheaply tractors and rotary power tillers;

2. Further research on the use of power tillers under Taiwan's conditions and dissemination of such information among the farmers;

3. Provision of competent mechanics and repair facilities at places convenient to the farmers;

4. Satisfactory fuel supplies; and

5. Provision of long-term credit at low rate of interest.

B. Improving Animal Drawn Plow

This was a project financed by JCRR and undertaken by the Agricultural Engineering Department of the National Taiwan University. After three years of study, a well balanced light plow was developed. This plow has an iron pipe framework and the shape of the share is between that of the western plowshare and the conventional middle pointed oriental plowshare (its point is located about 1/4 way from landside). Its moldboard is like the western plow but has a very narrow waist due to substantial trimming on its furrow side. This plow also has a convenient depth adjusting device and a breaking pin which help protect the plow from a sudden and heavy impact, such as hitting a big rock. This plow transmits power better and, therefore, uses the animal power more efficiently and turns the furrow slice better on both paddy field and upland. It is especially welcomed by the farmers working on heavier soil.

C. Rice Pile Ventilator

In Taiwan, paddy is dried under the sun. When rain comes, the farmers collect the grains together from the drying ground, pile them on higher spots and cover them up with rice straw to wait for the return of the sun. If the wet paddy is piled up long enough, heat will develop and impair its quality. In this connection, a rice pile ventilator was cooperatively developed by JCRR and the Agricultural Engineering Department of the National Taiwan University. It consists of a sheet metal air intake head, a bamboo pipe, and a Λ-shaped bamboo mat cage. These three parts are secured together, and a bamboo mat is used as a pile bed. The procedure in using this equipment is to place the bamboo mat on a high spot, pile paddy grains on the bed to a depth of about one foot, place the rice pile ventilator in the center, pile paddy grains around the ventilator to the usual height, and cover the pile with rice straw as usually practised. The air which comes in from the intake head of the ventilator will go out through the paddy pile and carry away the heat accumulated in the center of the grain pile.

D. Use of Volcanic Ash in Building Drying Grounds

Cement drying grounds are widely accepted by Taiwan's farmers. However, studies have been made on the use of volcanic ash which is produced cheaply and locally to substitute a part of the cement needed. After several trials, it was found that 33 to 35 percent of volcanic ash could be used to substitute the usual cement requirement in 1:4:8 concrete mixture.

E. Rice Dryer

Three rice dryers of different makes were introduced from the United States for testing. These are: a portable rice dryer made by the Behlen Manufacturing Co., a column type rice dryer made by the American Drying Systems, Inc., and a small portable rice dryer made by the American Drying Equipment Co. Our preliminary tests have revealed that the Behlen portable dryer has the lowest drying cost, while the other two produce rice of better quality. Farmers are enthusiastic about these artificial dryers. If a rice drying service can be organized with a portable dryer to serve in accordance with rice harvesting time from south to north, the servicing time of the machine in a year may be longer and consequently the cost may be lower.

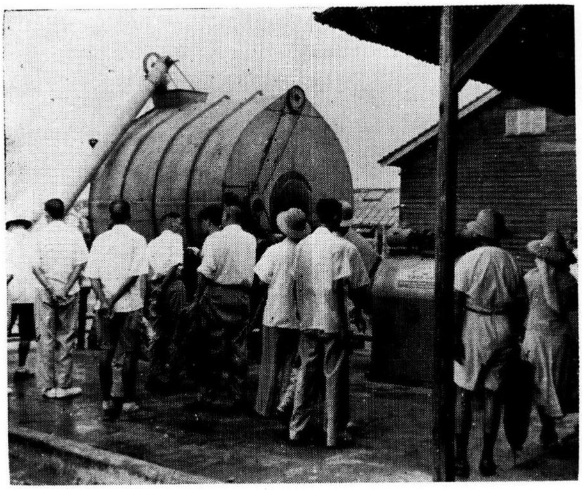

Fig. 13. Rice dryer

F. Aluminum Grain Storage Bin

The increasing rice production demands more storage space. To meet the demand, silo type round bins of western style were erected. These bins, in most cases, are erected in groups of three or four, and equipped with a power ventilator so that people can keep the temperature of stored grains down and moisture low. 110 bins were erected, each with a storage capacity of 70 metric tons. To facilitate loading and unloading of these bins, power auger loaders were also distributed with them.

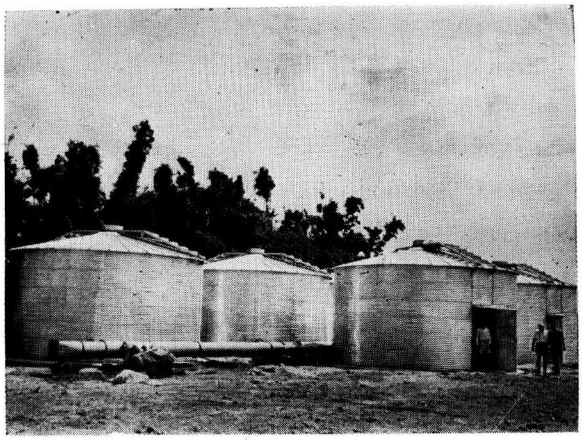

Fig. 14. Aluminum grain storage bin

69

G. Improving Rice Milling Machine

Since germ rice has been promoted by the nutritionists, local machinery manufacturers have started to produce the so-called germ rice milling machines. But their adoption will be slow and can only progress on a replacement basis because of the milling capacity of rice mills on this Island is now saturated.

BRIEF REPORT ON THE AGRICULTURAL MECHANIZATION IN TAIWAN

F. C. Ma

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Chinese-American Joint Commission on Rural Reconstruction

While preparing the first 4-Year Agricultural Production Plan in 1953, the Government found that, for intensive tilling of the 870,000 odd hectares of cropped land in Taiwan, there was a need of 110,000 head of buffaloes in addition to the 390,000 head Taiwan already had. The Joint Commission on Rural Reconstruction made a careful study of this problem and realized that to increase the buffalo population would not only take a long time, but would also need a big area of land to grow buffalo feed. In view of the rapidly increasing population in Taiwan, more land is needed for food production. Therefore, the use of power farming equipment becomes the only feasible way to solve the power shortage problem.

Experiment with small size power farming equipment was started by the JCRR in cooperation with local agricultural authorities at the early part of 1954. Seven different models of garden tractors ranging from 1.5 HP to 10 HP were introduced from the U. S. and distributed to private farms, agricultural schools and agricultural improvement stations for trial use. The general reaction was not very good because they were heavy, the handle and chassis were too high for the average sized oriental people to operate, the prices were high, and they could not be used on paddy fields.

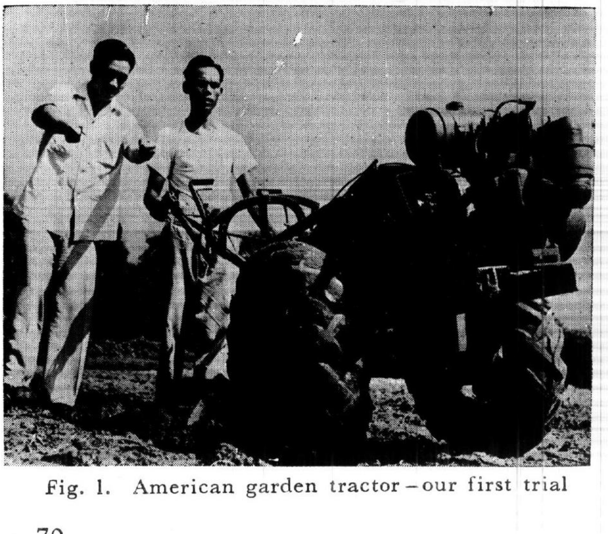

Fig. 1. American garden tractor – our first trial

JCRR, therefore, further studied the Japanese power tillers which could usually be used on both dryland and paddy field. Two different types of power tiller were selected for test use. One belonged to the typical Japanese driven type rotary tiller which had been popularly used in Japan for the past two decades, and the other belonged to the combined American and Japanese tractive-and-rotary type power tiller which was new then in Japan but we thought it might fit better Taiwan's farming condition. They were put into trial use on farmers' own land, and also demonstrated to farmers on various occasions. The general comment was that the tractive-and-rotary type power tiller would definitely be more acceptable to Taiwan farmers, because of its light weight, compact size, easy operation, high maneuverability in small field, ability to perform more kinds of work in and around the farm, and, most important of all, lower cost.

JCRR has, therefore, granted 13 such tractive-and-rotary type power tillers to 13 agricultural improvement stations on the Island, and trained operators for these stations, so that they could start a systematic power tiller adaptability test to find the proper way of utilizing power tillers on Taiwan farms and to evaluate their working efficiency and economic value as well when compared with buffalo. The result indicates that power tiller can plow the land about one inch deeper within 2/3 to 1/2 of the time needed for buffalo plowing. The 2.5 HP machines are suitable for use in fields of light soil, 3.5 HP machine on heavier soil, and 5 HP machine for farms of again heavier soil or farmers who carry out some other side jobs requiring more power. Power tiller of this type can also be used for row crop intertilling, weeding, hilling ridges, propelling power sprayers, rice threshing machines, sweet potato slicing machines, winnowing machines, etc. When attached with a trailer, the power tiller can serve as a transporting vehicle for a load up to 1,000 kg. at 15 kilometers per hour.

Fig. 2. Typical Japanese driven type rotary tiller

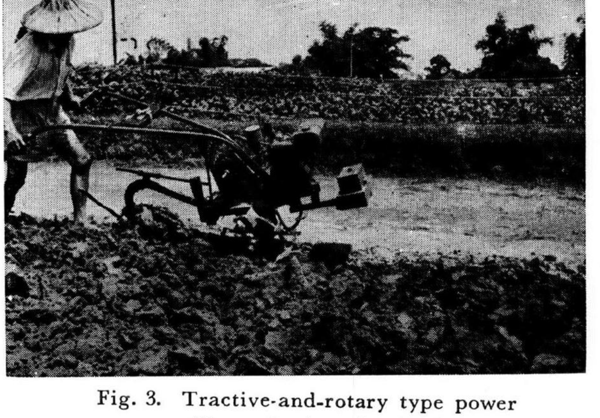

Fig. 3. Tractive-and-rotary type power tiller—plowing dry land

Advanced experiments on better use and on possible annual working hours of power tillers were started after the preliminary test was completed. Comparative field test on some newly developed power tillers was also made to keep up with the progress. In this connection, JCRR and the National Taiwan University arranged a one-year training class in the latter's Agricultural Engineering Department to train farm machinery technicians for the agricultural experiment stations, so that more specific field experiment on power tillers might be conducted to solve farmers' problems.

Fig. 4. Tractive-and-rotary type power tiller—plowing paddy field

With all these efforts, farmers in places where labor and buffalo shortage is more acute and cropping system is more tight and dense started to adopt power tillers on their own farms. Since the rural conditions in Taiwan provided nothing to accommodate a new-comer like power tiller, we were, therefore, very much encouraged by those pioneer farmers who started useing the power tillers. And from their problems we have proceeded to take the following steps aside from purely technical points:

1. Encouraging domestic machinery manufacturers to produce power tillers:

Taiwan is in short of foreign exchange. It is impossible to supply every needy farmer with a power tiller imported from foreign countries. Also the domestic machinery manufacturing industry is amply ready for making small power equipment such as power tillers of 2.5 HP to 5 HP. The JCRR, in cooperation with the industrial authorities, encouraged some machinery manufacturers to start manufacturing power tillers, not to copy any imported model, but to take the local agricultural conditions in mind to develop our own. Up until now, there are six manufacturers engaged in power tiller manufacturing, four for the tractive-and-rotary type and two for the driven type rotary tiller. They have already sold a total of about

Fig. 5. Harrowing with tractive-and-rotary type power tiller

1000 power tillers till October 1959. Three other machinery manufacturers have engaged in the manufacturing of engines, one producing the four stroke cycle gasoline engine, one the two stroke cycle gasoline engine, and the other the water-cooling diesel engine. They are trying their best to match their products to the locally produced power tillers. However, there still are rooms for improvement.

2. Regulations to encourage the use of power tillers:

Petroleum fuel is strictly rationed in Taiwan. Since power tiller is new, the old regulation provides no rationing of gasoline or diesel to power tiller users. At the suggestion of the JCRR, the Taiwan Provincial Government has promulgated a regulation governing the ration of petroleum fuels to power tiller users, which was put into effect in February 1958. Also, a Provincial Government decree exempted power tiller users from licence tax. The JCRR is now suggesting to the petroleum fuel authority the exemption of highway tax for fuels sold to power tiller users as such item is included in the gasoline price. The Legistrative Yuan of the National Government is now considering a national act on the promotion of agricultural mechanization.

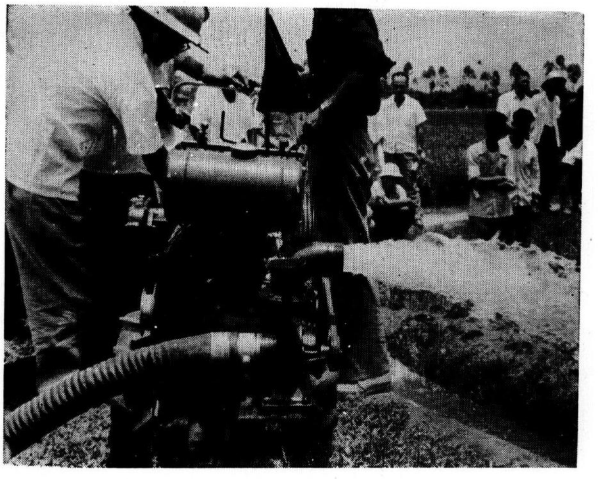

Fig. 6. Propelling water pump

3. Farm machinery purchase loan:

A power tiller, complete with all attachments, costs about 3-4 times higher than a water buffalo. Many farmers and agricultural agencies have suggest ed a subsidy system to encourage the use of power tillers. However, we believe the power tiller is part of the production cost and farmers have to face it squarely, and, therefore, have inspired the Taiwan Provincial Food Bureau, Taiwan Land Bank and Taiwan

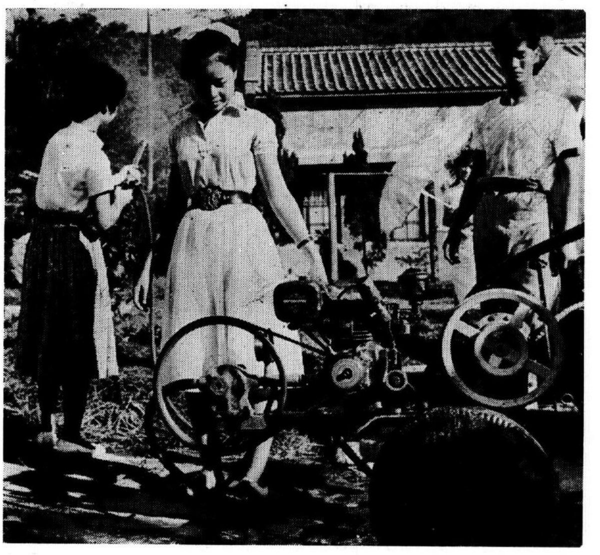

Fig. 7. Matched with sprayer

Provincial Cooperative Bank to establish farm machinery purchase loans. Farmers may loan 100% of the purchase cost from the Food Bureau if they agree to repay the loan in terms of paddy rice (actually a barter loan system); or loan up to 70% of the purchase cost from the said banks. The term of repayment is now set at three years, which is considered long enough when compared with other kinds of farm loans. With this measure, we believe farmers of good standing will have no trouble in getting the power tillers they need.

4. Establishment of farm machinery extension system:

Agricultural extension in Taiwan largely depends on the farmers' associations of various levels. The Government agricultural research and improvement stations pass results of their work directly or indirectly to the farmers' associations, which in turn disseminate such information to their member-farmers through their field agents. Since power farming is quite new even to these field agents, we have selected from the power tiller owners who are willing to help their neighbours in selecting, operating, utilizing power tillers, and have given them a short period of professional training and made them honorary power tiller demonstrators. They are now the down-to-the-earth cells in the promotion of agricultural mechanization.

Fig. 8. Using power tiller engine on rice thresher

By so doing, rural Taiwan is progressing toward mechanization. Starting from no power tiller at all in 1953, the numbers of power tillers increased up until October 1959 are shown as follows:

1954	7
1955	9
1956	60
1957	180
1958	500
1959 (till Oct.)	1500

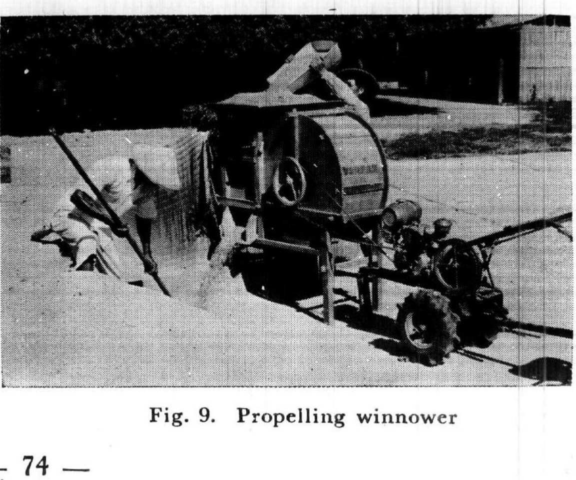

Fig. 9. Propelling winnower

We can see the agricultural mechanization program is young and progressing slowly, but its steps are very steady and accelerating. In the course of progress, we do have quite diversified ideas on the mode of owning and ways of utilizing power tillers in the countryside. Some were in favor of cooperative owning and using; some insisted on public or private concerns owning the power tillers and offering custom plowing service to farmers. But the fact proved that all the farmers prefer the individual ownership, with the alternate of two or at most three neighbours or relatives owning a power tiller and using it in turn. Farms in Taiwan are privately owned and individually managed. Farmers like to exercise complete right over their own power farming equipment. They also know that the power tiller can be utilized in many other ways in and around their farms and they will not be able to get all these advantages if they engage custom service instead of owning it. People can see now quite a number of the power tiller owners taking their whole family on the trailer to go visiting or to town for movies.

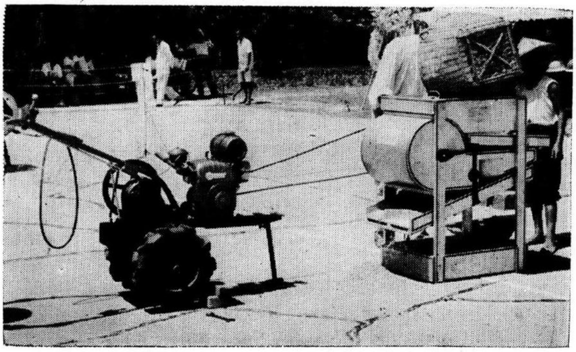

Fig. 10. Driving a seed cleaner

The JCRR is not satisfied with the present situation yet, and believes that the completion of the following measures will further promote the progress of agricultural mechanization:

1. Assistance in the establishment of power tiller repair network in the rural area:

This matter ought to be the duty of the manufacturers, distributors, or importing agents. However, the widely scattered distribution of power tillers of various makes comparatively small in total number makes it impossible for these manufacturers to provide efficient and timely repair service to the power tiller owners. The Government and/or the farmers' associations may have to help them conduct the repair service in the beginning stage, gradually turning it over to the manufacturers or professional repair shops.

Fig. 11. As prime mover for rice milling machine

2. Establishment of official power tiller testing system:

This is considered very necessary because more domestic manufacturers are interested in making power tillers. An official test and inspection system will not only protect the farmers' interests, but also help up-grade the quality of locally produced power tillers. This system, after being established, will be applicable to all local and foreign makes because we have found cases of unsatisfactory power tillers imported from other countries.

3. Better cooperation among farmers, agricultural experiment stations and manufactures:

It has always been the feeling that the local machinery manufacturers, who newly stepped into the power tiller manufacturing enterprise, are quite unfamiliar with the customers' need. On the other hand, farmers are also unacquainted with power farming. They do not know how to express their needs. It is, therefore, the agricultural experiment stations' responsibility to link them up. In this connection, the agricultural experiment stations have to strengthen their work relative to agricultural machineries in finding farmers' need, solving the problem through experiment and research and passing such result on to the manufacturers, so that machineries that meet precisely the farmers' needs may be eventually available.

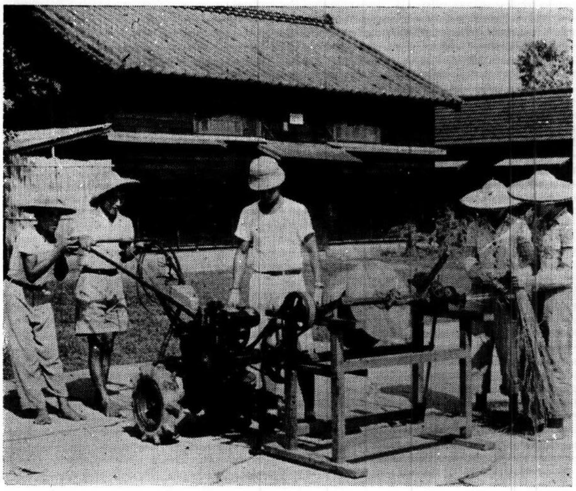

Fig. 12. Belted onto a straw rope machine

Further analysis has revealed that of the some 1,500 power tillers now in rural Taiwan, about 20% of them belong to the diesel or kerosene burning driven heavy rotary type, and 80% belong to the tractive-and-rotary type that are matched with air-cooling gasoline engine. Looking from the angle of the source of supply, about 2/3 of the power tillers are supplied by local manufacturers,

Fig. 13. Attached to a potato slicing machine

and 1/3 by those abroad. Classifying by the ownership to which they belong, about 95% of them are owned by individuals or 2-3 farmers on partnership basis, and only 5% or so are owned by cooperative farms and custom service teams. We also know that 3.5-5.0 HP will eventually be the most popular range of power for Taiwan farmers' need. It may be optimistic, and, judging from the trend, we cannot help but conclude that, within the next decade or so, the power tiller will no doubt solve the rural power shortage problem and will also help promote the agricultural production and improve the rural mode of living to an amazing extent.

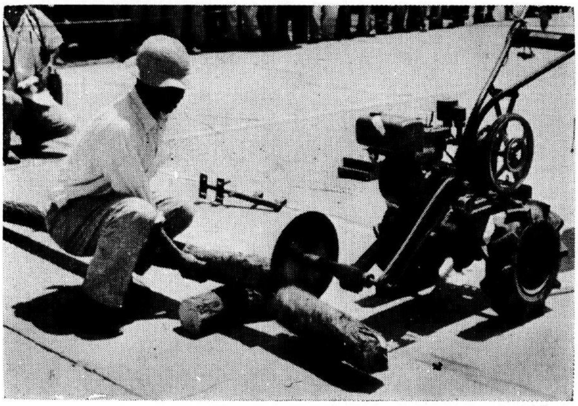

Fig. 14. Sawing logs

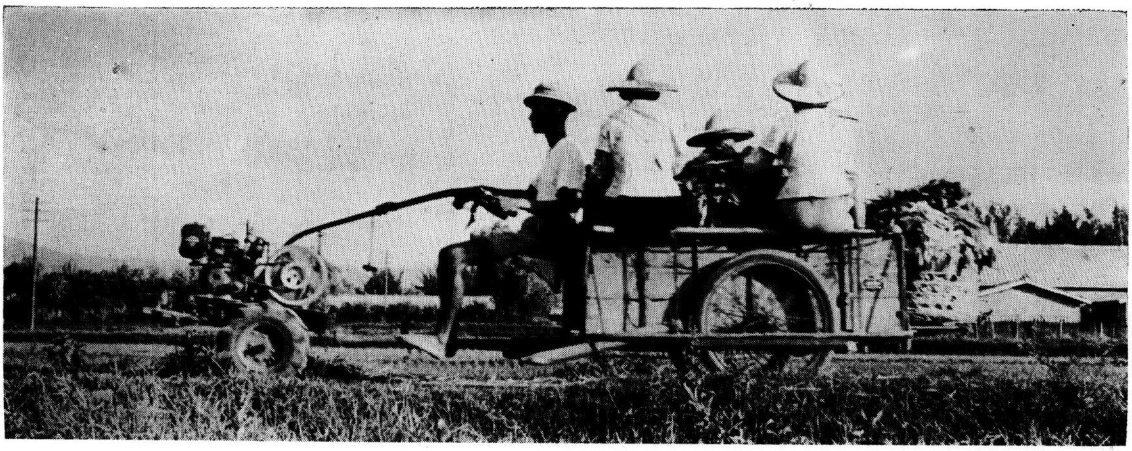

Fig. 15. Shipping vegetables to market

IRRIGATION FACILITIES FOR RICE CULTURE IN TAIWAN

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Irrigation facilities in Taiwan are mainly for rice culture. This is because the profit from rice growing is higher in comparison with all other crops.

Historically, irrigation work in Taiwan can be traced as far back as the Yuan Dynasty (1279-1368) of China. At that time, Taiwan was already a part of China. The land was reclaimed by the immigrants from mainland China with the so-called net-canal irrigation and drainage system. Later in the Ming Dynasty (1368-1662), General Cheng Chenkung came to Taiwan, with waves of people following him from the mainland. They further developed the irrigation system to produce more food for the people and the soldiers. By 1683, when the Ching Dynasty (1644-1911) had sovereignty over Taiwan, irrigation systems were developed to a still greater extent. This continued for a period of 212 years until 1895 when the Japanese took control of Taiwan. Up to that time, there had been 351,019 hectares of cultivated land, of which 196,679 were irrigated. All canals, except one, were built and maintained by individual farmers or by a group of farmers, practically with no assistance from the Government.

After Taiwan was occupied by Japan in 1895, there had been remarkable development in irrigation work in an effort to develop Taiwan into a main rice and sugar producing area. An enormous amount of investment had been made by the Japanese on irrigation in Taiwan. Some of the highlights were (1) improvement of the original irrigation systems by introducing more scientific methods; (2) research and experimentation on water duty and establishment of gauging stations; (3) overall reconnaissance of all irrigation systems for possible development and extension; (4) supervision and administration for all systems; (5) help in financing irrigation projects; and (6) construction of several large irrigation projects, notably, the Chia-nan Canal System. By the time of the restoration of the Island to China in 1945, there had been about 523,208 hectares of irrigated land out of a total of 816,016 hectares of cultivated land. However, the actual area planted to paddy rice was only 499,531 crop hectares. This indicates that, toward the end of World War II, many irrigation systems in Taiwan were not functioning.

After the War, the repair of the distorted irrigation systems and the construction of new ones have been rapidly undertaken by the Taiwan Provincial Water Conservancy Bureau and local hydraulic associations, with financial and technical assistance from the Chinese-American Joint Commission on Rural Reconstruction. In the following pages an effort is made to describe briefly the existing irrigation facilities and the improvements made in recent years.

I. Irrigation Facilities

The irrigation facilities in Taiwan fall mainly into two categories—the gravity system and the pumping system. The former is by far more common.

There are over a thousand separate gravity systems on the island, with varying irrigation capacities ranging from less than 100 hectares to over 100,000 hectares each. With the exception of the six major systems that are supplied from reservoirs, most of the systems are supplied directly from streams. The intakes of such systems fall under three different groups: (1) those without diversion weirs, (2) those with temporary ones, and (3) those with permanent ones.

An intake without a diversion weir is usually located in the concave side of a stream with a stable water course and a rock bank. Such intake is the best of all types. Intakes with temporary diversion weirs or dikes are the most troublesome and expensive ones. However, irrigation canal intakes of this type are most common in Taiwan. Temporary training dikes or weirs may be built of sand, gravels, rock, or bamboo cages, depending on the material locally available. The temporary diversion weir for the Tsaokung Canal, one of the oldest, was built of mats and sand. The difference of water surfaces above and below the weir is as large as four meters. The bamboo cages with pointed ends are filled with cobbles and laid with the pointed ends toward the down-stream. These temporary structures are subject to flood damage and are usually washed out several times a year. The intakes with permanent diversion weirs are usually provided with sluices at right angles to the intakes. Some canal intakes have been out of function due to a change in water course.

Pumping systems are usually supplied from streams, drainage channels, or underground sources. Irrigation pumps vary in size, ranging from a few horse power to 300 horse power. The prime mover is mostly electric power, although Diesel engine power is also commonly used. The engines, generators and motors are mostly imported, while the pumps are made locally.

It may be noted that some irrigation systems in Taiwan are a combination of both gravity and pumping systems. The first rice crop may be irrigated from a river elevated by a temporary diversion weir. The second crop will have to depend on pumping because the diversion weir will be washed away and cannot be restored until the water subsides. In some places, one crop depends on gravity irrigation from surface flow, while the other crop will have to be supplied by pumping ground water.

II. Progress Made

The following table is prepared to show the progress made in the irrigation facilities in Taiwan since the end of the War:

	1945	1956	
Land with irrigation facilities, in ha.	523,208	555,000	(estimated)
Area of rice planted, in crop ha.	499,531	783,629	
Rice production, in M.T. of brown rice	580,894	1,789,828	
Rice planted, in crop ha. per ha. of irrigated land	0.955	1.412	
Rice yield, in M.T. of brown rice per crop ha.	1.163	2.284	

The above table reveals a number of important facts. First, the work so far has been concentrated more on rehabilitation and improvement of the existing systems than on construction of new ones, as the area of land with irrigation facilities in 1956 was 555,000 ha., compared to 523,208 ha. in 1945. Secondly, the rehabilitation and improvement work has been very successful. Only 0.955 crop ha. of rice was produced from one ha. of irrigated land in 1945, while 1.412 crop ha. of rice was produced from one ha. of irrigated land in 1956. Thirdly, the yield of rice per ha. in 1956 was 2.284 M.T., compared 1.163 M.T. in 1945. The increase of the unit yield is not only due to the improvement of irrigation facilities, but also to the use of improved seed, insect control, higher fertilizer application, and so forth.

III. Improvements of the Existing Irrigation Systems

As indicated in the above table, the irrigation facilities in Taiwan today are more efficient than before. This is due to the fact that these facilities were not only rehabilitated but also improved. These improvements included (1) a number of permanent diversion weirs built to replace temporary ones, which used to be repaired several times a year at flooding times; (2) construction of several storage reservoirs; (3) miles of canals with cement lining; and (4) the improvement of old drainage channels and the construction of several new ones.

The plan for the rotational irrigation method, which will be described later in this paper, embodies two important changes in the history of irrigation in Taiwan. First, the quantity of water needed for a certain area is now planned and controlled by installing regulatory and measuring devices. Secondly, a government regulation governing irrigation was recently promulgated.

IV. Better Construction Methods Adopted

In recent years better construction methods have been adopted and more complicated structures built. In mixing concrete, aggregates are now measured by weight instead of by volume and water-cement ratio is strictly controlled with a view to safeguarding strength. In earthwork construction, a high degree of compaction of soil is required. In this connection, a new laboratory is now under construction and will soon be completed.

Irrigation structures are now more complicated than they were before. A diversion dam may have an inverted siphon embedded in it. Siphon spillways are also used. For the purpose of removing a bed load, vortex tubes are installed below the intake. Radial gates are sometimes operated by electricity. Structures for irrigation canals have better hydraulic features too.

V. Adoption of Rotational Irrigation

In the past, with very few exceptions, farmers in Taiwan used to apply irrigation water continuously. Except for the time of weeding, fertilization and harvesting, when no water is applied, irrigation continued for about one hundred days. For the purpose of irrigating more land with the same amount of water available, extensive experiments had been made from 1933 to 1943 by the Japanese on the effects of different irrigation methods on crop yields, and of different depths of water on different varieties of rice. Other experiments were designed to ascertain the best intervals between irrigation. Careful analysis of these experimental results made in 1951-1953 by JCRR led to the following three conclusions:

A. As far as yield is concerned, most tests did not show any appreciable differences between the rotational and the continuous methods, although some tests did show a noticeable increase in yield from the rotational method over the continuous method.

B. Most tests, however, showed an appreciable decreased water depth for the rotational method as follows:

Depths of water for rotational method	Corresponding depths of water for continuous method
0.015 m.	0.030 m.
0.030 m.	0.045-0.050 m.
0.036 m.	0.060 m.

C. Five of the tests indicated a saving of 15.8 percent to 38.7 percent of water, or an average of 26.1 percent for the rotational method. It seems possible that use of the rotational method, together with a better utilization of rainfall and more efficient operation of an irrigation system, could effect a saving of 25 percent to 50 percent of water.

The above conclusions have finally received the attention of the government. As a result, one experiment station and four demonstration centers on rotational irrigation were established late in 1954. However, the drought in the spring of 1955 carried rotational irrigation immediately from an experimental stage to an island-wide practice. Of the 35 irrigation districts on the island, 33 practised rotational irrigation, and, out of the total transplanted area of 212,010 ha., 195,959 ha. or 92.4 percent practised rotational irrigation. If the rotational method had not been used in 1955, the transplanted area would have been only 139,797 ha. In other words, an increase of 72,213 ha. or 51.7 percent was accomplished by rotational irrigation. In addition, another 35,011 ha. were saved by the more rational use of water. The amount of water available during the spring of 1955 was only about 40 percent of that of normal years.

The 1955 drought was a real test for rotational irrigation. The result has proven beyond doubt that rotational irrigation is a better method and is welcome by the farmers. To run rotational irrigation more effectively, however, most of the existing canal systems have to be improved as follows: (1) to control irrigation through installing gates and measuring devices; (2) to reduce percolation loss through lining the canals; (3) to combine small direct turnouts into larger ones; and (4) to enlarge canal capacities. Improvement work along these lines for 3,900 ha. was already completed in 1956, and in 1957 it would be extended to another 17,800 ha.

It is expected that, by the end of 1960, 116,000 ha. of land in Taiwan will have been provided with irrigation facilities suitable for rotational irrigation.

VI. Multi-purpose Projects Emphasized

A Chinese proverb says: "Irrigation without proper drainage will not be successful". This means that irrigation and drainage should go together. Therefore, for the purpose of attaining maximum benefit from water, a complete basin-wide plan is necessary before any individual project can be considered in a hopeful river basin area. This principle has been strictly followed in all recent hydraulic works. For example, the A-kung-tien Reservoir completed in 1951 is for flood control, irrigation and city water supply; the Tsao Tan Pei Project is for both drainage and irrigation; and the Mukwa Project, which is now under construction, is planned for power and irrigation.

The planning phase of a multi-purpose project — Shihmen Reservoir — was completed in 1955 and the construction work is just underway. After the completion of this reservoir, about 7,395 ha. of dry land will be provided with water and another 46,937 ha. will be made secure with supplementary irrigation. In addition, benefits from power generation, flood prevention, water supply, etc., are also considerable. Two more basin-wide plans are being considered, one is the Ta-Chia River Basin and the other the Cho-Shui River Basin; and it is believed that over 200,000 ha. of land would be affected by these two projects.

VII. Ground Water Also Tapped for Irrigation Purposes

With abundant rainfall and favorable geological formation, Taiwan has substantial supplies of ground water. The wells dug by the Johnston Company in 1950 for the Taiwan Sugar Corporation aroused much local interest in digging wells for irrigation of rice fields. Many surveys have been successfully made, including those on geological formation, existing wells and water levels, to determine the ultimate possible supplies of ground water in order to map out a ground water development program. For instance, the report of the Yunlin ground water survey indicates that at least 250 wells with a possible output of 1,000 g.p.m. each can be developed for irrigation of about 15,000 ha. of rice fields. The ground water surveys in other areas in Taiwan have also given hopeful results.

VIII. Local Irrigation Organizations Recently Reorganized

After the promulgation of the Public Irrigation System Regulations in 1903 and of the Regulation Governing All Government Built Systems in 1909 by the Japanese, nearly all the irrigation systems in Taiwan were turned over to the local hydraulic associations concerned.

In 1937, by order of the Japanese, 106 hydraulic associations were combined into 38. The number of the associations was raised to 40 after the restoration of Taiwan to China in 1945. After much consideration, these 40 hydraulic associations were further reduced to 26 in 1956. By comparison, the reorganization gave the new association the following advantages:

(1) By law, the new associations are public entities.

(2) The jurisdictional areas of the various associations are fixed with reference to their natural environment, water resource distribution, use of water for irrigation and other economic factors.

(3) The authority of each irrigation association is vested in the members' representatives' plenary session. These representatives are elected by the members of the association, and the chairman of the members' representatives is also the executive head of the association.

ROTATIONAL IRRIGATION FOR RICE — A REVOLUTION IN TAIWAN

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I. Introduction

The sub-tropical climate in Taiwan makes it possible for farmers to grow two crops of rice a year wherever there is sufficient water for irrigation. The first crop matures in about four months in the first half of the year, while the second crop requires slightly less time in the second half. In southern Taiwan, the crop season is about one to two months earlier than that in the north. The conventional method of irrigation is a continuous flow, starting from the time of transplanting until ten days or two weeks before harvesting, except for weeding and fertilization when irrigation ceases. In hilly sections of the Island where canal systems do not exist, water flows down from upper fields to lower ones.

Such a practice results in high water consumption. During the early years when the Island was sparsely populated, water was plentiful and there was no need to restrict its use. But with the influx of people from mainland China, the need for more efficient use of water for crop growth began to be felt.

Since the Chinese-American Joint Commission on Rural Reconstruction—JCRR—began to operate in Taiwan in 1949, the extremely low duty of irrigation water on the Island, averaging only about four hundred hectares per cubic meter of water per second, immediately attracted the author's attention. His findings were published in 1951[1] The study reveals that the conventional irrigation method can be replaced with an intermittant or rotational method without sacrificing the yield. By the latter method, 20-30 percent of water could be saved. This, together with more efficient use of rain-water and more satisfactory operation of the existing canal systems, might mean that 50 percent more water could be made available for crop production.

II. Experiment Stations and Demonstration Farms

An organization, known as the "Rotational Irrigation Promotion Commission", was formed in 1954 by the Government. All government agencies at the national, provincial and local levels that are concerned with food production are represented on this Promotion Commission. The Promotion Commission immediately established experiment stations and demonstration farms. The former is to determine the best rotation intervals and the most desirable amounts of water for irrigation in the different parts of the Island, while the latter is to demonstrate to the farmers that rotational irrigation is just as good as continuous flow, if not better. At present, there are three experiment stations in existence in northern, central and southern Taiwan respectively. At one time there were eleven demonstration farms, the land of several of them having been converted into regular paddy fields under the rotational irrigation system.

The experiment station generally has a small area divided into plots. For example, in the Taoyuan Experiment Station, the plots are grouped together to receive four different treatments, each with four replications. The four treatments are irrigations at 6-day, 8-day, 10-day and 15-day intervals. A total of sixteen plots, each of 8 meters long and 2 meters wide, is required. The Station has cement lined ditches, water gates and measuring devices. The amount of water that should be applied to a particular plot can thus be exactly controlled and measured. For all different rotation intervals, 45 millimeter depth of water is applied for each irrigation. Clayey material was used to build the boundary dikes between the plots in order to prevent seepage losses. Precipitation, temperature, humidity and sunshine are daily recorded. The drained off water is also measured. Surrounding the experimental plots, a protection belt is provided. The Central Experiment Station was similarly designed, except for three important modifications. The first is that there are eight replications instead of four for each of the four treatments; the second, an inclusion of a study on soil fertility; and the third, concrete dikes are used between the plots.

The demonstration farms are much larger in size, but the water use is not so perfectly controlled as at the experiment stations. They are designed to demonstrate to the farmers the relative merits between the rotational and conventional methods of irrigation and to determine possible difficulties that may be encountered in the enforcement of the rotational method of irrigation on a large scale. In these demonstration areas some changes had to be made in the existing canal systems. Most of these demonstration farms were established on request in districts where the water supply was insufficient and unevenly distributed or water disputes constantly arose. As a result, water disputes have been very much reduced in the areas where rotational irrigation has been practised. The benefits derived from rotational irrigation for the lower portion of a canal system are especially noticeable since these lower areas usually suffered the most in the past. For instance, in the area of the Tan Tsi Demonstration Farm in central Taiwan, the land in the lower irrigation section was worth only half the value of the upper section. Now, the price is about the same in both places.

The rotational intervals of these demonstration farms vary from four to seven days. Before the irrigation season begins, a detailed irrigation schedule must be set to determine the amount and time of irrigation for each section of land in a given area. At times of serious water shortage, the rotation intervals will have to be correspondingly lengthened. When this happens, the irrigation schedule will have to be changed. If any area remains unirrigated in any one round, it will be the first to receive water in the next round.

The Promotion Commission also conducted short term training courses to train people to prepare irrigation schedules, operate water gates, use measuring devices, and make proper adjustments in water distribution, if necessary. The trainees were selected mostly from among the graduates of agricultural vocational schools.

The expenses for conducting the experiment stations and the demonstration farms were first wholly and later partly financed by the government and the American aid agency. The expenditures for the experiment stations would usually cover the cost of fertilizers used, seed, land rent, labour and operation. In the case of the demonstration farms, the expenses would be mainly for operation, because fertilizers, seed and labour were to be provided by the farmers concerned.

The data for 1955, 1956 and part of 1957 have been gathered and analysed. This study involves a total of 17 cases in which a comparsion had been made between the rotational and conventional methods of irrigation in depths of water application and unit yields of rice. They all showed consistently that the rotational method saved from 4 percent to 231 percent of water, with an average of 91.5 percent. Five cases of rotational irrigation or 29 percent showed a decrease in yield, varying from 2.5 to 12.3 percent, with an average of 5.2 percent. However, the remaining 12 cases or 71 percent showed an increase in yield varying from 0.3 to 31.3 percent, with an average of 17 percent. The result seems to indicate that the author's conclusion made in 1951 regarding the advantages of the rotational method of irrigation over the conventional method was a little too conservative. The increase in unit yields may be explained by better aeration and more oxidation due to the periodic drying of the field, thus making fertilizers more available to the crop. Moreover, less fertilizers are likely to be lost by surface drainage as in the case of the continuous flow

Incidentally, a survey made by an expert of the World Health Organization shows that malaria control has been made more effective in areas where rotational irrigation was in practice.

III. Definite Measures to Adopt the New Practice

The success of the experiment stations and the demonstration farms was not the only factor that led the government to adopt the rotational irrigation policy. It was the 1954-55 drought that prompted the Government to do so. That drought affected two crops of rice, the second crop of 1954 and the first crop of 1955. During the period of drought, all canals on the Island carried only from one third to half of their normal capacity. Due to the government order and the encouragement of the Promotion Commission, rotational irrigation is now practised with remarkable success almost throughout the Island. To determine the result, however, an inspection team was organized in 1955 by the government, consisting of representatives of all agencies concerned. The findings were briefly reported in another paper[2]. The team recommended that rotational irrigation be adopted as a standard practice in Taiwan.

Subsequently, two actions were taken by the Government. One was the promulgation of an irrigation regulation in February 1957. This regulation has 7 chapters and 57 articles. These chapters cover the following headings: "General, Irrigation, Drainage, Maintenance, Supervision, Penalty and Appendix". This is the first time that irrigation methods in Taiwan have been placed under regulation. The second chapter on irrigation refers mainly to rotational irrigation.

The other government action to enforce rotational irrigation was the formulation of a 4-year plan, in which a total of 112,808 hectares of paddy fields would have their irrigation systems improved so that rotational irrigation could be practised. The selection of these paddy areas was based on the existence of most reliable sources of water supply and the most frequent water disputes. After the plan was implemented, an isolated area of 10,850 hectares, usually with an insufficient water supply, had enough water, and, in addition, another 9,075 hectares of land could be irrigated. The increase in production was 60,000 tons of paddy a year. The benefit-cost ratio of this 4-year plan is estimated at 2.76.

IV. The 1957 Program and Its Engineering Features

The 4-year rotational irrigation plan began in 1957. The first year program covered an improvement work on 17,824 hectares of paddy fields scattered over seven different districts. It called for NT$9,070,000 (approx. US$366,000) to be made available by JCRR. The improvement work consists of (1) installation of control structures and measuring devices, (2) modification of the existing irrigation system by transforming farm turnouts into sub-laterals, and (3) lining canals with cement. Some of the projects are completed and others underway. These projects will improve the existing systems and ensure the most effective use of water.

The rotational use of water may be accomplished in two ways: first, by rotating water supply in various reaches of a main canal, in laterals or in sub-laterals; and secondly, by rotating water supply among small areas, called rotation areas. In the first instance, when water is being conveyed in one stretch of a main canal or in one lateral, all the other reaches of the main canal or laterals would be dry. In the second instance, all the main canal, laterals, and sub-laterals would carry a continuous flow and irrigation would be rotated among the rotation areas. Various combinations of the two systems are also possible.

It has been demonstrated that rotation of water supply among rotation areas is a better method, because it calls for canals of smaller capacities, offers easier operation, creates less chances of water stealing and makes better use of the services of a common irrigator, which will be described later in this paper.

There is no single rule for determining the size of rotation areas. All such factors as topography, existing water courses, roads, soil conditions, agricultural practices and existing canal systems have to be taken into consideration. The areas may vary from several hectares up to two hundred hectares. The canal capacities, however, may become the determining factor of these areas, if due consideration is given to soil conditions, evaporation and percolation data, and water requirements of the possible crops. The canal capacities can be determined at the lower end after taking into consideration the losses due to conveyance. In Taiwan the average size of a rotation area is about 50 hectares. The area is further divided into small rotation units, among which water supply is rotated. The time when each unit needs water supply varies directly with its area.

The canal conveying water to each rotation area is always provided with a headgate or turnout structure and a measuring device. The most common measuring devices are the Parshall Flume and the Standard Weir.

Monolithic concrete lining has been installed in canals and laterals to prevent seepage. Thin concrete precast slabs 5 cm., 6 cm. and 7 cm. thick have also been used, and they are cheaper. These latter linings thus far have proven satisfactory and should last long, although it may be necessary to keep them in good repair.

A complete irrigation system, with reservoirs or ponds for storage and under efficient management together with a well designed and supervised operation schedule, will be able to reduce water losses to a minimum and to utilize water most effectively.

V. The Common Irrigator and the Common Seedling Bed

Engineers and agriculturists should cooperate with each other in order to obtain the maximum irrigation results. The success of irrigation also depends on farmers' ability to work together and to manage their farms cooperatively. This can be illustrated by the following examples:

Under the Chia-nan Irrigation Association in southern Taiwan, a practice of employing common irrigators has been developed by the farmers within a rotation area to take care of their irrigation work, such as diverting and distributing water, maintaining farm ditches, etc. These irrigators are usually farmers selected by themselves within the rotation area. They were generally industrious, impartial and familiar with the farming conditions in the area. For each rotation area of say 50 hectares, two common irrigators may be necessary. The whole area is under their care. They know what fields need special adjustments in the rotation system and how much water is required by reason of soil conditions or other factors. At the start, the common irrigator may experience some difficulties, but before long, he will acquire the necessary skill and experience.

It was estimated that the employment of a common irrigator would save for an average farmer about five sixths of the time required for irrigation under the old practice. Thus, with a total irrigation period of 90 days, on a 6-day rotation interval, one half of a man-day is required for each irrigation of 0.33 hectare and the total labour required for a 50-hectare rotation area would be $15 \times 0.5 \times 50/0.33$ or 1,125 man-days. If two common irrigators Were employed, the total labour required would be 90×2 or 180 man-days. This saving on man power means a good deal to the farmers, and will reduce the cost of production considerably.

The common seedling or nursery bed for rice is another development that can very well be incorporated into the rotational irrigation practice. The local practice is to place the seeds in the seedling bed one to two months before transplanting. Such beds are privately owned. Each farmer has his own way of farming. The need for proper seed treatment, nursery bed preparation, and other improved farming practices has developed the use of common seedling beds. Although the common seedling bed has not been widely used, its advantages are very obvious. Further demonstration work was carried out during 1955-1956. A total of 101 such common beds (12 in southern Taiwan and 89 in northern Taiwan) was installed with a combined area of 16,984 hectares. The seedbeds constitute about one twenty-fifth of the planted area. The trial results indicate that the farmers in northern Taiwan are reluctant to adopt the practice due to the travel distance between the seedling bed and the planted area. But, in southern Taiwan where the spring is usually dry, the common seedbed idea is more readily acceptable as the farmers need to locate their nursery beds in places of more dependable water supply.

The use of the common seedling bed can very well be incorporated into rotational irrigation because the age of the seedlings can be perfectly controlled so as to fit in with the irrigation schedule. The farmers should also work together cooperatively by forming teams for transplanting according to the seedling development and the irrigation schedule. It is very important in rice culture to transplant the seedlings at the proper time.

VI. Difficulties and Problems

The practice of rotational irrigation in Taiwan is not without difficulties. Some of them can be easily overcome, while others will take time to be solved. The most common difficulty lies in the fact that the people along the upper end of an irrigation system are oftentimes not interested in the program and even object to it since they have not previously experienced water shortage. The use of water was rarely controlled or limited in the past. The new method would therefore cause some inconvenience. Some farmers tried to interfere with its development. In two cases the farmers demolished the new structures. In modifying a conveyance system, a farmer's direct turnout from the main lateral might have to be abolished and instead his water supply might have to come from the lower end of a new lateral. Centainly this would disturb him. In digging the new lateral to modify the old system, right-of-way problems are also encountered. Land owners often refuse to give up their land even for a good compensation.

There are conflicts between irrigation and peak power generation. This is more so with rotational irrigation. Peak power is usually generated during low river stages by storing the natural river flow during daytime and releasing it during a few hours of peak electric load in the evening. This is in conflict with irrigation not only because this is also a time when the irrigation requirement is at the greatest, but also because the natural river discharge is changed into a highly fluctuating flow. This is especially undesirable in the case of rotational irrigation because the irrigation schedule is devised according to a known discharge which is usually fairly uniform. Furthermore, surges often result in wasting water down the river channels because the canals cannot cope with the large peak flows. This situation can be improved only by constructing an afterbay for re-regulation of water below the power plant.

Some people believe that rotational irrigation is likely to encourage weed growth. It is reasoned that continuous irrigation will prevent weed growth. After two or three weedings, weeds will not easily grow under standing water. With rotational irrigation, soil is more often exposed and so weeds grow more easily. This problem is now under close observation.

Some field workers think that rotational irrigation will increase the incidence of rice blast disease. Thus far, there has been no evidence of this in Taiwan.

The difficulties and problems mentioned above are not considered serious in the enforcement of rotational irrigation. They do point out, however, that further studies on them are desirable.

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