THE SEARCH FOR RICE VARIETIES ADAPTED TO RAINFED GROWING CONDITIONS

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ABSTRACT

Traditional rainfed rices are generally low yielders, tall, weak-strawed, and late maturing. To facilitate their improvement, the Cooperative National Rice Varietal Improvement Program was organized and launched in 1953 and continued up to the present with some revisions. The U.P. College of Agriculture and the Bureau of Plant Industry undertook the breeding work while the Bureau of Agricultural Extension and agricultural schools and colleges conducted the multilocation tests of new selections. Outstanding selections were recommended to the Seed Board for approval and release. Since then until 1996, 18 upland, 14 rainfed lowland, and 72 irrigated lowland, varieties were released. Comparison of the performance data on the released rainfed varieties revealed that there was hardly any perceptible increase in the yield of newer varieties. Hence, breeders are advised to utilize relevant findings from related disciplines in modifying the procedures and criteria for selection of the plant type appropriate to rainfed environments so as to achieve further yield improvement.

Key words: Rainfed rice breeding; rainfed-lowland rice breeding; upland rice breeding

INTRODUCTION

Rainfed rice is grown in 1.47 M hectares or 37 percent of the total rice area but accounts for only 27 percent of the total annual crop production in the Philippines (BAS, 1996). Because it is rainfall dependent, yields are low not only in upland but also in rainfed lowland areas. In general, the land is cropped to rice only once a year. It is on these ricelands that most of the rural poor depend for their livelihood.

In level, sloping, or undulating topography in the uplands, it is directly seeded, but in level, bunded lowland fields, it is either directly seeded or transplanted early during the rainy season. Since rainfall is uncontrollable, cultural management of the crop becomes difficult. This results in poor crop yields (2.19 t/ha) even with the use of high yielding varieties and fairly good cultural management compared to that of irrigated rice (3.37 t/ha) (BAS, 1996). Other constraints to the attainment of high yield include the use of traditional low yielding varieties especially in upland fields, poor native soil fertility, rodents, insect pests, diseases, and weeds.

To help alleviate the present living conditions of the families dependent on rainfed rice and to be able to meet as much as possible the national rice requirement of the fast expanding population (2.5%, BAS 1996), rice yield must be continuously improved. Increased production due to area expansion can no longer be relied upon for only very limited areas are available now for conversion to riceland. Besides, more and more ricelands are being diverted for commercial, industrial, residential, and recreational uses.

Of the various ways of improving rice yield, the use of adapted high and stable yielding varieties with built-in resistance to the various stresses is the cheapest and most readily accepted by farmers. But how much rice yield improvement has been attained so far in breeding this cultural type? This study was undertaken to be able to assess the degree of yield improvement in rainfed rice and, if the rate of improvement is nil or negligible, to suggest strategies on how to be able to raise the yield level through breeding.

MATERIALS AND METHODS

Breeding activities on rainfed rice during the last nearly half century were reviewed briefly in an attempt to provide answers to the objectives set forth in this study. Coordinated approach to varietal improvement of this cultural type started in 1952 when, at the initiative of the U.P. College of Agriculture (UPCA), a Memorandum of Understanding was signed by the heads of the participating agencies, UPCA, Bureau of Plant Industry (BPI), and Bureau of Agricultural Extension (BAE). In 1953, the National Cooperative Rice Improvement Program was organized (Fig. 1, Umali and Bernardo, 1959). The Bureau of Plant Industry and the UPCA assumed the responsibility for breeding and testing of new improved selections. The BAE participated in the regional testing of advanced selections. Subsequently the program expanded to include agricultural schools and colleges and public and private firms, such as the International Rice Research Institute and the Philippine Atomic Research Center in the 1960s.

Early implementation of this Program was made possible with financial assistance from the Philippine Council for US Aid (Philcusa) and the Mutual Security Agency (MSA), later from the National Economic Commission (NEC) and International Cooperation Administration (ICA), and still later from the National Rice and Corn Corporation (NARIC) Research Grant of 1955 (Umali and Bernardo, 1959). Subsequent funding of the Program was more or less assured with the enactment of the Rice and Corn Production Program in 1959. In 1987 the Program was assumed by the Philippine Rice Research Institute (PhilRice) which

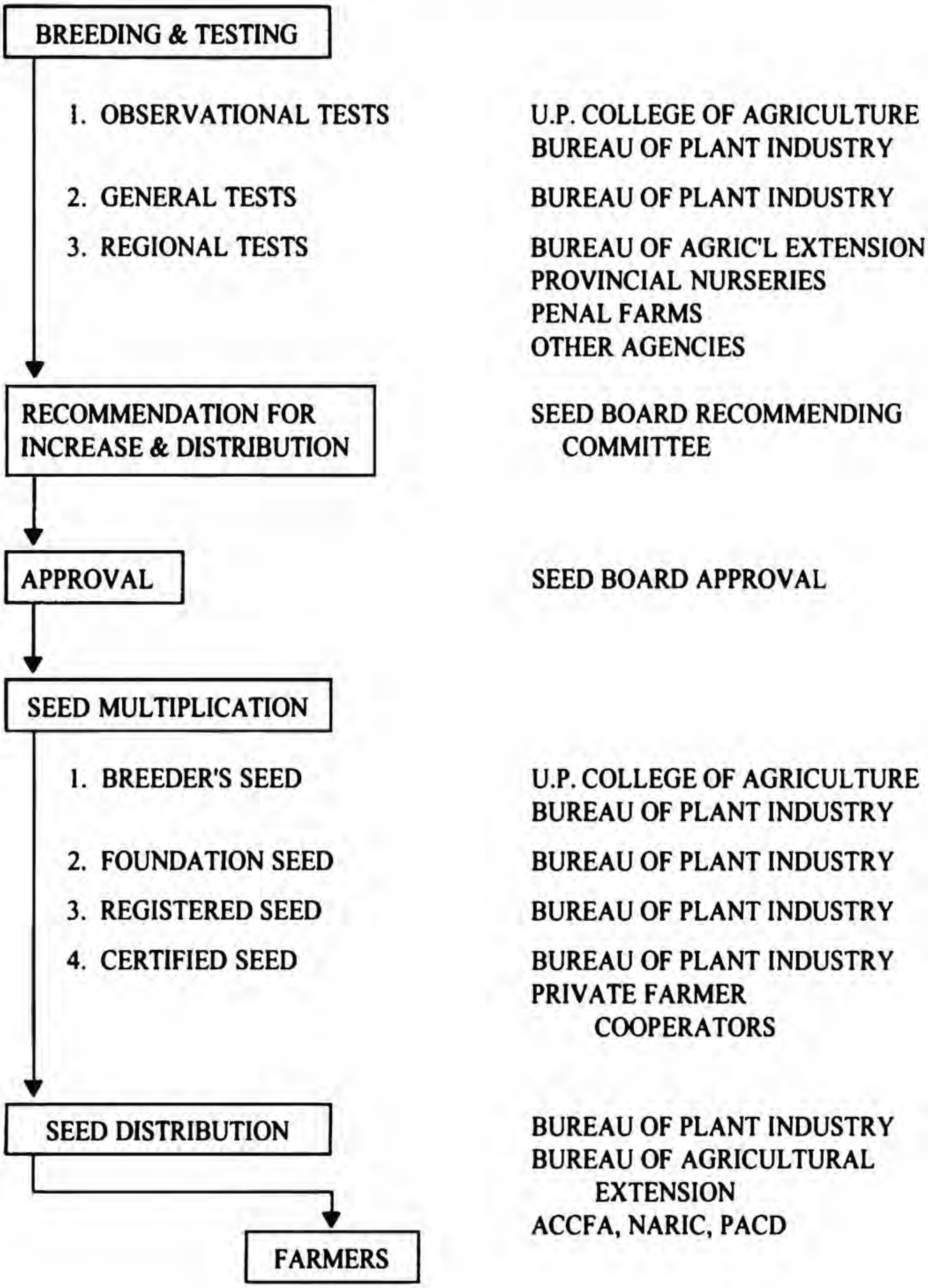

Figure 1. Diagram of the Philippine Cooperative Rice Improvement, Multiplication, and Distribution Program. Source: Umali and Bernardo, 1959.

was created in November 1985 by Executive Order No. 1061, amended in November 1986 by Executive Order No. 1061, and again in November 1986 by Executive Order No. 60 (Anonymous, 1997).

Soon after the start of the Cooperative Program, more than 900 local collections and 2362 accessions introduced from the US Department of Agriculture (USDA) were screened at the UPCA and BPI Maligaya Rice Experiment Station for adaptability to upland and/or lowland conditions. These, together with other local collections and foreign introductions, formed the foundation for the breeding work. With the establishment of IRRI at Los Baños, the varietal collections made available for breeding work continued to increase tremendously.

Conventional breeding methods and procedures were followed in the development, selection, testing, and release of new improved lines. Initially, the pure line method was employed in varietal development. Later, as commercial varieties became uniform, it became necessary to create variation through varietal hybridization from which selection can be made. The hybrid and segregating generations were handled in various ways (pedigree, bulk, and their modifications) depending upon the nature of the crosses, the parental materials, space availability, time, and preference of the plant breeders. When lines became uniform, those which had the desired traits were subjected to tests for resistance/tolerance to the common stresses. Selections were then tested for yield and other agronomic traits, first at one and later at more locations and seasons. Data were collected on important agronomic and grain traits and summarized.

At the end of each season the Technical Working Group of the Seed Board met and recommended the most outstanding selections to the Seed Board for release and seed increase. The Seed Board, which was created by Special Order No. 1616 of the Secretary of Agriculture and Natural Resources on 11 March 1955, was responsible for acting on variety recommendations. In 1995 the Seed Board was replaced by the National Seed Industry Council.

In this paper data on grain yield and growth duration from the advanced performance tests of Seed Board–approved varieties were summarized. The 10-year yield and growth duration averages of the upland and rainfed lowland selections were computed and the periodical changes in mean yield were compared to determine whether or not there was any progress achieved. The annual rates of change in their mean yields were computed by dividing the change in mean yield of a group from the mean yield of the preceding group by the average of the two mean yields and then dividing the result by the mean number of years of the two groups. If the progress achieved was nil or negligible, suggestions were made for modifying the procedures and revising the criteria to be followed in selection.

RESULTS

Upland Rice Improvement

Data on grain yield and growth duration of upland varieties approved by the Seed Board since 1995 were summarized (Appendix, Table 1) and the grain yields and growth durations were averaged periodically (Table 1). During the first period (Group I, 1953-60) the yields of five released varieties ranged form 2.48 t (Dinalaga) to 3.16 t/ha (Palawan) with an average of 2.75 tons. Growth durations did not vary very much from the average (126 days).

In the second period (Group II, 1961-70) only four varieties were released with yields ranging from 2.98 t to 3.52 t/ha (BPI 9-33). They averaged 3.19 tons/ ha or 16% higher than the average for the first group. On the average, the varieties matured 11 days earlier than those in Group I.

From 1971 to 1980 six varieties were released (Group III). Their yields ranged from 2.40 t to 3.88 t/ha (C 22), averaging 2.91 t/ha or 6 percent higher than the Group I average. Varieties in this group matured almost similarly as those in Group I but later than those in Group II.

During the next decade (1981-90) only two varieties were released, probably because of financial constraint during the mid 1980s. The average yield declined to 2.72 t/ha or 1% lower than Group I average.

The two varieties released during the present decade were the first products of breeding activities under PhilRice. These varieties yielded only an average of 2.88 t/ha or 5% lower than the yield average in the 1950's. They matured in 123 days similar to those released in the preceding decade.

The annual rates of change in mean yields per group are shown in Table 1. During the period 1952-70 the rate of annual increase in mean yield was 1.65%. In the next two decades however the rates of annual change in mean yields were negative (-0.92% and -0.67%, respectively). Only in the present decade was there a slight increase of 0.71%.

Rainfed Lowland Rice Improvement

As with upland rice, data on grain yield and other important traits of all 14 rainfed lowland varieties released by the Seed Board since the 1970's were summarized (Appendix, Table 2) and grain yields and growth durations were averaged periodically (Table 1).

During the first ten-year period (1971-80) grain yields ranged from 2.75 t to 3.9 t/ha (IR 46) with an average of 3.42 t. Mean growth duration was 123 days.

There was no rainfed lowland variety released in 1981-90.

From 1991 to 1996, ten varieties were released. Two of these (PSB Rc 16 and PSB Rc 24) were for dry seeding. The rest were recommended for transplanting. Yields of these varieties ranged from 2.71 t to 3.79 t/ha (PSB Rc 12) with an average of 3.24 t or a decrease of 5% from the mean of the first group. They mature from 109 to 130 days with a mean of 119 days.

Appendix, Table 1. Grain yield and growth duration of Seed Board approved upland rice varieties, 1952-96.

VARIETY	YEAR RELEASED	GRAIN YIELD (t/ha)	GROWTH DURATION (days)
Group I (1952-60)			
Azucena	1956	2.70	123
Palawan	1956	3.16	130
Mangarez	1959	2.82	126
Milpal 4	1959	2.58	124
Dinalaga	1960	2.48	127
Mean		2.75	126
Group II (1961-70)			
HBDA-2	1963	2.98	121
Azmil 26	1967	3.12	122
BPI 1-48	1965	3.14	116
BPI 9-33	1968	3.52	110
Mean		3.19	117.2
Group III (1971-80)			
C22	1972	3.88	127
IR43	1978	3.52	129
IR45	1978	2.51	131
UPL Ri 3	1979	2.40	125
BPI Ri 6	1979	2.54	125
UPL Ri 5	1980	2.58	120
Mean		2.91	126.2
Group IV (1981-90)			
UPL Ri 7	1981	3.04	116
PSB Rc 1	1990	2.39	121
Mean		2.72	118.5
Group V (1991-96)			
PSB Rc 3	1996	2.85	123
PSB Rc 5	1996	2.91	120
Mean		2.88	121.5
Grand Mean		2.90	122.9

Source: Anonymous, 1985, 1991.

Table 1. Mean growth duration, mean grain yield, and rate of annual change in mean grain yield of rainfed rice varieties by year groups.

GROUP NO.	NO. OF YEARS PER GROUP	MEAN GROWTH DURATION (days)	MEAN YIELD (t/ha)	YIELD DIFFERENCE FROM GROUP I (%)	ANNUAL RATE OF CHANGE IN MEAN YIELD (%)
Upland Rice					
I	8	126.0	2.75	–	–
II	10	117.2	3.19	+ 16	+1.65
III	10	126.2	2.91	+ 6	–0.92
IV	10	118.5	2.72	– 1	–0.67
V	6	121.5	2.88	+ 5	+0.71
Mean	–	122.9	2.90	–	–
Rainfed Rice					
I	10	123.3	3.42	–	–
II	6	118.9	3.24	– 5	0.42
Mean	–	–	–	–	
		120.1	3.23		–

The annual rate of change in the mean yield during the entire period was computed and found to be decreasing at 0.42%. Like the upland rice breeding work, varietal improvement of rainfed lowland rice during the past nearly three decades was ineffective in increasing the yield.

DISCUSSION

Rainfed rices released in the Philippines soon after the start of the Cooperative National Varietal Improvement Program were developed earlier following the pureline method of selection. This was effective in those years when there were many traditional or even exotic varieties commercially grown which were not uniform agronomically. Examples of these were the upland varieties Inintiw Strain 107, Azucena, and Dinalaga and a rainfed lowland variety, Seraup Keehil 36 Strain 482 (Cada et al., 1971). But as further selection from these varieties failed to achieve yield improvement, plant breeders resorted to hybridization as a means of creating genetic variation from which selection can be done. Practically all rainfed rices released after 1960 were products of breeding through hybridization.

Appendix, Table 2. Grain yield and growth duration of Seed Board approved upland rice varieties, 1971-96.

VARITIES	YEAR RELEASED	GRAIN YIELD (t/ha)	GROWTH DURATION (days)
Group I (1971-80)			
C168	1973	3.77	128
UPL Ri 2	1978	2.75	123
IR46	1978	3.98	123
IR52	1980	3.17	119
Mean		3.42	123.3
Group II (1981-90)			
(no variety was recommended)			
Group III (1991-96)			
PSB Rc 12	1992	3.54	109
PSB Rc 14	1992	3.79	110
PSB Rc 16	1993	2.71	125
PSB Rc 24	1994	3.10	117
PSB Rc 36	1995	2.73	127
PSB Rc 38	1995	3.22	127
PSB Rc 40	1995	2.80	130
PSB Rc 42	1995	3.22	114
PSB Rc 60	1996	3.63	113
PSB Rc 62	1996	3.70	117
Mean		3.24	118.9
Grand Mean		3.29	120.1

Source: Anonymous, 1985, 1991.

Most if not all of those varieties were selected from segregating generations using the pedigree and bulk methods or their modifications. Probably because of the savings in time needed to attain homozygosity in pedigree method and the simplicity and ease in handling bulked materials, these methods were commonly used.

In the present review of breeding work done so far, the conventional breeding methods and procedures used failed to produce noticeable yield improvement in released varieties. Similar results were reported during the international conference on rainfed rice held in Bhubaneswar, India in October 1984 (Misra et al., 1986).

Since the conventional methods and procedures appear ineffective in raising the yield level of rainfed rice, breeding and testing strategies appropriate for rainfed rice improvement are suggested:

Improvement of Genetic Variation Prior to Selection

There can be no varietal improvement without genetic variability. Hence, to be able to develop a superior variety, diverse genetic variation for the traits related to yielding ability must first be incorporated into the base population through hybridization. If possible parental varieties with known high combining ability for the components of yield should be used in intercrosses. Or parental varieties with complementary traits for yielding ability must be searched from diverse sources. Multiple crosses of those varieties can be made before starting selection in selfed progenies. A better alternative is to concentrate desired genes in the base population through population improvement by intercrossing several varieties in all possible combinations, and repeating this with their F_1s in several cycles before selection is made in their selfed progenies. Desired genes for yielding ability can be accumulated since the yield components are controlled by a number of genes with high genetic variances and heritabilities (Chaudhry, 1969).

Selection for Desired Agronomic Traits

The desired plant type for rainfed rice varieties has not been well defined although IRRI has identified several traits appropriate for upland and for rainfed lowland conditions (IRRI, 1989). By growing several hundred crosses and advanced lines in three drought prone and medium deep water rainfed lowland conditions three varieties with average yield of 5.5 t/ha were selected and their agronomic traits were described. Based on these findings, the following set of criteria is proposed for use in selection for high yielding lines/cultivars adapted to a wide range of rainfed lowland conditions (Fig. 2, IRRI, 1989):

* potential yield of 5-7 t/ha
* 6-10 panicles per plant
* no unproductive tillers
* 150-200 grains per panicle
* sturdy stems
* dark green, erect or moderately droopy leaves
* 130 cm tall
* extensive root system
* multiple disease and insect resistance
* 120-150 days growth duration

In upland rice, an analysis of results of 4-year trials of nearly 2,000 rices in 18 upland sites in the country, revealed an average maximum yield of over 3 t/ha across sites. (Fig. 3, IRRI, 1989). Based on the common plant type of the high

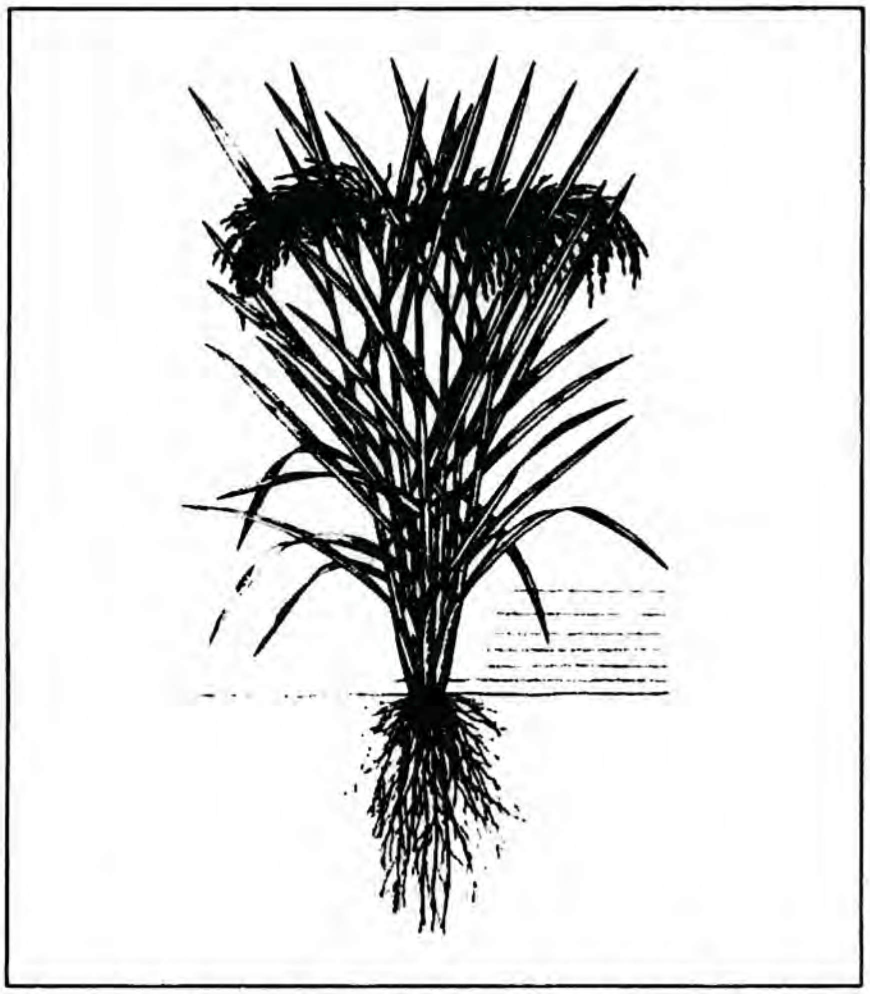

Figure 2. Optimum plant type for rainfed lowland rice. Source: IRRI, 1989.

Figure 3. Optimum plant type for upland rice. Source: IRRI, 1989.

yielding rices, the following set of criteria is proposed for use in selection of widely adapted high yielding lines:

* potential yield of 3-5 t/ha
* 5-8 panicles per plant
* sturdy stems
* erect upper leaves and droopy lower leaves
* 130 cm tall
* deep thick roots
* multiple disease and insect resistance
* 100 day growth duration

Selection for those plant traits can be started as soon as they can be identified. In the early segregating generations emphasis should be given to selection for traits controlled by one or only a few genes such as earliness, lodging resistance, and possibly early plant vigor, intermediate height, moderate tillering ability, and good grain quality.

In later generations, selection should be directed to more complexly inherited traits such as the yield components: number of panicles per plant, number of spikelets per panicle, percentage of filled spikelets, and mean grain weight.

Because of the difficulty in identifying high yielding genotypes in early segregating generations, the use of molecular markers closely linked to controlling the yield components could be explored (Courtois et al., 1995). By extracting DNA from leaf samples of F_2 plants and testing it with molecular markers closely linked to quantitative trait loci controlling the yield components, plants carrying the desired yield genes can be selected and grown in progeny rows until those genes are fixed.

Testing for yield starts when the progenies of crosses breed true for the trait which is about five years or longer from crossing. To be able to obtain fixed lines immediately, doubled haploids are selected through anther culture of F_2 pollen. These doubled haploids which are homozygous can be increased for yield testing.

Grain yield is highly correlated with panicle number followed by grain weight and grain number. However, the correlations between the yield components are negative (Chaudhry 1969). These negative correlations imply that an increase in one component reduces the other resulting in negligible or even neutral effect on final yield (Courtois et al., 1995). Therefore selection should be optimized for each component so that the final yield will be at its maximum.

Selection for Reaction to Various Stresses

Selection of plants and lines for resistance/tolerance to various insect pests, diseases, drought, and adverse soil conditions may be done earlier or later in the selfed progenies depending on their mode of inheritance and on seed availability.

The methods, procedures, and techniques being used at present in identification of plants or lines resistant or tolerant to the various stresses appear satisfactory.

However, in some cases where a few genes are involved as in bacterial leaf blight and rice blast, selection for plants/ lines which possess all resistance genes is difficult, especially if a particular race of the pathogen is absent. In such cases DNA-marker assisted selection can be employed with a high degree of accuracy (90-100%) even in the early segregating generations (Hittalmani et al., 1955). F_2 plants homozygous for two blast resistance genes were identified by DNA markers and confirmed in F_3 by the same markers and by conventional blast inoculation test.

The use of DNA markers is early selection or as an adjunct to conventional selection has been suggested for use in identification of gall midge resistance (Katiyar et al., 1995) and various root and drought-related traits (MacKill et al., 1996).

Testing for Yield and Yield Stability

Rainfed lowland and upland rice ecosystems are highly variable and risky. At present there is still no variety which possesses all the traits needed to reduce the inherent risk. Since the rainfed rices which have been released were tested and selected in performance tests over a number of seasons in different locations varying in growing conditions, their average yields were lower than could be expected when grown under favorable conditions. It is therefore necessary to breed and select for genotypes which are adapted to more specific sets of growing conditions. To be able to identify high yielding lines, those which performed fairly well in earlier performance tests in certain locations and seasons must be tested further only in those locations and seasons to determine their specific adaptability. Their yield stabilities can be measured by growing those selections in the stations where they are adapted and then regressing their yields at each location on the mean yield of all varieties grown in that location (Fig. 4, Seshu, 1986; MacKill et al., 1996). Selections with lower regression coefficients are more stable than those with higher coefficients. Therefore a desirable rainfed rice variety must both be high and stable yielding and adapted to the usual variations in growing conditions in certain locations.

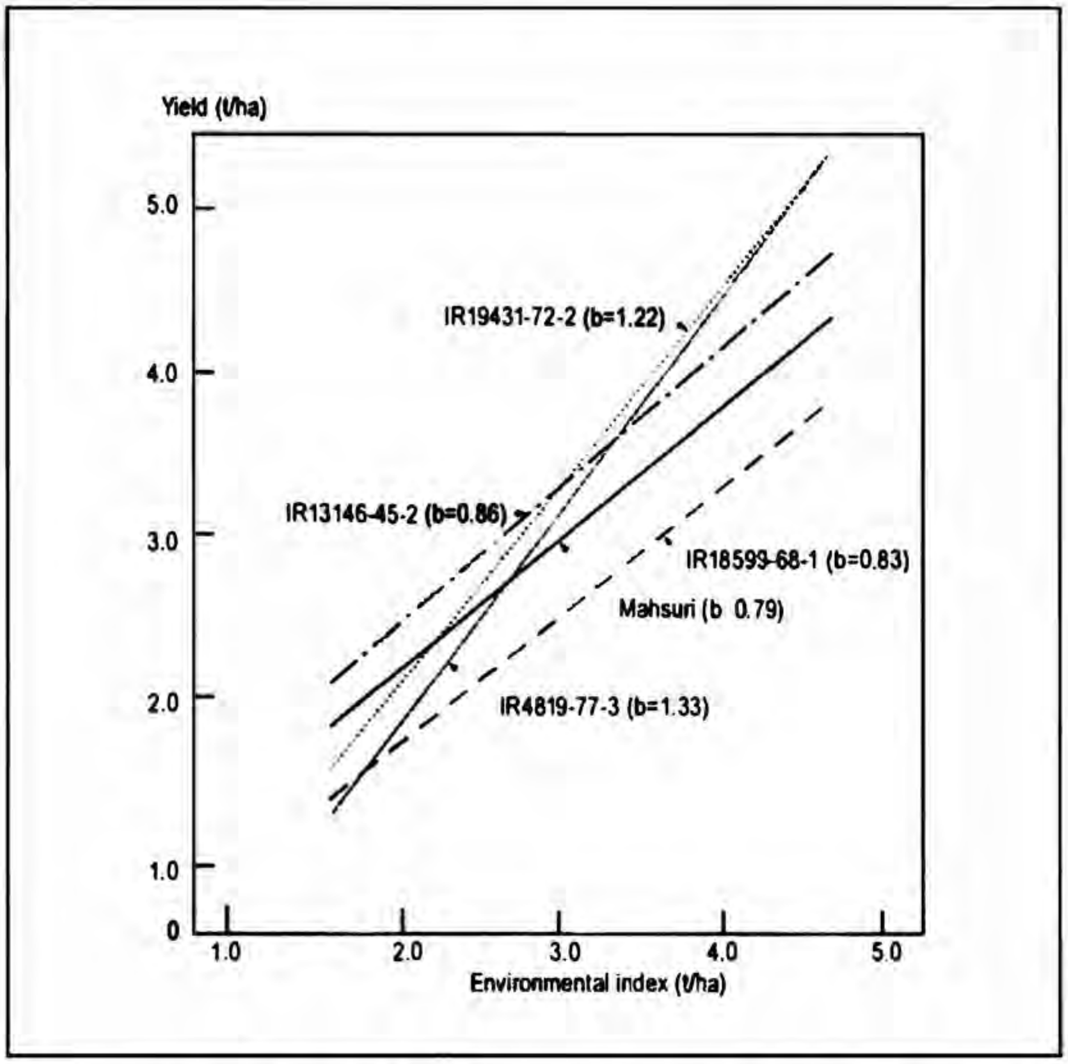

Figure 4. Regression of the yields of five rice lines on mean site yields for 24 varieties included in the 1983 International Rainfed Rice Shallow Water Yield Nursery. Varieties that have lower regression coefficients (b) are considered to be more stable (Seshu 1986).

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