Short Cut in Rice Breeding

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In Japan's rice breeding program, good grain quality, disease resistance and high yield are usually listed as the most important breeding purposes and these essential traits are desired to be achieved as early as possible.

In our rice breeding undertakings, rice cultivation cannot be usually practiced only one time in a year under the natural conditions of temperature and day-length in the temperate zone so the generation of breeding materials cannot be advanced more than two generations.

For breeding methods such as pedigree, derived line and bulk methods which are adopted in our breeding project, it usually takes 10 years or more until a promising variety from crossing is recommended.

There are so many years required to develop a new variety that breeding work is difficult to respond to the social demand which is desired to be achieved as quickly as possible. Therefore, it is absolutely necessary to have a lot of devices to reduce the breeding period.

All of the rice breeding laboratories in Japan have adopted the special rice cultivation system in a greenhouse as an effective procedure for shortening the breeding cycle and have curtailed the number of years for development of a new variety.

The details of the newly devised procedure are introduced by the breeding method adopted at the Chugoku National Agricultural Experiment Station.

Newly devised breeding procedure

This breeding procedure is based on bulk method, in which the special cultivation in a greenhouse is assorted for advancing three generations of breeding materials in a year at comparatively early filial generations. Outline of this procedure is shown in Table 1.

Crossing; After setting up the breeding objectives, parental varieties are selected from among the varieties recommended in various parts of the country, indigenous and foreign varieties. For accumulating some kinds of desirable genes, triple and double cross methods are also used in the breeding program. F_1 seeds are harvested at the end of October.

F_1; After harvesting F_1 seeds, seeds are soon treated for breaking dormancy in an air dryer with 55°C for five days. F_1 plants grow in 1/5000 a pot in a greenhouse. Plants are irradiated at night by electric lamps to promote growth until the 7th- to 8th-leaf stage.

Day-length treatment is suspended in the middle of January and afterwards blooming of F_1 plant is accelerated under natural short-day-length (10 to 11.5 hrs.). In the middle of March, F_2 seeds are harvested.

F_2 to F_4; Three generations of hybrid populations of F_2 to F_4 are controlled in a greenhouse throughout the year. In each generation seeds are sown in a seeding box with the density of 3.0 cm × 2.5 cm. Each cross combination consists of 1,000 plants.

During these generations, control of day-length and temperature in a greenhouse is shown in Fig. 1.

At harvesting time hybrid seeds must be harvested from the respective plants equally in

Table 1. Outline of rice breeding procedure which assorted the cultivation in a greenhouse for hastening the generation of hybrid population

Year and season	Generation	Cultivating condition and some tests
1) Summer	Crossing	G., About 30 combinations
Winter	F_1	G., Pot culture, 15 pots per combination
2) Spring	F_2	G., Box culture, Density 3.0 cm × 2.5 cm 1,000 plants per cross combination Harvested one seed from one plant
Summer	F_3	G., Ditto
Winter	F_4	G., Ditto, Harvested one panicle from one plant
3) Summer	F_5	F., Transplanting, Density 30 cm × 20 cm 1,000 panicles per cross combination, 5 plants per panicle Line and individual selection
4) Summer	F_6	F., Direct seeding Yield trial by micro plot design Test of disease resistance and grain quality Line selection, 10 panicles from line selected
5) Summer	F_7	F., Direct seeding and transplanting Yield trial by large plot Test of disease resistance, lodging and grain quality, Ecological adaptability test Line and individual selection
6) Summer	F_8	F., Direct seeding and transplanting, Yield trial by large plot Test of disease resistance, lodging and grain quality Line and individual selection "Local Number" is assigned
7) Summer	F_9	Forwarded to the respective Pref. Agri. Expt. Stas.

Note: G; Greenhouse, F; Field

quantity as far as possible, and attention must be paid so as not to give a bias to the population. In harvesting the F_5 seeds, one panicle is harvested from each plant.

F_5; At the beginning of May when seeding work is practiced in the ordinary rice cultivation in Japan, F_5 seeds are sown on a nursery bed, by the ear-to-row method, with panicle.

Five plants randomly chosen from one panicle are transplanted as one line with planting density 30 cm×20 cm.

Before breeders handle the selection, heading day of respective lines is marked with the different color paints corresponding with each group of heading date. Breeders, therefore, can select easily a desirable line according to the color paint marked on a plant.

In this F_5 generation, selection is carried out on the basis of line. Three major criteria for line selection are that (1) date of maturity is practical one, (2) plant type is desirable, and (3) segregation of traits in a line is not so much. In the superior lines selected, one plant is selected as a promising individual.

Furthermore, the respective individuals are put to the indoor test on grain quality in order

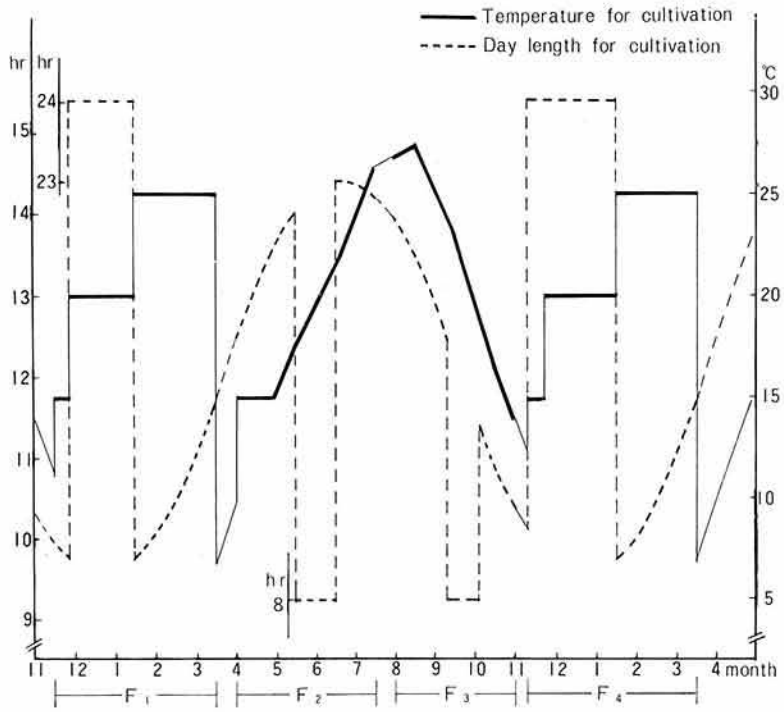

Fig. 1. Temperature and day-length in rice cultivation in a greenhouse

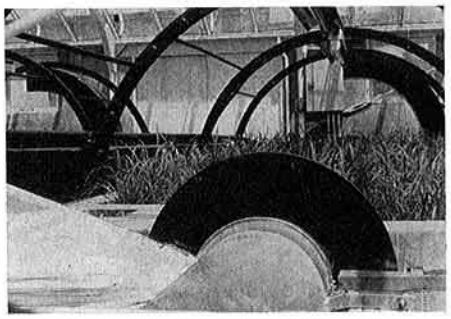

Fig. 2. Automatic apparatus for short day treatment in a greenhouse

to select a superior individual for the succeeding generation.

F_6; Lines selected in F_5 generation are assorted into several groups by maturing date, and are put to the yielding test by means of micro plot design under the direct seeding condition (TORIYAMA and SHINODA, 1965). On the other field where much nitrogenous fertilizer is applied, the respective lines are subjected to the test for blast resistance.

According to yield, grain quality, plant type, blast and lodging resistance, line selection is carried out strictly in this generation. The

respective lines thus selected are listed in the breeder's note as the promising lines. Ten panicles are picked from each line selected and reserved as family seeds consisted of 10 lines for the succeeding generation.

F_7; Four major works carried out in this generation are (1) yield test under the direct seeding condition, (2) ecological adaptability test of the bred lines for the respective regions, (3) test of resistance against blast and leaf blight, and (4) line and individual selection. The last work is practiced by means of the results of the other tests.

F_8; Superior lines are put to the same kind of tests as those in F_7. Of these lines a certain line, which is confirmed to be superior to the check variety in adaptability for a certain region, is assigned a "Local Number".

F_9; The line with a "Local Number" is forwarded in the year following to the respective Prefectural Agricultural Experiment Stations where trial cultivation is carried out for one or two years in "the recommendable variety determining test".

Some incidental problems of the breeding procedure

1) In this breeding procedure there are four times for seed to be sown immediately after harvesting, especially from F_1 to F_5 generation. Therefore, germination trouble appears due to variety of ripening and various degrees of dormancy. This defect may cause skew of gene constitution of hybrid population with advance of generation. For breaking dormancy a few devices practiced are that seeds are kept (1) in moisture with 45°C to 50°C for 3 to 5 days (IWASHITA and SHINYA, 1970), (2) in air dryer with 40°C to 43°C for 10 days (ASAKUMA, 1965) and (3) with 50°C to 55°C for five days (IWASHITA and SHINYA, 1970).

Conversely, breeder can put existence of dormancy to a good use to eliminate viviparous seeds from population. It is very easy for breeder to eliminate viviparous seeds by means of germination test which is done just after harvesting seeds. In this work much attention should be paid not to eliminate favorable genes with elimination of viviparous seeds.

2) During the period when rice plants grow in a greenhouse, plant is cultivated under different conditions on the point of seeding density, temperature and day-length from ordinary rice cultivation.

When rice plants grow under extremely high seeding density or much application of nitrogenous fertilizer in a greenhouse, severe competition is brought about among plants.

Actually, the more nitrogenous fertilizer is applied, the less quantity of seed on dwarf plant is produced in comparison with that on tall plant.

In our laboratory breeders have managed rice growth under a small quantity of fertilizer and harvested the same quantity of seeds from the respective plants to avoid skew of genetic constitution of hybrid population.

3) Regarding the artificial selection handled during the cultivation in a greenhouse, selection of this kind seems to be very effective because breeders are able to manipulate the F_5 population in which the desirable genotypes are included with high frequency.

Actually, breeder has handled the hybrid population against cool weather tolerance, blast disease and leaf blight resistance in a greenhouse.

Besides, it will be necessary to investigate an effect of selection on the metric traits such as culm length, panicle number, physiological traits and yielding ability.

In these selection works, selection for certain gene of plant may cause the elimination of other desirable gene or genes. Many problems concerned with the artificial selection should be solved on the order of traits in selection, selection intensity and genetic correlation between traits.

Future development of the improved breeding procedure

This improved breeding procedure has some merits.

1) Conventional rice breeding methods including pedigree, bulk and derived line methods need generally comparatively long period to develop the new variety. But this improved method can save the time—three years.

2) In the sharply developing agriculture this improved procedure is contributable to develop the new rice variety which is able to respond to economical and morphological desires demanded in agriculture.

3) Since the cultural condition in a greenhouse can be operated easily, breeders are able to select resistant individuals against some major diseases and to identify some qualitative traits.

4) During the cultivation in a greenhouse breeders can handle many hybrid populations and many genotypes in small area and moreover with a small number of labors.

This improved rice breeding procedure has been applied in Japan's rice breeding program because of many merits. Furthermore, regarding the particular trait such as disease resistance, the derived line method, as an effective method, in which rice cultivation in a greenhouse for hastening generation is assorted, can be applied to execute the object.

In Japan the breeding method in which crop cultivation is practiced in a greenhouse for reducing breeding cycle has been applied to barley, wheat and soybean breeding programs other than rice breeding.

Though the improved breeding procedure mentioned above is only one example of improvement of breeding procedure, breeding procedure for all important crops will be better in the future.

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