Present Conditions and Subjects of Rice Breeding For Cold-Tolerance in Japan

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In Japan, the areas where great importance is attached to the cold-tolerance of rice plants are the Tōhoku and Hokkaidō districts. Although there remain some reliable records on the poor harvests of rice caused by cold injury since the seventeenth century in the Tōhoku district,[3] studies and experiments on the breeding of cold-tolerant rice varieties started only in the beginning of this century.

After cold injuries in 1931 and 1934, the Ministry of Agriculture and Forestry established an experiment farm for prevention of cold injury in each prefecture of the Tōhoku district in 1935 and at the same time started fundamental studies on the damage in the Agricultural Experiment Station of the Ministry, the Ōu Experiment Farm and the Tōhoku Wheat Experiment Farm, etc.[4]

Since then, the cold water irrigation method (in the field) has been adopted as a test method of cold-tolerance by many agricultural experiment stations in the Tōhoku and Hokkaidō districts.[2] This method is in use even now in many breeding farms, because it can be easily applied to any place if cold water is available there and is suitable to treat a large number of plants at the same time. The results obtained by this method (the order of varieties in the percentage of sterile grains) coincide comparatively well with those actually observed in the years of cold injury.

The breeding of cold-tolerant rice varieties and the improvement of test methods for the purpose are now taken up as important subjects of study by such experiment stations as the Fujisaka branch of the Aomori Agricultural Experiment Station, Kamikawa Agricultural Experiment Station of Hokkaidō and the Hokkaidō National Agricultural Experiment Station, etc.

Types of cold injuries

Cold injuries result finally in a decrease in yield or deterioration in rice quality, and the effects are variable according to the developmental stages when rice plants were affected by low temperatures, being classified into two main groups, delayed and sterile types.

1) Delayed-type cold injury

This type of cold injury causes delayed growth of rice plants and prevents them from maturity, inducing a decrease in yield or deterioration in quality of rice.

The occurrence of delayed-type cold injury is related to many characters of rice varieties. The main characters are as follows:

(1) Germinating ability at a low temperature.
(2) Growing ability of seedlings at a low temperature.
(3) Rooting ability at a low temperature.
(4) Tillering ability at a low temperature.
(5) Heading ability at a low temperature.
(6) Ripening ability at a low temperature.

Among these characters, (1) and (2) are principally important when rice plants are cultured by direct sowing in flooded condition and (3) and (4) count for much in the condi-

tion of transplanting culture, while (5) and (6) are important in both of these conditions. Among them (5) is now regarded as an essential character in the breeding of cold-resistant rice varieties because it is related to (1)~(4) and also greatly influences the ripening time.

2) Sterile-type cold injury

This type of injury causes imcomplete fertilization and increases the number of sterile grains, resulting in a decreased yield.

Improvement of the heading ability at a low temperature

1) Test method

The greatest delay of heading is generally observed when rice plants are subjected to the influence of a low temperature in the period of 45~30 days before heading. The sensitivity to low temperatures is reduced after the flower primordia differentiation stage, though it is natural that the heading is affected at any time until just before the coming-out of heads if the temperature is below about 10°C. An example of delayed heading caused by cold-water irrigation for 10 days in shown in Table 1.[4)]

Besides the short-dated cold water irrigation method as shown in Table 1, a long-dated treatment is also widely adopted. This method is of use for the judgment of resistance to both the delayed-type and the sterile-type cold injuries, though it needs a proper temperature of cold water, especially for the latter purpose.

In addition, it is necessary for this method that the heading in the control is not later than that of ordinary years, because in years of cold injury heading is delayed also in the control and it is meaningless to make comparison on the basis of the delayed heading in the control. The test method of delayed-type cold injury is thus not yet established. This method should be completed by using

Table 1. Time of cold-water irrigation and delay of heading (in day)

Period of cold-water irrigation	Control	July 11–21	July 21–31	July 31–Aug. 10	Aug. 10–20	Aug. 20–30
Heading date	Aug. 29	Sept. 4	Sept. 5	Sept. 3	Aug. 29	Aug. 28
Days between the beginning of treatment and the heading	—	49	39	29	19	9
Delay of heading (days)	—	6	7	5	0	−1

Notes: From Tanaka's data (1962)[4)], variety: Kyuhei No. 2; Cold water: about 14°C, 3~4.5 cm deep.

Table 2. Relation between the temperature of irrigated water and the heading time in different rice varieties

Variety	Water temp. 2) 23.2°C (Control)	3) 22.1°C	3) 21.4°C	3) 20.7°C	3) 20.6°C	3) 18.9°C	3) 17.3°C
Wasenishiki	Aug. 3	+3	+ 7	+ 7	+ 8	+19	+23
Norin No. 20	Aug. 3	+4	+ 8	+10	+ 9	+21	+27
Mimasari	Aug. 8	+4	+ 8	+ 9	+11	+21	+25
Eiko	Aug. 6	+9	+11	+10	+11	+21	+26
Toyohikari	Aug. 7	+6	+10	+10	+13	+26	+30

Notes: Unpublished data of Shibata;
1) Mean temperatures in the period from June 16 to Aug. 31.
2) Heading time in the control.
3) Delay of heading time (days) in treated lots as compared with the control.

artificial weather equipment.

Some examples of water temperatures and delayed heading in the long-dated cold water irrigation are shown in Table 2.

In this case, the results obtained at the temperatures above 21.4°C coincide comparatively well with the actual delay of heading observed in a year of cold injury. The delays are less than 10 days and nearly agree with yearly changes of heading time in ordinary fields in Hokkaidō. Namely, it is necessary to select a proper range of water temperatures for the examination of delay in heading time from a practical viewpoint.

2) Inheritance

It seems that there is nearly no genetical study on the resistance of rice plants to the delayed-type cold injury. But the fact that most of the varieties which often show delayed heading in Hokkaidō are traced back to the parents having the same tendency suggests the possibility that the tolerance to delayed-type cold injury may be a hereditary character, though this character does not appear to have intimate genetical correlation with other known characters including the resistance to sterile-type cold injury.

At any rate, genetical studies on the tolerance of rice plants to delayed-type cold injury can not be expected to make progress before the test method of the resistance is established.

Breeding of rice varieties resistant to sterile-type cold injury

1) Test method

There are many reports on the developmental stage when rice plants are sensitive to low temperatures to suffer from sterile-type cold injury, showing that the sensitive period extends over a period from the flower primordia differentiation stage to the flowering time.

Judging from the frequency and degree of the injury induced about 10 days centering around the stage of the reduction division of the pollen mother cells are looked upon as the most important time in this period. The cold-resistance test, therefore, is usually conducted at this time. The cold water irrigation method is used for the test for a long time. The artificial-weather method is also in use recently. The result of the former method is influenced by the weather (temperature and light) and is not the same every year, but it is known experientially that if a mean value of the results of experiments in 3 years or so is calculated, it coincides fairly well with actual damage observed in a year of cold injury.

In the case of the artificial-weather method, the environmental conditions can be accurately controlled, so it is possible to obtain a good result by only one trial. Of course, it is necessary in this case to control the temperature and light, etc. also throughout the other developmental stages than the period of cold treatment to avoid the occurrence of sterility caused by bad environmental conditions in these stages.

The cold treatment in the artificial-weather method is usually conducted in such a condition as 14~15°C for 5~7 days or 12°C for

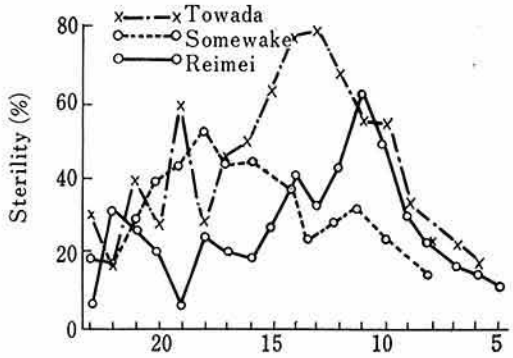

Fig. 1. Difference of rice varieties in sterility (temperature: 15°C, 8 days treatment).[1)]

3 days at present. Such a short-term treatment, however, is often insufficient, because the length of the temperature-sensitive period varies with the variety as shown in Fig. 1.[1)] This point appears to be improved by a longer treatment at a higher temperature, though it

is a problem to be solved in future.

2) Inheritance

The heritability of the character manifesting cold sterility is fairly high (0.6~0.8), and the number of genes concerned in this character is estimated to be more than 7.[5]

There are some reports saying that the cold tolerance is correlated with the awnedness and the color of the tip of hull.

Most of the old varieties tolerant to cold sterility were apt to suffer from lodging and inferior in the quality of hulled rice in Hokkaidō, but good varieties without such defects have been recently developed.

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