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Author(s)	SAWADA, Souhei; TAKAHASHI, Man-emon
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SEED STERILITY AND ANTHOR DEHISCENCE  
IN F<sub>1</sub> PLANTS OF RECIPROCAL  
CROSSES BETWEEN COOL TOLERANT AND  
SUSCEPTIBLE VARIETIES OF RICE

— Genetical studies on rice plant, LXVII —

Souhei SAWADA and Man-emon TAKAHASHI

(Plant Breeding Institute, Faculty of Agriculture,  
Hokkaido University, Sapporo, Japan)

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**Introduction**

Studies on the mode of inheritance of cool tolerance have been made few (SAKAI and SHIMAZAKI 1948, TORIYAMA and FUTSUHARA 1960, 1961, FUTSUHARA and TORIYAMA 1966, 1969). In these researches, it was assumed that the genes were existant only in the nucleus.

On the other hand, the effect of the cytoplasm was clearly present in the some cases of sterility in hybrids of distantly related varieties (KITAMURA 1962).

The purpose of this investigation is to elucidate whether the genetic factors of cool tolerance are existant or not in cytoplasm in the physiological sterility caused by low temperature.

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**Materials and Methods**

Experiment was carried out in 1974 and 1975. F<sub>1</sub> plants of reciprocal crosses between tolerant and susceptible varieties were used (Table 1). Cool treatments were made in a phytotron for three days at the stage when the so-called "auricle distance" between the last two leaves was  $0 \pm 4$  cm.

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Contribution from the Plant Breeding Institute, Faculty of Agriculture, Hokkaido University and the Laboratory of Forage Crops, Obihiro University of Veterinary Medicine, Obihiro, Hokkaido, Japan.

TABLE 1. Reciprocal crosses and their parents used and number of plants observed

1974			
P 1	Hayayuki (H)	19*	17**
P 2	Norin 20 (N 20)	13	12
F <sub>1</sub> (1·2)	H×N 20	23	6
F <sub>1</sub> (2·1)	N 20×H	22	6
1975			
P 1	Hayayuki (H)		12
P 2	Norin 20 (N 20)		28
P 3	Norin 9 (N 9)		14
P 4	Wasenishiki (W)		35
F <sub>1</sub> (1·2)	H×N 20		22
F <sub>1</sub> (2·1)	N 20×H		19
F <sub>1</sub> (1·4)	H×W		30
F <sub>1</sub> (4·1)	W×H		62
F <sub>1</sub> (2·3)	N 20×N 9		42
F <sub>1</sub> (3·2)	N 9×N 20		53

\* for anther dehiscence

\*\* for seed sterility

Hayayuki and Norin 9 are tolerant to cool weather, Norin 20 and Wasenishiki are susceptible to cool weather.

Anther dehiscence were observed at anthesis. An anther is considered to be dehisced, even if one theca opened. All spikelets in 1974 and ten spikelets in 1975 were removed from the panicle of main stem. Each anther was grouped into either a dehiscent or into one of the three indehiscent types. Percentage of sterile spikelets was investigated at maturity. In 1974, those plants which were not investigated for anther dehiscence, and in 1975 those plants which were investigated were used.

The degree of dehiscence is expressed by dehiscence index. Dehiscence index is defined as follows.

$$\text{Dehiscence index} = \frac{1}{3} (3D + 2A + 1B + 0C)$$

where D: percentage of dehiscent anther  
 A: " of indehiscent anther **a**  
 B: " of " **b**  
 C: " of " **c**.

When all anthers dehiscid, dehiscence index is 100 and when all were c type, dehiscence index is 0. Since a spikelet would be fertilized if more than three anthers in it dehiscid (SAWADA 1974), dehiscence index of a panicle in which all spikelets are fertile ranges from 50 to 100 and that of a panicle with 50% fertile spikelets is 25-89 and a panicle which had no fertile spikelet has 0-78 dehiscence index.

Because each of the three types of indehiscent anthers stopped their development at various stages (SAWADA 1976), dehiscence index represents not only the frequency of each type of anthers but also the response of plants to low temperatures during the booting stage. Thus, dehiscence index represents cool tolerance like seed sterility.

### Results

Table 2 shows seed sterility and dehiscence index of F<sub>1</sub> plants of reciprocal crosses and their parents. In every combination, there was hardly

TABLE 2. Seed sterility and dehiscence index of parents and F<sub>1</sub> plants of reciprocal crosses

	Seed sterility (%)	Dehiscence index
1974		
Hayayuki	42	83
Norin 20	91	40
F <sub>1</sub> (H×N 20)	19	91
F <sub>1</sub> (N 20×H)	20	90
Mid-parent	66	62
1975		
Hayayuki	36	88
Norin 20	75	62
Norin 9	72	72
Wasenishiki	82	72
F <sub>1</sub> (H×N 20)	22	89
F <sub>1</sub> (N 20×H)	28	92
Mid-parent	55	74
F <sub>1</sub> (H×W)	21	95
F <sub>1</sub> (W×H)	28	87
Mid-parent	59	79
F <sub>1</sub> (N 20×N 9)	46	83
F <sub>1</sub> (N 9×N 20)	53	81
Mid-parent	73	67

any difference in seed sterility between  $F_1$  plants of reciprocal crosses. For instance, in the cross between Hayayuki and Norin 20 in 1974 the seed sterility of Hayayuki was 42% and that of Norin 20 was 91%. In  $F_1$  plants that derived its cytoplasm from Hayayuki, seed sterility was 19% and that derived from Norin 20 was 20%. There were considerable differences between the parents but little difference between  $F_1$  plants of reciprocal crossings. The results in 1975 were also the same, that is, the seed sterility of Hayayuki and Norin 20 were 36% and 75% respectively and difference between these was 61%. While the difference between  $F_1$  plants of reciprocal crosses was only 6%.

The same tendency was found in dehiscence index. Namely, the dehiscence index of  $F_1$  plants between Hayayuki (♀) and Norin 20 was 91 in 1974, and that of  $F_1$  of the reciprocal cross, Norin 20 (♀) × Hayayuki, was 90. In the combination, in 1975, there was negligible difference in dehiscence index between  $F_1$  plants of reciprocal crosses.

The results also indicated that heterosis was found in cool tolerance. Each of the  $F_1$  plants was higher than its parents in seed sterility and indehiscence index. When the value of mid-parent was 100, that of  $F_1$  plants ranged from 173 to 238 in seed sterility and from 110 to 147 in dehiscence index. This is due to the vigor of  $F_1$  plants.

### Discussion

SAKAI (1943) pointed out that one of the important abnormalities in sterility of destructive type cool weather damage was hypertrophy of tapetal tissue. Then, SAKAI and SHIMAZAKI (1948) found that two recessive genes were concerned with the occurrence of hypertrophy of tapetum under cool weather conditions, therefore cool tolerance is controlled at least by two pairs of genes which were partially dominant.

TORIYAMA and FUTSUHARA made a series of genetic studies on cool tolerance during 1960–1969 and obtained the following results. Heritability for cool tolerance was comparatively high even in the early generations. The heritability in the narrow sense was 0.639 in  $F_2$  plants and 0.835 in  $F_3$  lines, so that early selection for cool tolerance is effective. Cool tolerance was determined by seven effective genes (TORIYAMA and FUTSUHARA 1960). Besides, they indicated that cool tolerance was associated with well-known six major genes which belong to four linkage groups and estimated that the number of pairs of genes controlling cool tolerance is four or more (FUTSUHARA and TORIYAMA 1966).

These were the main results which were obtained with respect to the inheritance of cool tolerance until now. Every research has been made assuming that the genes are existant only in the nucleus. No mention has thus far been made as to the relationship between genetic factors and cytoplasm. The results obtained from this investigation showed that there was little difference between F<sub>1</sub> plants to reciprocal crosses in both seed sterility and dehiscence index, although there were large differences between their parents. It is suggested from this that the genetic factors of cool tolerance are non-existant or not detected in cytoplasm of the varieties employed in the present investigation.

The results of this examination also indicated that F<sub>1</sub> plants showed considerable heterosis in cool tolerance. It was reported in wheat and barley that heterosis in winter hardness was evident (WIENHUES 1954). It may be expected that in these physiological characters, the vigor of F<sub>1</sub> hybrids promote the metabolic activity which was weakened by low temperatures. However, heterosis did not occur in hypertrophy of tapetum due to low temperatures (SAKAI and SHIMAZAKI 1948) and in sterile index (TORIYAMA and FUTSUHARA 1960). This difference seems to depend on materials and testing methods. Further investigation is necessary in this respect.

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### Summary

An investigation was carried out to clarify whether genetic factors controlling cool tolerance are existant or not in cytoplasm. F<sub>1</sub> hybrids of three reciprocal crosses between tolerant and susceptible varieties were compared in seed sterility and dehiscence index of anther under low temperatures. The result obtained from this investigation indicated that the genetic factors of cool tolerance are non-existant in cytoplasm. The result also indicated that F<sub>1</sub> plants showed heterosis in cool tolerance.

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