SEED STERILITY AND ANTHER DEHISCENCE IN F_1 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)

Received Oct. 7, 1976

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.

The authors wish to express their gratitude to Dr. T. KINOSHITA for his critical reading of the manuscript. The authors are also grateful to Dr. K. MORIMURA for kindly supplying F_1 hybrid seeds of reciprocal crosses. Thanks are also due to the Hokkaido Tokachi Pref. Agri. Exp. Station for making a phytotron available for this experiment.

Materials and Methods

Experiment was carried out in 1974 and 1975. F_1 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 ± 4 cm.

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_1 (1·2)	H×N 20	23	6
F_1 (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_1 (1·2)	H×N 20	22	
F_1 (2·1)	N 20×H	19	
F_1 (1·4)	H×W	30	
F_1 (4·1)	W×H	62	
F_1 (2·3)	N 20×N 9	42	
F_1 (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 dehisced, 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 dehisced (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_1 plants of reciprocal crosses and their parents. In every combination, there was hardly

TABLE 2. Seed sterility and dehiscence index of parents and F_1 plants of reciprocal crosses

	Seed sterility (%)	Dehiscence index
1974		
Hayayuki	42	83
Norin 20	91	40
F_1 (H×N 20)	19	91
F_1 (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_1 (H×N 20)	22	89
F_1 (N 20×H)	28	92
Mid-parent	55	74
F_1 (H×W)	21	95
F_1 (W×H)	28	87
Mid-parent	59	79
F_1 (N 20×N 9)	46	83
F_1 (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_1 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_1 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_1 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.

A part of this research was supported by scientific fund from the Ministry of Education.

Summary

An investigation was carried out to clarify whether genetic factors controlling cool tolerance are existant or not in cytoplasm. F_1 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_1 plants showed heterosis in cool tolerance.

Literature cited

FUTSUHARA, Y. and K. TORIYAMA 1966. Genetic studies on cool tolerance in rice. III. Linkage relations between genes controlling cool tolerance and marker genes of NAGAO and TAKAHASHI. Japan J. Breed. 16: 231-242.

FUTSUHARA, Y. and K. TORIYAMA 1969. Genetic studies on cool tolerance in rice. IV. Direct and indirect effects of selection for cool tolerance. Japan J. Breed. 19: 286-292.

SAKAI, K. 1943. Zytologisch-histologische Untersuchungen über die Sterilitätserscheinungen bei Reispflanzen Nordnippons im Jare 1941. Hokkaido Agric. Exp. Stn. Report 40: 1-17. (In Japanese with German résumé)

SAKAI, K. and Y. SHIMAZAKI 1948. Genetical studies on abnormal hypertrophy of tapetal cells in *Oryza sativa* L. (A Preliminary note). Kanchinogaku 2 (1): 93-95. (In Japanese)

SAWADA, S. 1976. Frequency of indehiscent anthers and sterility, induced by low temperatures at the booting stage in rice plants. Res. Bull. Obihiro Univ. 9. (In press)

KITAMURA, E. 1962. Studies on cytoplasmic sterility of hybrids in distantly related varieties of rice, *Oryza sativa* L. I. Fertility of the F_1 hybrids between strains derived from a certain Philippines × Japanese variety crosses and Japan varieties. Japan J. Breed. 12: 81-84. (In Japanese with English summary)

TORIYAMA, K. and Y. FUTSUHARA 1960. Genetic studies on cool tolerance in rice. I. Inheritance of cool tolerance. Japan J. Breed. 10: 143-152. (In Japanese with English summary)

TORIYAMA, K. and Y. FUTSUHARA 1961. Genetic studies on cool tolerance and the other characters. Japan J. Breed. 11: 191-198. (In Japanese with English summary)

WIENHUES, F. 1954. Fortschritte in der Züchtung auf Winterhärte bei Weizen und Gerste. Z. Pflanzenz. 33: 437-458.