J. Fac. Agr. Hokkaido Univ., Vol. 64, Pt. 1: 1~9 (1989)

SEGREGATION OF HEADING TRAIT IN F_2 OF THE CROSS BETWEEN NORIN 20 AND SILEWAH, INDONESIAN NATIVE CULTIVAR, OF RICE

Masahiko MAEKAWA and Fumiji KITA

Agricultural Experiment Farm, Faculty of Agriculture,
Hokkaido University, Sapporo 060

Received November 18, 1988

Introduction

In order to breed highly tolerant rice varieties to cool injury at the booting stage in Hokkaido, genetic resources of rice introduced from foreign countries have been screened for cool injury tolerance, and a few highly tolerant rice varieties to cool injury such as Silewah and Leng Kwang from foreign countries have been revealed hitherto[4]. For using these foreign rice varieties in a breeding program in Hokkaido, it was required to elucidate the inheritances for the limiting factors such as hybrid sterility, late heading trait or grain quality. Although Silewah from Indonesia was found to be highly tolerant to cool injury at the booting stage, it was not easy to use Silewah as genetic resource for high tolerance to cool injury because of its late heading trait.

The objectives of this study was to reveal the heading property of Silewah based on segregation of heading trait in F_2 of the cross between Silewah and Norin 20.

Materials and Methods

Rice varieties used in this experiment were Silewah from the highlands in Indonesia[1] and Norin 20 from Hokkaido.

〈Experiment 1〉 *Comparison of segregation of heading trait in F_2s derived from F_1 plants grown in different seasons.*

F_1 plant of the cross between Norin 20 and Silewah was grown in the greenhouse in summer, 1986, and after harvesting F_1 plant was ratooned and harvested again in winter, 1986. Parents, F_1 plants and F_2 plants were sown on 26 April, 1987 and were transplanted in paired-row units with 36 cm between units, 18 cm between rows and 18 cm between plants in the paddy field of Agricultural Experiment Farm, Faculty of Agriculture, Hokkaido University on 1 June, 1987. The field was broadcast fertilized with 5 kg/10 a N, 5 kg/10 a P and 5 kg/10 a K prior to transplanting. The heading date of main culm of each plants was recorded.

⟨Experiment 2⟩ *Segregation of heading trait in F_2 of the cross, Norin 20/Silewah and in B_1F_1 of Norin 20/Silewah//Norin 20 in the controlled environment.*

Parents, F_1 plants, F_2 plants and B_1F_1 plants backcrossed F_1 plants with Norin 20 were individually and directly sown in 200 cc plastic pots with 7 cm diameter in a controlled greenhouse (natural light room under 24°C (day)-19°C (night) (12 hours treatment)) of the phytotron of Hokkaido National Agricultural Experiment Station on 5 May, 1986. The plastic pots were fertilized with 45 kg/10 a N, 45 kg/10 a P and 45 kg/10 a K prior to sowing. These materials were grown in an artificial light room controlled under 26°C (day)-20°C (night) with light on for 12 hours and off 12 hours of the phytotron from 8 May till the finishing of fertilization. All plants were exposed to cool treatment of 12°C for 4 days at the stage of −7 cm to −4 cm auricle distance. All tillers were cut off and the heading date of main culm of each plants was recorded.

Results

Seed fertility of F_1 plants of the cross, Norin 20/Silewah, grown in different seasons in 1986 was shown in Table 1. Since Silewah was found to possess high tolerance to cool injury at the booting stage, F_1 plants grown in winter showed slightly lower seed fertility than F_1 plant grown in summer. F_1 plant which produced No. 4 F_2 population reduced seed fertility to a greater extent than the other F_1 plants grown in winter. F_2 segregations of heading time of the cross, Norin 20/Silewah were presented in Table 2, showing the heading time of parents and F_1 plants. Silewah showed a wider range of heading time than Norin 20 and the heading time of F_1 plants was closely similar to that (114.9) of the mid-parent between parents. Although the frequency distributions of days from sowing to heading in all F_2 populations were continuous, no F_2 plants showing the heading time of Norin 20 type were observed in all F_2 populations. Because of this phenomena, mean heading time of each F_2 populations was later

TABLE 1. Seed fertility of F_1 plants of the cross, Norin 20/Silewah

F_2 population No.	Growing season of F_1 in 1986	Seed fertility (%)
1	Summer	91.3
2	Winter	89.7
3	Winter	87.5
4	Winter	79.4
5	Winter	90.3

TABLE 2. Segregations of days from sowing to heading in F_2 of the cross, Norin 20/Silewah in the paddy field in 1987

Line or population	Days from sowing to heading												Total	Mean±SD
	85–90	90–95	95–100	100–105	105–110	110–115	115–120	120–125	125–130	130–135	135–140	140–145		
Norin 20	7	8	1										16	91.6±2.5
Silewah									1	2	5	5	13	138.2±4.3
Norin 20/Silewah F_1						5	10						15	116.3±1.0
F_2 population														
No. 1				1	22	62	77	84	39	17	5	2	309	120.2±7.0
No. 2					10	23	27	15	7	3			85	117.9±6.4
No. 3					7	9	20	18	5	1			60	118.6±5.9
No. 4					2	19	19	31	24	9	2		106	119.9±7.4
No. 5					5	23	24	17	7	6	1		83	119.3±6.5

Note. Population 1 derived from F_1 plants grown in summer 1986.
Populations 2, 3, 4, 5 derived from F_1 plants grown in winter 1986.

TABLE 3. Chi-square values for F_2 segregation patterns of days from sowing to heading between F_2 populations of the cross, Norin 20/Silewah

F_2 population	Chi-square value			
	2	3	4	5
1	10.129	6.918	12.418	5.166
2		5.146	24.987**	3.945
3			19.416**	8.270
4				13.996*

*, **; Significant at 5% and 1% levels, respectively.

TABLE 4. Significance tests for mean days from sowing to heading among F_2 populations of the cross, Norin 20/Silewah

F_2 population	*t*-value			
	2	3	4	5
1	2.762**	1.704	0.314	1.075
2		0.653	2.056*	1.420
3			1.256	0.687
4				0.651

*, **; Significant at 5% and 1% levels, respectively.

than that of F_1 plants. To determine whether any differences of frequency distributions of heading time between F_2 populations in the growing season of F_1 plants, chi-square test was conducted between F_2 populations. As shown in Table

TABLE 5. Segregations of days from sowing to heading in F_2 of the cross, Norin 20/Silewah and B_1F_1 of the cross, (Norin 20/Silewah) F_1/Norin 20 in the artificial light room in 1986

Line or population	Days from sowing to heading											Total	Mean±SD
	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100		
Norin 20	11	10										21	49.6±1.0
Silewah									4	12	5	21	92.2±3.0
Norin 20/Silewah F_1					12	14						26	70.0±1.8
F_2		2	28	46	68	34	7	2	1			188	65.6±5.7
(Norin 20/Silewah) F_1/Norin 20 B_1F_1		17	76	60	15	3	1					172	59.5±4.2

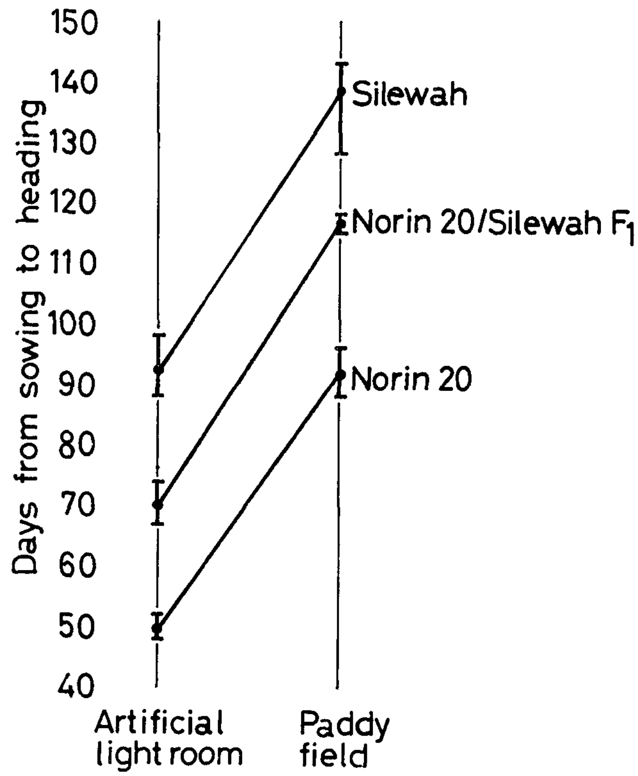

Fig. 1. Days from sowing to heading of Norin 20, Silewah and Norin 20/Silewah F_1 plants in artificial light room (1986) and paddy field (1987).

3, significant differences between No. 4 and No. 2, No. 3 or No. 5 F_2 populations were observed. Though no significance between No. 4 and No. 1 F_2 population was detected, chi-square value obtained between No. 1 and No. 4 suggested that frequency distribution of heading time of No. 4 population was slightly different from that of No. 1 population. This result obtained was caused by an increase in late-heading plants of No. 4 population. However, no significant differences of mean days from sowing to heading between F_2 populations were observed except between No. 1 and No. 2, and between No. 2 and No. 4, as given in Table 4. Namely, slightly early-heading plants increased in No. 2 population.

Segregation of heading trait in F_2 population of the cross, Norin 20/Silewah, and B_1F_1 population backcrossed F_1 plant with Norin 20 were examined in an artificial light room of the phytotron, as shown in Table 5. Although the range of heading time in parents, F_1 plants and F_2 population observed in the controlled environment was smaller than that in a natural environment, Silewah showed a wider range of heading time than Norin 20. A similar tendency was also found in a natural environment. F_1 plants showed the same heading time as the mid-parent between parents and the frequency distribution of days from sowing to heading in F_2 population was continuous. In opposition to F_2 populations in a natural environment, early-heading plants increased considerably in the controlled environment and mean days from sowing to heading in F_2 population was earlier than that of F_1 plants. In B_1F_1 population, early-heading plants increased more largely than those in F_2 population and mean days from sowing to heading in B_1F_1 population was earlier than that in F_2 population.

The heading time of parents and F_1 plants grown in controlled and natural environments was compared, as shown in Fig. 1. It was found that parents and F_1 plants in a natural environment showed about 40 days later heading time than those in the controlled environment. This result indicated that Silewah possess long basic vegetative growth and it was suggested that the segregation of the heading trait in F_2 population was attributable to the segregation of vegetative growth. Further, it was observed that minimum days to heading of Norin 20 in natural and controlled environments were 88 and 47 days, respectively, and maximum days to heading of Silewah in natural and controlled environments were 143 and 98 days, respectively. Thus, the differences between minimum days to heading of Norin 20 and maximum days to heading of Silewah in natural and controlled environments were 56 and 52, respectively. In order to compare the segregations of heading time in F_2 population grown in controlled and natural environments, days from sowing to heading of individual F_2 plants was transformed to the percentage of the difference between days to heading of individual F_2 plant and minimum days to heading of Norin 20 to the difference between minimum days to heading of Norin 20 and maximum days to heading of Silewah. In Table 6, No. 1 F_2 population derived from F_1 plant grown in summer was used as F_2 population in a natural environment because of the large population

TABLE 6. Comparison of heading trait of Norin 20, Silewah, Norin 20/Silewah F_1 and F_2 in different environments

Line or population	Envir.	Percentage										Total
		0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
Norin 20	PF	10	6									16
	AL	21										21
Silewah	PF								1	4	8	13
	AL								1	11	9	21
Norin 20/Silewah F_1	PF					5	10					15
	AL				1	16	9					26
F_2	PF				14	71	77	96	28	17	6	309
	AL		10	50	62	45	15	4	2			188

Note. PF; Paddy field. AL; Artificial light room.
Percentage = (days to heading of individual F_2 plants-minimum days to heading of Norin 20)/(maximum days to heading of Silewah-minimum days to heading of Norin 20) × 100.

size, and presumed normal fertilization and maturity in F_1 plant grown in summer. As shown in Table 6, the difference of frequency distribution of days from sowing to heading between natural and controlled environments was observed clearly. Namely, in a natural environment almost no early-heading type plants were observed. On the other hand, early-heading type plants increased largely in the controlled environment.

Discussion

Silewah from Indonesia was found to be the most important rice variety as the gene source for cool injury tolerance in Hokkaido, because Silewah is Japonica type and the hybrids between Silewah and Japanese rice varieties did not showed any sterility[1,3,4]. However, Silewah showed a very late-heading, and this trait makes it difficult to utilize Silewah for the improvement of cool injury tolerance in Hokkaido rice varieties. Until now, no workers have reported the heading trait of Silewah. The characteristics of the heading trait of Silewah was studied in F_2 populations of the cross between Norin 20 and Silewah. Since Silewah and Norin 20 possessed the highest[4] and medium or slightly weak tolerance to cool injury, respectively, it might be possible that the different growing seasons of F_1 plants caused change of frequency distribution of heading trait in F_2 populations, as ZAMIR *et al.*[8] pointed out. When compared segregations of heading trait in F_2 populations derived from the same F_1 plant grown in summer and winter by chi-square test, No. 4 population from F_1 plant grown in winter showed different frequency distribution of heading trait from the other populations.

On the other hand, by significance test for mean days to heading between F_2 populations, No. 2 population significantly indicated slightly earlier mean days to heading than No. 1 and No. 4 populations. F_1 plant which produced No. 4 F_2 population showed the lowest seed fertility in all F_1 plants. As this F_1 plant was grown in winter, the lowest seed fertility was caused by cool injury damage of pollen grains of F_1 plant, and the lowest seed fertility of F_1 plant might be correlated with the different frequency distribution of heading trait in No. 4 F_2 population. However, the different frequency distribution of heading trait in No. 4 F_2 population was considered to be caused by environmental factors rather than by pollen sellection that ZAMIR *et al.*[8] demonstrated, because a clear difference of frequency distribution of heading trait between No. 4 and the other F_2 populations was not observed and non-significance of mean days to heading between No. 4 and No. 1 populations derived from F_1 plant grown in summer populations was obtained. From these results, it was concluded that F_2 segregation of heading trait was not influenced by different growing seasons of F_1 plants. In 1987, the panicle of Silewah in a natural environment was emerged with 138 days to heading. These days to heading was very similar to those of EG2, EG3 and EG5 (YAMAGATA *et al.*[7]). Form Yamagatas' experiments[7] it was presumed that Silewah possessed relatively long basic vegetative growth and weak photoperiod sensitivity. This characteristic was also supported from the result obtained based on comparison of heading traits of Norin 20, Silewah and F_1 plants between controlled (12 hours day length) and natural environments, though these experiments were not accurate. Namely, the relationships for heading traits among Silewah, Norin 20 and F_1 plants observed in the controlled environment (12 hours day length) were obtained similarly in a natural environment. F_1 plants of the cross, Norin 20/Silewah showed heading time of the mid-parent between Norin 20 and Silewah in the controlled and natural environments and F_2 segregations for heading trait were expressed as normal distribution curves in both environments. These results suggested that F_2 segregation for heading trait of the cross, Norin 20/Silewah was caused by polygenes for basic vegetative growth with an additive effect. However, from the comparison run on F_2 segregations for heading trait between controlled and natural environments, a great difference of distribution frequency of heading trait between two environments was found. In a natural environment no F_2 plants did showed days to heading of Norin 20 type. On the other hand, few F_2 plants showed a late heading type of Silewah in the controlled environment. It was not clear whether this difference of frequency distribution was caused by environmental factors or interaction of genetic factors and environmental factors. Since at least, however, parents and F_1 plants showed parallel consistency for heading trait in both environments, environmental factors alone were not considered to be responsible for the difference. As TSAI[6], SATO and OGATA[5] and ARAKI[2] pointed out, the genic system for the heading trait is highly complexed and it was possible that masked gene(s) acted with other heading trait gene(s) in F_2 populations of variable cross combinations. Thus, masked recessive gene(s) for photoperiod sensitivity which Silewah carried might act on the early heading trait gene of Norin 20 in F_2 in a natural environment. In order to reveal the causes for the difference, it will be necessary to examine F_2 segregations for heading trait of the crosses between other rice varieties and Silewah are examined in a natural environment.

Summary

The objectives of this study was to elucidate the characteristics of heading trait of Silewah from Indonesia, based on F_2 segregation of the heading trait of the cross between Silewah and Norin 20. Segregations of the heading trait in F_2 populations derived from F_1 plants grown in summer and winter 1986 were compared in a natural environment in 1987. F_1 plants showed a medium heading time between parents. Generally, F_2 segregations of heading trait were expressed as normal distribution curves, increasing in slightly late-heading types. It was found by chi-square test that No. 4 F_2 population derived from F_1 plant grown in winter which showed the lowest seed fertility, indicated different frequency distributions of the heading trait from those in the other populations. On the other hand, significant differences of mean days to heading between No. 2 and No. 1 or No. 4 populations were obtained by significance test. F_2 segregation of the heading trait in the controlled environment (artificial light room with 26°C (day)-20°C (night) and 12 hours day length) was also expressed as normal distribution curve. Contrary to F_2 segregation in No. 1 population from F_1 plant grown in summer in a natural environment, early-heading type plants increased slightly in F_2 population in the controlled environment. When heading traits of parents and F_1 plants between controlled and natural environments were compared, parallel consistency of the relation for heading trait among parents and F_1 plants was recognized between the two environments. This result suggested that Silewah possessed long basic vegetative growth and F_2 segregation was due to polygenes for basic vegetative growth.

Acknowledgement

This work was supported in part by Grant-in-Aid for Cooperative Research (No. 61304015) from the Ministry of Education, Science and Culture, Japan.

The authors wish to express their gratitude to Drs. T. SATAKE, K. KARIYA, S. KOIKE and Mrs. C. HOSHI, Hokkaido National Agricultural Experiment Station, for many suggestions and encouragement.

Literature Cited

1. ABE, N., KOTAKA, S., TORIYAMA, K. and KOBAYASHI, M.: Breeding of rice Norin PL-8, a new germplasm with high tolerance to sterile-type cool injury. *Jpn. J. Breed.* **37** (Suppl. 2): 228–229. 1987 (in Japanese)
2. ARAKI, H.: A genetic analysis of heading time of "Shen" rice varieties. *Jpn. J. Breed.* **38** (Suppl. 1): 276–277. 1988 (in Japanese)
3. MATSUMOTO, S., TORIYAMA, K. and SAITO, S.: Evaluation of the Indonesian cultivar, Silewah, as a new genetic source for cold tolerance in rice. *Jpn. J. Breed.* **31** (Suppl. 2): 6–7. 1981 (in Japanese)
4. SATAKE, T. and TORIYAMA, K.: Two extremely cool-tolerant varieties. *IRRN.* **4** (2): 9–10. 1979
5. SATO, S. and OGATA, K.: Genetical studies on heading time in isogenic line of a rice cultivar, Taichung 65 carrying two kinds of earliness genes derived from Kokushokuto-2. *Jpn. J. Breed.* **38** (Suppl. 1): 278–279. 1988 (in Japanese)
6. TSAI, K. H.: Gene loci and alleles controlling the duration of basic vegetative growth of rice. *In* Rice genetics. Proc. Intl. Rice Genet. Symp. pp. 339–349. 1986
7. YAMAGATA, H., OKUMOTO, Y. and TANISAKA, T.: Analysis of genes controlling heading time in Japanese rice. *In* Rice genetics. Proc. Intl. Rice Genet. Symp. pp. 351–359. 1986
8. ZAMIR, D., TANKSLEY, S. D. and JONES, R. A.: Haploid selection for low temperature tolerance of tomato pollen. *Genet.* **101**: 129–137. 1982