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PHENOTYPIC STABILITY FOR REPRODUCTIVE STAGE COLD TOLERANCE IN RICE

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ABSTRACT

Stability parameters in respect of fertility representing reproductive stage cold tolerance were studied using 21 parents and their 90 F_1 hybrids at three cold stressed locations. Pooled analysis of variance revealed high genotype–environment interaction for fertility with importance of both the linear as well as nonlinear components. Twenty seven genotypes had significantly greater fertility than the population mean. Three indica and 5 japonica females, and six indica x indica hybrids constituted the top ranking group. Forty nine genotypes had $b_i<1$ and 45 $b_i>1$. $S^{-2}d$ was greater than 0 for 66 genotypes. Indica parent K39-96, japonica parent Suweon 235, and 5 indica x indica hybrids (Suweon 287 x IR-15889, K39-96 x IR-7167, Shoa-Nan-Tsan x IR-7167, Suweon 287 x IR-9202 and Shoa- Nan-Tsan x IR-9202) had high fertility, were most stable, and could be considered as ideal genotypes for cultivation under cold environments.

Key words: Rice, reproductive stage cold tolerance, stability.

The rice yields are subject to considerable environmental fluctuations, especially under cold stress. Tolerance to cold injury at the reproductive stage, measured by seed sterility, is an indispensable trait for varieties to be grown in low-temperature areas. A variety possessing reasonable yield stability in low-temperature environments is as important as the one with high yield potential. Reports of genotype–environment interactions under low-temperature conditions in rice are not available. In the present investigation, data on fertility of 74 F_1 and 20 parents grown in three different cold environments have been analysed to identify genotypes that would give superior performance over a range of environments.

MATERIALS AND METHODS

Six high yielding indica elite IRRI lines were crossed as pollinators to eight japonica and

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seven indica rice cultivars and elite lines, having low-temperature tolerance at different growth stages. The 15 female parents were Suweon 235, SR 3044-78-3, SR 5204-91-4-1, Barkat, K 332, Shimokita, Stejaree 45 and K84 among japonica, and Suweon 287, Samgangbyeo, China 988, K 39-96-3-1-1-1-2, Leng Kwang, Shoa-Nan-Tsan and Silewah among indica types. The six male parents crossed with each of the females were IR 8866-30-3-1-4, IR 8455-K2, IR 15889-32-1, IR 7167-33-2-3, IR 29506-60-3-3-2, and IR 9202-10-2-1-5-1. The 21 parents and their 90 F_1 hybrids were transplanted in single row plots, 15 hills/row, replicated thrice, in randomized block design at 3 locations.

At Chuncheon, Korea (38°N, 74 m altitude), the genotypes were raised in the cold tolerance screening nursery of the Crop Experiment Station and were subjected to a continuous cold water stress at 20°C, starting from 20th day after transplantation until maturity, maintaining the water depth of 5 cm. At Khawazakhela, Upper Swat, Pakistan (35°N, 1250 m altitude), and Banaue, Ifugo mountain province, Philippines (17°N, 1200 m altitude), the experiment was conducted under natural field conditions with the hills spaced at 25 cm x 20 cm. At Swat, the inlet water temperature varied from 14.9°C to 19.6°C during the growing season. Because of cool night temperatures throughout the growing season, these locations appeared well suited for evaluating cool weather damage of rice plants.

Data were recorded on five random plants/plot in each replications at each of the three locations for fertility. Since some genotypes did not flower/mature at these locations, data on only 74 hybrids (38 japonica x indica and 36 indica x indica) and 20 parents (15 females and 5 males) were utilized for stability analysis [1].

RESULTS AND DISCUSSION

Pooled analysis of variance (Table 1) showed that the mean differences between genotypes and the environments were highly significant ($P<0.01$). The genotype–environment interactions, including environmental linear effects, were significant, indicating differences between environments and their considerable influence on fertility. Both linear and nonlinear components of genotype–environment interactions were statistically significant when tested against pooled error. Significant pooled deviations for fertility indicated that the genotypes differed considerably in their stability for this character. However, when tested against significant pooled deviations (nonlinear component), the linear component was found to be nonsignificant.

Twenty seven genotypes had significantly greater fertility than the population mean ($\overline{X} = 50.0 \pm 9.2\%$) which included 3 indica females, 1 indica tester, 8 japonica females, and 15 indica x indica hybrids. Only two japonica x indica hybrids, viz., Stejaree 45 x IR 9202 and Shimokita x IR 9202 were, more fertile (although statistically nonsignificant) than the population mean. Of the twenty-seven genotypes, 3 indica females: K39-96 (88.1%), China 988 (81.1%), and Shoa-Nan-Tsan (75.2%); 5 japonica females: Shimokita (84.1%), Stejaree 45

(82.0%), SR 3044-78-3 (79.3%), Suweon 235 (78.9%), and SR 5204-91-4-1 (75.4%); and 6 indica x indica hybrids: Suweon 287 x IR 7167 (84.7%), Samgangbyeo x IR 7167 (80.2%), Suweon 287 x IR 15889 (80.1%), K 39-96 x IR 8455 (79.3%), Samgangbyeo x IR 845 (79.2%), and Suweon 287 x IR 8455 (77.0%) constituted the top ranking group of fertility. While K39-96, China, 988, Shoa-Nan-Tsan, and SR 5204-91-4-1 have been reported to be high general combiners for reproductive stage cold tolerance earlier [2, 3], Stejaree 45 and SR 3044-78-3 appeared to suffer minimum damage due to low temperature treatment at flowering. The linear sensitivity coefficients (bi) ranged from -2.50^{**} to 2.14^{*}. Forty nine genotypes recorded bi<1 and 45 had bi>1. Only linear component was significant for five genotypes, which indicated that variation in regression coefficient accounted for all the interactions. The measure of stability, the deviation around the regression line ($\bar{S}^2d$), was significantly greater than 0 for 66 genotypes, pointing to the difficulty in prediction across environments. Further, the absence of genotype–environment interactions was indicated by the nonsignificant linear and nonlinear components for 23 genotypes.

Table 1. Pooled analysis of variance for fertility in 94 genotypes of rice

Source	d.f.	M.S.	V. R. (pooled error M.S.)	V. R. (pooled deviations M.S.)	V. R. (G x E M.S.)
Genotypes (G)	93	1486.4	37.3^{**}	8.8^{**}	9.9^{**}
Environments (E)	2	9517.4	239.1^{**}	56.6^{**}	63.1^{**}
G x E	186	150.7	3.8^{**}	0.9	3.8
E (L)	1	19032.6	478.2^{**}	113.1^{**}	
G x E (L)	93	131.3	3.3^{**}	0.8	
Pooled deviations	94	168.2	4.2^{**}		
Pooled error	558	39.8			

**Significant at 1% level.

The study of genotype–environment interactions not only helps in planning the breeding programmes but also enables identification of highly responsive and high yielding genotypes suitable for cultivation under the targeted production conditions, where the genetic potential of the genotype could be fully exploited. Eberhart and Russell [1] emphasized the need for considering both the linear (bi) and nonlinear ($\bar{S}^2d$) components of genotype–environment interactions in judging the phenotypic stability of a genotype. Breese [2] and Samuel et al. [3], however, advocated that the linear regressions could simply be regarded as a measure of response of a genotype, whereas the deviations around the regression line ($\bar{S}^2d$) were considered as a measure of stability; genotypes with the lowest standard deviations being the most stable and vice versa.

Grain fertility and the two parameters of stability (bi and $\bar{S}^2d$) for 29 selected genotypes grown at three locations are presented in Table 2. The location mean for fertility varied from 61.6% in Swat (Pakistan) to 44.0% in Chuncheon (Korea), indicating that the genotypes were more cold stressed in Korea. The genotypes appear to be under equal cold stress in Banaue (Philippines) with the mean fertility of 44.4%.

Table 2. Fertility (%) and parameters of stability of 29 selected genotypes of rice grown at three cold stress locations

Genotype	Type	Fertility (%) at				bi	$\bar{S}^2d$
		Chuncheon	Banaue	Swat	mean		
Male parents:							
IR 15889-32-1	I	62.8	64.1	66.1	64.3	0.15	–12.5
IR 9202-10-2-1-5-1	I	49.2	65.9	59.8	58.3	0.15	125.9**
Female parents:							
K 39-96	I	85.2	87.4	91.9	88.1	0.32	–11.1
Leng Kwang	I	73.3	70.9	47.3	63.8	–1.42	–11.4
Silewah	I	69.1	62.7	22.5	51.4	–2.50**	2.4
Suweon 235	J	72.0	77.4	87.5	78.9	0.74	–0.4
SR 3044-78-3	J	71.3	80.4	86.3	79.3	0.61	26.5
SR 5204-91-4-1	J	61.0	71.1	94.0	75.4	1.61	32.3*
F_1 Hybrids:							
Silewah x IR 8866	I x I	7.2	9.1	42.4	19.6	1.97*	–12.6
China 988 x IR 8455	I x I	71.2	62.6	78.7	70.8	0.67	26.3*
Silewah x IR 8455	I x I	14.6	19.6	41.6	25.2	1.41	–3.2
Suweon 287 x IR 15889	I x I	74.0	78.4	87.9	80.1	0.67	–5.0
K 39-96 x IR 15889	I x I	66.5	57.4	74.2	66.0	0.70	30.9*
Leng Kwang x IR 15889	I x I	30.5	33.8	69.4	44.6	2.14*	–10.2
Silewah x IR 15889	I x I	28.1	29.6	54.1	37.3	1.45	–12.8
K 39-96 x IR 7167	I x I	72.6	76.5	64.1	71.1	–0.60	–4.7
Shoa-Nan-Tsan x IR 7167	I x I	73.0	70.8	74.7	72.8	0.16	–10.8
Suweon 287 x IR 9202	I x I	70.3	69.1	80.3	73.2	0.61	–12.2
Samgangbyeo x IR 9202	I x I	66.9	58.3	77.0	67.4	0.82	25.5*
China 988 x IR 9202	I x I	64.9	59.0	76.8	66.9	0.85	5.8
K 39-96 x IR 9202	I x I	55.0	62.6	79.1	65.6	1.17	13.1
Shoa-Nan-Tsan x IR 9202	I x I	66.1	71.6	68.2	68.6	–0.03	1.9
SR 5204 x IR 8455	J x I	17.8	10.7	42.1	23.5	1.59	16.2
Barkat x IR 8455	J x I	21.6	24.9	22.3	22.9	–0.05	7.8
K 332 x IR 15889	J x I	23.9	25.6	40.7	30.0	0.92	–12.3
SR 5204 x IR 29506	J x I	29.8	21.1	59.1	36.7	1.92*	30.1*
Shimokita x IR 9202	J x I	54.4	44.0	58.7	52.3	0.53	42.7*
Stejaree 45 x IR 9202	J x I	47.4	44.3	66.3	52.7	1.17	–7.3
K 84 x IR 9202	J x I	40.3	44.1	55.1	46.5	0.75	–6.9
Mean ± SE		44.0 ±7.1	44.4 ±3.2	61.6 ±4.3	50.0 ±9.2		

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

I—indica; J—japonica.

A simultaneous consideration of three parameters ($\bar{X}$, bi, $\bar{S}^2d$) for individual genotypes showed that the indica parent K39-96, japonica parent Suweon 235, and the indica x indica hybrids Suweon 287 x IR 15889, K 39-96 x IR 7167, Shoa-Nan-Tsan x IR 7167, Suweon 287 x IR 9202 and Shoa-Nan-Tsan x IR 9202 had higher fertility and were most stable, and therefore could be considered as ideal genotypes. Kaw et al. [4] have identified Suweon 287 x IR 15889 and Suweon 287 x IR 9202 as the superior crosses with regard to cold tolerance based on fertility and fertile spikelets/panicle, respectively, from field tests conducted at three locations. Most of the japonica parents and two indica parents, viz., China 988 and Shoa-Nan- Tsan, which had high fertility showed less stability. Similar observations have been reported in sunflower [5].

No japonica x indica hybrid had significantly higher fertility, and with average stability they were poorly adapted to all the environments. Only the hybrids Stejaree 45 x IR 9202 and Shimokita x IR 9202 had fertility at par with the overall mean. However, only the former hybrid could be classified as a stable genotype across environments. The hybrid Stejaree 45x IR 9202 was indicated to possess high vegetative and reproductive stage cold tolerance earlier [6], and this hybrid could be expected to give desirable segregates particularly suited to cold environments where japonica types are desired.

In plant breeding programmes, it is usually desired to identify promising genotypes for high, medium and low yielding environments. In this investigation, the genotypes SR 5204-91-4-1, K 39-96 x IR 9202 and Stejaree 45 x IR 9202 could be utilized for cultivation under high yielding and cold environments. They have relatively higher mean fertility with the regression values more than one (stability below average) and deviations from regression 0 or near-0. The genotypes Suweon 287 x IR 15889, SR 3044-78-3, Suweon 235, Suweon 287 x IR 9202, China 988 x IR 8455-K2, Samgangbyeo x IR 9202, and China 988 x IR 9202 appeared suitable for medium yielding and cold environemnts, as these genotypes have higher fertility with the regression coefficient approaching unity (average stability) and deviations from regression approac hing 0. The cultures suitable for low yielding and cold environments could be K 39-96, Shoa-Nan-Tsan x IR 7167, K 39-96 x IR 7167, Shoa-Nan-Tsan x IR 9202, and IR 15889-32-1. They have high to moderately high fertility, the regression coefficients close to 0 (above average stability) and deviation from regression also almost equalling 0.

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