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Study on genetics of some important phonological traits in rice using line × tester analysis

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ABSTRACT

A study was conducted on genetics of some important phonological traits (heading date, plant height and panicle length) in rice. Five lines were crossed with 2 testers in line × tester fashion to produce 10 F_1 hybrids. Results showed that GCA effect was only significant for heading date and SCA effect was significant for heading date and plant height. Four parents including three lines (Neda-A/IR36, IR36 and Pouya) and one tester (Usen) showed highest negative GCA for heading date and were identified as better general combiners for early maturation. Lines Pouya and IR42 showed highest negative GCA for plant height, indicating that these lines were good general combiners for reducing plant height. Line Neda-A/IR36 showed highest significant GCA for panicle length, indicating that this line was a good general combiner for panicle length. Combinations Usen/IR42 and IR68897/IR42 showed significant SCA in opposite directions for plant height (10.7 and -10.7 cm, respectively), indicating that hybridization can be a choice for improving hybrids with shorter height. Highest general heritability (h^2_b) was obtained for heading date (97.5%), indicating slight effects of environment on the trait. Highest specific heritability (h^2_n) was obtained for heading date (73.3%), indicating that additive effects control the trait. In contrast, minimum h^2_n was obtained for plant height and panicle length, indicating that non-additive effects play important roll in genetic control of these traits. Therefore, it seems that improving the lines with early maturation will be promising via selection in segregating populations, while hybridization must be preferred for plant height and panicle length.

Key words: Rice, Line × tester, combining ability, Heritability.

INTRODUCTION

Rice as a staple food crop plays an important role in food security and economics of Asia. Improving the productivity of rice systems would contribute to hunger eradication, poverty alleviation and economic development [10]. The most important characters in rice breeding may include reduced plant height, strong culms; moderate tillering, short and erect leaves, large and compact panicles, and earliness [11, 14, 16, 17, 25]. Line × tester technique [8] is useful in deciding the relative ability of female and male lines to produce desirable hybrid combinations. It also provides information on genetic components and enables the breeders to choose appropriate breeding methods for hybrid variety or cultivar development programs.

Roh et al. [18] reported that non-additive gene effects preponderated in the genetic control of plant height. In contrast, Kaushik and Sharma [7] reported preponderance of additive gene effects in control of plant height and panicle length. Honarnejad [6] reported preponderance of additive gene effects in the control of plant height and preponderance of non-additive gene effects in the control of heading date and panicle length. Ahmadikhah [1] estimated general heritability of 78.4% and 70.2% for plant height and panicle length, respectively. He also estimated specific heritability of 30.8% and <1% for these traits, respectively. Wu et al. [26] reported a high general heritability for heading date and panicle fertility. Sardana and Borthankur [21] reported the important roll of both GCA and SCA for heading date, plant height and panicle length. Mishra and Verma [15] evaluated 16 rice genotypes along with 72 F_1 hybrids and noted high heritability with high genetic advance for flag leaf area and plant height, indicating dominant role of additive gene action. Swati and Ramesh [23] reported high heritability for grain yield while moderate heritability for flag leaf area and plant height. Saleem et al. [20] noted high broad sense heritability and expected genetic advance in response to selection in next generation for all the studied traits. Bisne et al. [2] obtained 98.7% general heritability for plant height and 89.4% for panicle length.

Marilia et al. [13] stated that specific combining ability (SCA) effects of hybrids alone had limited power for parental selection in breeding programmes, and must be used in combination with other parameters such as hybrid means and GCA of the respective parents. The hybrid combinations with high mean performance, desirable SCA estimates and involving at least one of the parents with high GCA would likely to enhance the concentration of favorable alleles [5, 9, 12, 24].

Our objectives in this research were to study the important genetic parameters and to estimate the GCA and SCA for some important phonological traits in rice using line × tester analysis.

MATERIAL AND METHODS

Five lines along with 2 testers were grown and crossed with each other in a line × tester design to produce 10 hybrids in 2009. Lines and testers were Pouya (L1), IR42 (L2), IR36 (L3), IR8 (L4), Neda-A/IR36 (L5), Usen (T1) and IR68897 (T2). Hybrids along with parents were grown next year in a randomized complete block design with three replications. Fourteen plants established in each plot with 25 cm × 25 cm spacing.

Three phonological characters [viz. heading date (days after germination), plant height (cm) and panicle length (cm)] were recorded at desirable times. Genotype means were used for the analysis of variance as described by Singh and Chaudhary, [22]. Line × tester analysis was conducted out as described for by Kempthorne [8]. Combining ability analysis was also performed according to Singh and Chaudhary [22]. Mid-parent based heterosis (MP) and better-parent based heterosis (BP) were determined as outlined by Falconar and Mackey [3]. General combing ability (GCA) and specific combing ability (SCA) values were estimated as described for by Kempthorne [8]. Some important genetic parameters such as additive variance, non-additive variance, degree of dominance (d), broad-sense heritability (h^2_b) and narrow-sense heritability (h^2_n) were also estimated according to Falconar and Mackey [3].

RESULTS AND DISCUSSION

Analysis of variance (ANOVA)

Results of ANOVA are shown in Table 1. As seen, genotype effect, parent's effect, parents vs. crosses effect and crosses effect was highly significant at 1% level for all the studied traits, indicating that there were adequate genetic variation for line × tester study. Significant mean square for parents vs. crosses indicated that crosses differed from the parents significantly; therefore, it is inferred that variations were transmitted to progeny [19]. Lines effect was significant only for heading date and line × tester effect was significant for heading date and plant height, indicating the possibility of making subsequent analyses.

Table 1. Analysis of variance (ANOVA) for line × tester experiment

		Mean square		
SOV	d.f	Heading date	Plant height	Panicle length
Replication	2	0.14	1.78	0.104
Genotype	16	235.56**	454.84**	61.54**
Parents	6	364.43**	768.21**	147.56**
Parents vs. crosses	1	463.25**	446.12**	28.50**
Crosses	9	124.36**	246.90**	7.86**
Lines	4	261.13**	322.20	12.47
Testers	1	43.20	26.13	0.012
Lines x Testers	4	7.87**	226.80**	5.21
Error	32	1.951	36.348	2.153
Mean		94.2	107.1	28.5
C.V(%)		1.4	22.6	5.0

** and ** indicate significance at 5% and 1% level of probability, respectively.*

Mean comparisons

Mean performance is shown in Table 2. Among parents, both testers were most early-maturating genotypes (87.7 and 88.7 days after germination, respectively), while line L4 (IR8) was most late-maturating parent (~122 days after germination). In the case of plant height, line L3 (IR36) had the shortest height and tester T1 (Usen) had the tallest height. In the case of panicle length, line L3 showed the shortest panicle (~23 cm) and lines L4 and L5 produced the longest panicles (~31 cm).

Among hybrids, combinations L4T2 and L2T2 showed highest heading date (~101 days) and combinations L5T1, L3T1 and L5T2 were most early-maturating hybrids (84, 85 and ~86 days, respectively) which their parents were amongst early-maturating ones. In plant height, combination L5T2 and combination L2T2 showed tallest and shortest height, respectively (~121 cm and 90 cm, respectively). In panicle length, L2T2 and L5T2 showed shortest and longest panicle, respectively (~26 cm and ~32 cm, respectively).

Heterosis performance

Heterosis values of hybrids were estimated based on mid-parent (MP) and better parent (BP) performance, which are shown in Table 3. In heading date, highest significant negative MP-based heterosis was estimated for L5T2 and L5T1 (-11 and -10.5 days, respectively), and highest significant negative BP-based heterosis was estimated for L5T1 and L3T1 (-4.7 and -3.7 days, respectively). In plant height, highest significant negative MP-based heterosis was estimated for L2T2 and L1T1 (-11.2 and -9.7 cm, respectively), and highest significant negative BP-based heterosis was estimated for the same L2T2 (-9.7 cm). In panicle length, highest significant positive MP-based heterosis was estimated for L3T2 and L2T1 (4.3 and 2.8 cm, respectively), and highest significant positive BP-based heterosis was estimated for L3T2 (5.7 cm).

Table 2. Mean performance of lines, testers and their hybrids

	Heading date (day)	Plant height (cm)	Panicle length (cm)
L1	94.3^{de}	106.3^{bcde}	29.4^{abc}
L2	108.0^{b}	100.0^{ef}	24.9^{ef}
L3	90.3^{fg}	97.3^{ef}	23.3^{f}
L4	122.3^{a}	103.7^{cde}	30.7^{ab}
L5	92.3^{ef}	101.7^{de}	30.7^{ab}
T1	88.7^{ghi}	112.3^{abcd}	29.3^{abc}
T2	87.7^{hij}	107.7^{bcde}	27.4^{cde}
L1T1	91.0^{fg}	99.7^{ef}	28.1^{bcd}
L1T2	90.0^{fgh}	103.0^{cde}	27.9^{bcd}
L2T1	96.0^{d}	113.7^{abc}	29.3^{abc}
L2T2	100.7^{c}	90.3^{f}	26.1^{de}
L3T1	85.0^{kl}	108.7^{bcde}	28.0^{bcd}
L3T2	87.3^{ijk}	115.3^{ab}	29.1^{bc}
L4T1	96.7^{d}	112.7^{abcd}	28.1^{bcd}
L4T2	101.0^{c}	112.0^{abcd}	29.1^{bc}
L5T1	84.0^{l}	116.0^{ab}	30.7^{ab}
L5T2	85.7^{jkl}	120.7^{a}	31.9^{a}
S.E	0.806	3.481	0.841

Note: means with common letters have not significant differences.

Table 3. Values of mid-parent (MP) and better parent (BP) heterosis

	Heading date (day)		Plant height (cm)		Panicle length (cm)	
	MP	BP	MP	BP	MP	BP
L1T1	-0.5	2.3*	**-9.67***	-6.67	-1.2	-1.27
L1T2	-1.0	2.3*	-4.0	-3.33	-0.52	-1.53
L2T1	**-3.5****	7.3**	13.83**	13.67**	**2.83****	0.07
L2T2	1.7*	13.0**	**-11.17****	**-9.67***	-0.23	-1.23
L3T1	**-8.2****	**-3.7****	3.17	11.33**	1.67	-1.27
L3T2	**-8.2****	-0.3	21.5**	18.00**	**4.33****	**5.73****
L4T1	**-7.0****	8.0**	6.5	0.33	-1.27	-2.60**
L4T2	**-3.8****	13.3**	2.5	4.33	-0.80	-1.60
L5T1	**-10.5****	**-4.7****	8.83*	3.67	1.33	0.0
L5T2	**-11.0****	-2.0	13.83**	13.00**	2.03*	1.20
S.E	0.806		3.481		0.847	

** and ** indicate significance at 5% and 1% level of probability, respectively.*

GCA and SCA values

Analysis of combining ability effects is shown in Table 4. GCA effect was only significant for heading date and SCA effect was significant for heading date and plant height, while none of GCA and SCA were significant for panicle length. One reason for this observation may be the involvement of epistatic effects in the genetic control of panicle length [4]. These results indicate that both additive and non-additive effects were important for heading date, and only non-additive effects were important for plant height. Ratio of $\delta^2_{gca}/\ \delta^2_{sca}$ shows that additive effects are preponderant in the control of heading date, while non-additive effects are preponderant in the control of plant height.

Table 4. Analysis of combining ability effects

S.O.V	Mean square		
	Heading date (day)	Plant height (cm)	Panicle length (cm)
GCA	5.376**	0.928	0.122
SCA	1.972*	63.484**	1.017
Error	0.650	12.116	0.718
$\delta^2_{gca}/\delta^2_{sca}$	2.726	0.015	-

** and ** indicate significance at 5% and 1% level of probability, respectively.*

GCA of parents is shown in Table 5. As seen, in heading date three lines L5, L3 and L1 and a tester T1 had highest significant negative GCA (-6.9, -5.6, -1.2 and -1.2 days, respectively); that is, these four parents are better general combiners for heading date and the use of them in breeding programs causes early maturation. In contrast, lines L4 and L2 and tester T2 had significant positive GCA; that is, the use of these parents in breeding programs causes late maturation. Lines L1 and L2 showed highest significant negative GCA for plant height (-7.9 and -7.2 cm), while line L5 showed highest significant GCA for plant height (9.1 cm). These results indicate that two lines L1 and L2 are good general combiners for plant height and the use of these parents in breeding programs causes shortening in plant height. In the case of panicle length, only line L5 showed highest significant GCA (2.5), indicating that this line is a good general combiner for panicle length.

Table 5. Estimated GCA values of parents in the study

Parents	Heading date (day)	Plant height (cm)	Panicle length (cm)
Lines			
L1	**-1.23***	**-7.87****	-0.83
L2	6.60**	**-7.20****	-1.1
L3	**-5.57****	2.80	-0.3
L4	7.10**	3.13	-0.27
L5	**-6.90****	9.13**	**2.5****
S.E(gi)	0.570	2.461	0.599
Testers			
T1	**-1.2***	0.93	0.02
T2	1.2*	-0.93	-0.02
S.E(gi)	0.361	1.557	0.379

** and ** indicate significance at 5% and 1% level of probability, respectively.*

SCA values of hybrids are shown in Table 6. As seen, in the case of heading date, only the combinations of L1T1 and L1T2 showed significant SCA at 5% level in opposite directions (values as small as 1.7 and -1.7 days, respectively), indicating that hybridization is of little preference in improving heading date. In the case of plant height, combinations L2T1 and L2T2 showed significant SCA at 1% level in opposite directions (10.7 and -10.7 cm, respectively). The SCA values of these hybrids are enough large, so that hybridization can be a choice for improving hybrids with shorter height. In the case of panicle length were not observed any significant SCA .

Table 6. Estimated SCA values for different hybrid combinations

Combination	Heading date (day)	Plant height (cm)	Panicle length (cm)
L1T1	1.70*	-2.60	0.113
L1T2	**-1.70***	2.60	-0.11
L2T1	-1.13	10.73**	1.58
L2T2	1.13	**-10.73****	-1.58
L3T1	-0.03	-4.27	-0.55
L3T2	0.03	4.27	0.553
L4T1	-0.97	-0.60	-0.52
L4T2	0.97	0.60	0.52
L5T1	0.37	-3.27	-0.62
L5T2	-0.37	3.27	0.62
S.E(sca)	0.806	3.481	0.847

* and ** indicate significance at 5% and 1% level of probability, respectively.

Important genetic parameters

Important genetic parameters are shown in Table 7. Additive variance was significant only for heading date (1.75), while non-additive variance was significant only for plant height, again confirming the results of Table 4. Degree of dominance for heading date was estimated <1, while for plant height and panicle height was estimated ~8.3 and ~2.9, respectively; that is, partial dominance for heading date and over-dominance for plant height and panicle length. These results obviously reveal the preponderance of additive effects in controlling heading date and preponderance of non-additive effects in controlling plant height and panicle length. Highest general heritability (h^2_b) was obtained for heading date (97.5%), indicating slight effects of environment on the trait. Highest specific heritability (h^2_n) was obtained for heading date (73.3%), indicating that additive effects control the trait. In contrast, minimum h^2_n was obtained for plant height and panicle length, indicating that non-additive effects play important roll in inheritance of these traits. Therefore, it seems that improving the lines with early maturation will be promising via selection in segregating populations, while hybridization must be preferred for plant height and panicle length.

Table 7. Some important genetic parameters estimated in the study

Parameter	Heading date (day)	Plant height (cm)	Panicle length (cm)
δ^2_A	10.753**	1.856	0.245
$S.E_{(\delta^2 A)}$	0.361	1.557	0.379
δ^2_D	1.931*	63.484**	1.017
$S.E_{(\delta^2 D)}$	0.806	3.481	0.847
δ^2_P	79.82	175.85	21.95
δ^2_G	77.87	139.50	19.79
δ^2_E	1.951	36.348	2.153
d	0.606	8.27	2.88
h^2_b	97.56	79.33	90.19
h^2_n	73.27	1.82	7.17

** and ** indicate significance at 5% and 1% level of probability, respectively.*

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