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Genetic Dissection of Some Important Agronomic Traits in Rice Using Line × Tester Method

Zeinab Montazeri[1*], Nadali Babaeian Jelodar[2], Nadali Bagheri[3]

[1] *MSc student, Sari Agricultural Science and Natural Resources University, Sari, Iran*

[2,3] *Professor and Associate Professor, Sari Agricultural Science and Natural Resources University, Sari, Iran.*

Abstract

A study was conducted on genetics of some important agronomic traits (number of productive tillers per hill, plant height (cm), panicle length (cm), number of spikelets per panicle and 100-grain weight) in rice during 2012-13. Two lines were crossed with five testers in line × tester fashion to produce 10 F_1 hybrids. Analysis of variance revealed significant differences among genotypes and crosses. Variances of SCA were higher than the GCA variances for number of productive tillers per hill, panicle length (cm) and 100-grain weight (gr) which indicated predominance of non-additive gene action in the inheritance of these traits. P_{35} tester produced the lowest height among testers, highest number of productive tillers and number of spikelets per panicle among parents and its hybrids produced highest number of productive tillers, highest panicle length (cm), highest number of spikelets per panicle (Tarom-Jelodar × P_{35}) and lowest height (Danesh × P_{35}) among hybrids. Also this variety was found to be good general combiner for height (cm) and panicle length (cm). Crosses namely Tarom-Jelodar × Sange-Tarom, Danesh × Jahesh and Danesh × P_{35} had useful and significant heterosis for all traits. These crosses were identified as promising genotypes for increasing of rice yield in future improvement programs. Thus hybrid varieties have positive potential for rice breeding.

Key words: Rice, Line × Tester, Combining Ability, Heterosis, Yield.

1. Introduction

Rice is the most important food crop, providing the staple food for nearly half of the global population, especially in Asia, Africa, and Latin America (FAO, 2004). It is necessary for securing of world needed rice in 2030 to increase production rate of rice 60 % more than its rate in 1995. In this way breeding programs are effective and essential for improving of present varieties and increasing of yield (Nematzade and Valizade, 2002). Reduced plant height, oderate tillering, large and compact panicles, increased kernel number per panicle, increased thousand kernel weight and higher yield are the most important rice characters to be improved in breeding programs (Mackill and Lei, 1997; Paterson et al., 2005; Wayne & Dilday, 2003). Success of any plant breeding programme depends on the choice of appropriate genotypes as parents in the hybridization programme. Selection is an important technique in plant breeding and breeders uses this method for improving the architecture of a crop by management of available genetic variability (Eidi Kohnaki et al. 2013). Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability. Combining ability analysis is

Corresponding Author E-mail: zeinabmontazeri7@yahoo.com

one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis. Line × tester technique (Kempthorne et al. 1957) 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 (Mirarab and Ahmadikhah 2010). Farshadfar et al (2013) estimated combining ability effects for agro-morphological characters of rapeseed (Brassica napus L.) using line×tester mating design. Among the 7 female lines, RGS003 revealed maximum GCA effects for seed yield, thousand kernel weight, seed per pod and number of branches. Among the testers, Option500 was desirable as it manifested higher estimates of GCA effects for seed yield and thousand kernel weight. Also they reported three cross-combiners Magent × Opera, Elect × Option500 and Shiralee × Opera were found to be the best specific crosses for seed yield. Presence of heterosis and SCA effects for some important agronomic traits in rice are reported by Roy & Mandal (2001). Singh & Kumar (2004) also identified suitable parents through line x tester analysis in rice. Roh et al. (1989) reported that non-additive gene effects preponderated in the genetic control of plant height. In contrast, Kaushik and Sharma (1988) reported preponderance of additive gene effects in control of plant height and panicle length. Sardana and Borthankur (1987) reported the important role of both GCA and SCA for heading date, plant height and panicle length. Marilia et al. (2001) 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 (Gnanasekaran et al. 2006; Kenga et al. 2004; Manivannan et al. 2001; Thirumeni et al. 2000). In the present study 2 lines × 5 testers mating design along with 7 rice genotypes and 10 F_1s were used to determine the heterosis, combining ability as well as the gene action on some important agronomic traits.

2. Materials and Methods

2.1 Plant materials

The experimental materials consist of seven rice genotypes, two genotypes (Tarom-Jelodar and Danesh) were used as females (designated as lines) and five genotypes (Sange-Tarom, Jahesh, Moosa-Tarom, Basmati 370 and P_{35}[1]) designated as testers were used as males. These parents were crossed to produce 10 F_1 hybrids according to line × tester mating design (Kempthorne, 1957). This study was conducted in 2012-2013 years at Research Field of Sari Agricultural Sciences and Natural Resources University. Single seedlings of each entry were transplanted at 20 × 20 cm spacing in 3 × 5 m^2 plots in a RCBD (randomized complete block design) with three replications. In this study five traits includes productive tiller number per hill, plant height (cm), panicle length (cm), number of spikelets per panicle and 100-grain weight were evaluated based on standard evaluation rice system (Scshu, 1988).

2.2 Statistical analysis

Data were recorded on nine randomly selected plants from parents and F_1s plant samples. Heterosis was estimated from mean values according to Fehr (1987) and t-test was performed. Combining ability analysis was done using line x tester method (Kempthorne, 1957). The variances for general combining ability and specific combining ability were tested against their respective error variances derived from ANOVA reduced to mean level. Significance test for GCA and SCA effects were performed using t-test. Midparent heterosis

1- P_{35}: Mutant of Tarom-Mahalli

(Ht) and high-parent heterosis (Htb) or heterobeltiosis were determined as outlined by Falconar and Mackay (1996). Also significance test for heterosis values were performed using t-test (Wynne et al., 1970).

3. Results and discussion

3.1 Means of the estimated traits

Mean of lines, testers and their hybrids (Table 1) indicated worth of genetic variability for the improvement of number of productive tillers per hill, plant height (cm), panicle length (cm), number of spikelets per panicle and 100-grain weight (gr) traits, which are important in hybrid rice yield. Mean of traits classified using Duncan's multiple range test (p = 0.05). P_{35} variety produced the lowest height among testers, highest number of productive tillers and number of spikelets per panicle among parents and its hybrids produced highest number of productive tillers, highest panicle length (cm), highest number of spikelets per panicle (Tarom-Jelodar × P_{35}), and lowest height (Danesh × P_{35}) among hybrids. Danesh line and its hybrid (Danesh × Jahesh) produced lowest height and highest 100-grain weight (gr), respectively. Also the longest panicle length among parents was given by Moosa-Tarom that was similar to the results reported by Bagheri and Babaeian (2010). Significant differences among various traits have been observed earlier reports (Surek and Korkut, 2002; Swati and Ramesh, 2004). The results showed that different genetic systems involved in controlling traits, which emphasized on important of study of these traits. More productive tillers/plant, increased panicle length and 100-grain weight are desirable traits of these hybrids helping for increasing rice yield.

3.2 Analysis of variance (ANOVA)

Results of ANOVA (Table 2) showed that there was high significant difference among genotypes, crosses, parents vs. crosses and testers for all the studied traits indicating that there was adequate genetic variation among parental varieties and crosses for line × tester study. Analysis of crosses effect to its components (lines, testers and parents vs. crosses) indicated there was highly significant difference at 1% level among testers for all traits and among lines for panicle length (cm) and 100-grain weight (gr). The significant differences among the lines, testers and lines x testers indicated that the genotypes had wide genetic diversity among themselves for all traits. The significance of the means of sum of squares due to lines and testers indicated a prevalence of additive variance. However, significant differences due to interactions of line x tester for some of the characters, suggesting the importance of both additive and non-additive variance for these traits (Bagheri and Babaeian 2010). Thus both additive and non-additive gene actions should be studied for improving related-yield traits. Variances of SCA were higher than the GCA variances for tiller number, panicle length (cm) and 100-grain weight (gr) which showed preponderance of non-additive gene action in the inheritance of the traits. This was further supported by low magnitude of MSgca/MSsca ratios for these traits (Table 2). It suggested greater importance of non-additive gene action in its expression and present very good prospect for the exploitation of non-additive genetic variation for traits through hybrid breeding (Ramalingam, 1997; Annadurai and Nadarajan, 2001). Lines effect wasn't significant for productive tiller number, plant height (cm) and number of spikelets per panicle. Therefore it can inferred that variation among testers was more than lines for these traits. Also lines vs. testers effect was highly significant for all traits except panicle length (cm) and number of spikelets per panicle exhibiting different response of lines in combining with different testers associated with ability of traits transfer. The proportional contribution of lines, testers and their interactions to total variances showed that testers played an important role toward for traits, indicating predominant testers influence for these traits (Table 3). The smaller contribution of interactions of the line x tester than testers, indicating higher estimates of variances due to general combining ability. Rissi et al. (1991) observed higher estimates of GCA variances due to testers in rice. Contribution of interactions of line x tester was higher than lines for productive tiller number, plant height (cm) and number of spikelets per panicle, exhibiting higher estimates of GCA variances for interaction. For example productive tiller number in Tarom-jelodar × Basmati 370 cross was 19.11 but in Danesh × Basmati 370 cross was 28.67.

3.3 Combining ability analysis

3.3.1 General combining ability

The results of GCA of parents is shown in Table 4. For plant height negative GCA was desirable. As seen P_{35} tester had lowest significant negative GCA. Hence this parent is better general combiners for height and the use of it in breeding programs causes dwarf and resistance to lodging. Also for number of spikelets per panicle positive GCA was desirable that was given by P_{35}. Therefore this pollinator was found to be good general combiner for these two traits. In panicle length (cm) Moosa-tarom tester had highest significant positive GCA.

3.3.2 Specific combining ability

None of the lines or pollinators was found to be good specific combiner for all the characters studied (Table 5). Only for number of productive tillers per hill, Danesh × Basmati 370 had significant positive SCA. Therefore this hybrid was is better specific combiners for this trait.

3.4 *Evaluation of heterosis*

Heterosis values of hybrids were estimated based on mid-parent (MP) and better parent (BP) performance, which are shown in Table 6. The degree of heterosis varied from cross to cross and from character to character. The data on estimates of heterosis (Ht) and heterobeltiosis (Htb) revealed that midparent heterosis for number of productive tillers per hill ranged 24.62 to 107.41 percent and that of high-parent heterosis was 19.44 to 95.43 percent (Table 6). Six hybrids present significantly positive heterosis as well as heterobeltiosis. Out of these six hybrids viz. Tarom-jelodar × Sange-tarom (Ht = 107.41, Htb = 85.43), Tarom-jelodar × P_{35} (Ht = 95.92, Htb = 93.94), Danesh × Sange-tarom (Ht = 99.63, Htb = 86.32), Danesh × Jahesh (Ht = 59.03, Htb = 54.23), Danesh × Basmati 370 (Ht = 96.23, Htb = 95.43) and Danesh × P_{35} (Ht = 46.82, Htb = 38.82) were important based on high significant heterosis of both types. Over-dominant type of gene action was suggested for them. Three hybrids (Tarom-jelodar × Jahesh, Tarom-jelodar × Moosa-tarom and Danesh × Moosa-tarom) showed significant and positive mid-parent heterosis but non-significant positive heterobeltiosis manifesting partial dominant type of gene action, while Tarom-jelodar × Basmati 370 indicated non-significant heterosis and heterobeltiosis displaying additive type of gene action. These results are in agreement with earlier findings (Vanaja and Babu, 2004; Verma et al., 2002). Negative heterosis for plant height is desirable for breeding short statured hybrids and varieties. None of the hybrids manifested significantly negative mid-parent and high-parent heterosis for plant height. The extent of heterosis over mid-parent was 2.63 to 23.48 percent and that of better parent was 0.98 to 21.61 percent. Danesh × P_{35} had the lowest degree of heterosis for height (Ht = 2.63) but it was non-significant. For panicle length (cm), all hybrids except Tarom-jelodar × Jahesh were important based on highly significant heterosis of both types (Ht = 7.5 to 16.08, Htb = 5.59 to 13.40). Over-dominant type of gene action was suggested for them. Tarom-Jelodar × Jahesh showed significant and positive mid-parent heterosis but non-significant heterobeltiosis manifesting partial dominant type of gene action. For spikelets per panicle only Danesh × Moosa-tarom (Ht = 22.97, Htr = 18.51) had significantly positive heterosis and heterobeltiosis manifesting over dominance type of gene action. Also three hybrids (Tarom-jelodar × Sange-tarom, Danesh × Jahesh and Danesh × P_{35}) had significantly positive heterosis but non-significant positive or negative heterobeltiosis exhibiting partial dominance type of gene action for increased number of spikelets per panicle. These four hybrids can be regarded as promising based on both types of heterosis for the improvement of number of spikelets per panicle. For 100-grain weight (gr) highly significant heterosis and heterobeltiosis was expressed by crosses namely Tarom-jelodar × Sange-tarom, Tarom-jelodar × Jahesh, Tarom-jelodar × Moosa-tarom, Tarom-jelodar × Basmati 370, Tarom-jelodar × P_{35} and Danesh × Basmati 370. Therefore these hybrids can be regarded as promising based on both types of heterosis for the improvement of number of spikelets per panicle.

5. Conclusion

Ultimate aim of rice breeding is to gain the heterotics yield associated with other heterotic characters. Yield is the complex character of all other yield contributing characters such as height, number of productive tillers, 100-grain weight and etc. Decreased height, Increased tiller number and high grain weight can be effective for improving yield. In this study crosses namely Tarom-Jelodar × Sange-Tarom, Danesh × Jahesh and Danesh × P_{35} had heterotic effects for all traits. These hybrids are recommended as desirable crosses for improving of related-yield traits in rice. Thus hybrid genotypes can be used for producing of promising rice varieties in the future.

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Table 1. Means of the estimated traits for seven parents and 10 F1 hybrids in rice

Genotypes	Tiller number	Plant height (cm)	Panicle length (cm)	Number of spikelets per panicle	100-grain weight (gr)
Lines					
1. TaromJelodar	16.00 cde	122.61 f	29.54 de	152.50 a-d	2.15 h
2. Danesh	14.55 de	121.56 f	26.54 gh	141.057 bcd	3.08 a
Testers					
3. Sange-Tarom	12.61 e	143.72 d	27.13 fgh	128.72 d	2.32 g
4. Jahesh	13.67 de	125.35 f	25.32 h	95.28 e	2.67 cde
5. Moosa-Tarom	13.11 e	150.80 c	30.59 b-e	130.83 d	2.16 h
6. Basmati 370	14.67 de	149.99 c	28.49 efg	150.613 a-d	1.90 i
7. P_{35}	16.33 cde	124.83 f	27.43 fg	162.613 abc	2.32 g
Hybrids					
1 × 3	29.67 a	158.66 ab	32.17 abc	160.39 abc	2.58 def
1 × 4	20.44 cd	151.89 c	29.68 de	143.00 bcd	2.79 bc
1 × 5	20.45 cd	152.28 c	32.55 ab	154.72 a-d	2.53 f
1 × 6	19.11 cde	160.56 ab	31.19 a-d	170.06 a	2.67 cde
1 × 7	31.67 a	136.45 e	33.09 a	175.67 a	2.56 ef
2 × 3	27.11 ab	161.83 a	29.16 def	142.22 bcd	3.00 a
2 × 4	22.44 bc	152.44 c	28.69 ef	138.00 cd	3.12 a
2 × 5	19.22 cde	155.00 bc	32.64 ab	167.17 ab	2.57 def
2 × 6	28.67 ab	155.44 bc	30.33 cde	161.61 abc	2.70 cd
2 × 7	22.67 bc	126.44 f	31.15 a-d	172.39 a	2.83 b

In each column, any two means having a common letter are not significantly different at $p = 0.05$ based on Duncan,s Multiple Range Test.

Table 2. Analysis of variance for combining ability effects of different traits in rice

Sources of variation	df	MS				
		Tiller number	Plant height (cm)	Panicle length (cm)	Number of spikelets per panicle	100-grain weight (gr)
Replication	2	20.74 ns	14.72 ns	0.19 ns	94.85 ns	0.02*
Genotypes	16	112.41**	634.62**	15.67**	1206.63**	0.34**
Parents (p)	6	5.89 ns	537.82**	10.71**	1472.23**	0.45**
P vs C	1	1168.09**	3559.93**	121.07**	5525.15**	1.63**
Crosses (c)	9	66.13**	374.12**	7.27**	549.72*	0.12**
Lines	1	0.45 ns	22.56 ns	13.53**	151.06 ns	0.36**
Testers	4	79.63**	787.79**	10.88**	1014.91**	0.135**
L × T	4	69.05**	48.35**	2.09 ns	184.19 ns	0.045**
Error	32	12.84	10.58	1.255	194.85	0.005
σ^2gca	6	-0.13 ns	15.04 ns	0.24 ns	16.87 ns	0.003 ns
σ^2sca	9	18.74 ns	12.59 ns	0.28 ns	-3.55 ns	0.013*
σ^2gca / σ^2sca		-0.007	1.19	0.86	-4.75	0.23
CV (%)		17.79	2.26	3.76	9.32	2.73

* and **; Significant at p = 0.05 and p = 0.01 levels, based on an F-test, respectively.
ns: non-significant.

Table 3. Proportional contribution of lines, testers and their interactions to total variance in rice

Source	Tiller number	Plant height (cm)	Panicle length (cm)	Number of spikelets per panicle	100-grain weight (gr)
Due to line	0.07	0.67	20.68	3.05	33.33
Due to tester	53.52	93.59	66.54	82.06	50.00
Due to line x tester	46.41	5.74	12.78	14.89	16.67

Table 4. General combining ability (g_i) effects for traits in rice parents

Genotypes	Tiller number	Plant height (cm)	Panicle length (cm)	Number of spikelets per panicle	100-grain weight (gr)
Lines					
1. Tarom-Jelodar	0.12	0.87	0.67	2.24	-0.11
2. Danesh	-0.12	-0.87	-0.67	-2.24	0.11
SE (g_i)	0.92	0.839	0.29	3.6	0.018
Testers					
3. Sange-Tarom	4.24	9.15**	-0.4	-7.22	0.05
4. Jahesh	-2.70	1.07	-1.88*	-18.02*	0.22
5. Moosa-Tarom	-4.31*	2.54	1.53*	2.42	-0.18
6. Basmati 370	-0.26	6.90**	-0.31	7.31	-0.05
7. P_{35}	3.02	-19.66**	1.06	15.51*	-0.04
SE (g_i)	1.46	1.328	0.457	5.69	0.029

* and ** General combining ability estimate significantly different from zero at p = 0.05 and 0.01, respectively, based on an T-Test.

Table 5. Specific combining ability (sij) effects for traits in rice crosses.

Crosses	Tiller number	Plant height (cm)	Panicle length (cm)	Number of spikelets per panicle	100-grain weight (gr)
1 × 3	1.16	-2.45	0.84	6.84	-0.10*
1 × 4	-1.12	-1.14	-0.175	0.26	-0.05
1 × 5	0.49	-2.23	-0.72	-8.47	0.09
1 × 6	-4.90*	1.69	-0.24	1.98	0.09
1 × 7	4.38	4.13	0.3	-0.61	-0.03
2 × 3	-1.16	2.45	-0.84	-6.84	0.10
2 × 4	1.12	1.14	0.175	-0.26	0.05
2 × 5	-0.49	2.23	0.72	8.47	-0.09
2 × 6	4.90*	-1.69	0.24	-1.98	-0.09
2 × 7	-4.38	-4.13	-0.3	0.61	0.03
SE (s_{ij})	2.068	1.878	0.647	8.059	0.04

* and ** Specific combining ability estimate significantly different from zero at p = 0.05 and 0.01, respectively, based on an T-Test.

Table 6. Heterosis (Ht) and Heterobetiosis (Htb) estimates (%) in rice crosses.

Crosses	Tiller number		Plant height (cm)		Panicle length (cm)		Number of spikelets per panicle		100-grain weight (gr)	
	Ht	Htb	Ht	Htb	Ht	Htb	Ht	Htb	Ht	Htb
1 × 3	107.41**	85.43**	19.14**	10.39**	13.53**	8.90**	14.07*	5.17 ns	15.44**	11.21**
1 × 4	37.78*	27.75 ns	22.51**	21.17**	8.20**	0.47 ns	15.42 ns	-6.23 ns	15.77**	4.49*
1 × 5	40.50*	27.81 ns	11.39**	0.98 ns	8.27**	6.41*	9.21 ns	1.46 ns	17.40**	17.13**
1 × 6	24.62 ns	19.44 ns	17.8**	7.05**	7.50*	5.59*	12.21 ns	11.51 ns	31.85**	24.19**
1 × 7	95.92**	93.94**	10.29**	9.31**	16.08**	12.02**	11.5 ns	8.03 ns	14.54**	10.34**
2 × 3	99.63**	86.32**	22.01**	12.6**	8.66**	7.48*	5.43 ns	0.82 ns	11.11**	-2.60 ns
2 × 4	59.03**	54.23**	23.48**	21.61**	10.64**	8.10*	16.78*	-2.17 ns	8.52**	1.30 ns
2 × 5	38.97*	32.1 ns	13.82**	2.78 ns	14.27**	6.70*	22.97**	18.51*	-1.91 ns	-16.56**
2 × 6	96.23**	95.43**	14.48**	3.63*	10.23**	6.46*	10.82 ns	7.3 ns	8.43**	-12.34**
2 × 7	46.82**	38.82*	2.63 ns	1.29 ns	15.35**	13.40**	13.54*	6.01 ns	4.81*	-8.12**

* and **; Significant at p = 0.05 and p = 0.01 levels, based on an t-test, respectively. ns: non-significant.