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Paranthaman M
Agricultural College and Research Institute, Madurai, Tamil Nadu, India

A Ramalingam
Agricultural College and Research Institute, Killikulam, Tamil Nadu, India

P Arunachalam
Agricultural College and Research Institute, Madurai, Tamil Nadu, India

M Maavimani
Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Correspondence
Paranthaman M
Agricultural College and Research Institute, Madurai, Tamil Nadu, India

Estimation of gene action in rice (*Oryza sativa* L.) for extra earliness

Paranthaman M, A Ramalingam, P Arunachalam and M Maavimani

Abstract
The line x tester analysis was made in rice using good yielding 12 lines and three very early testers. The objective of the experiment is the development of better yielding with very early/ extra early rice cultivars by utilizing various duration high yielding varieties as lines and low yielding very early duration varieties as testers, collected from various places of India. The L x T analysis revealed the importance of dominance gene action for all the eleven traits namely, days to panicle initiation, days to 50 per cent flowering, plant height, total number of tillers per plant, number of productive tillers per plant, panicle length, flag leaf length, flag leaf width, number of grains per panicle, 100 grain weight and single plant yield. Heterosis breeding or hybridization followed by selection in later generations was suggested for the improvement of these traits. The parents of four lines *viz.,* ADT (R) 45, ADT (R) 48, MDU 5, ADT (R) 37 and two testers *viz.,* ANJALI and JALDHI DHAN-6 were found to be good general combiners for earliness and single plant yield and most of the yield attributing characters. The cross combinations *viz.,* MDU 5 x ANJALI, ADT (R) 37 x ANJALI, ADT (R) 45 x JALDHI DHAN – 6, ADT (R) 48 x JALDHI DHAN – 6 and ADT (R) 45 x ANJALI was the best specific combiners for earliness along with single plant yield and most of the yield attributing characters. These four cross combinations may be useful for exploitation of heterosis and back cross to development of new extreme early cultivars with good yield.

Keywords: Rice, gene action, extra early, extreme early, very short duration

1. Introduction

In India, the major emphasis has been on increasing the grain yield of rice and as such the breeding goals for this crop have been made for understanding the nature and magnitude of gene effects and genetic variances controlling gene effects of various traits. Certain specific gene combinations cause the superiority of the improved new variety and how rapidly these gene combinations can be marshalled in a single plant or variety depends on the system through which the genes in the available material are mobilized. So, it is understood the success of plant breeding programme largely depends on the correct choice of parents. The combining ability studies provide useful information for the selection of high order parents, it also helps to understand the nature and magnitude of gene action in the expression of desired traits, which is essential to plan appropriate and efficient hybridization strategies.

Combining ability analysis is one of the powerful available evaluation tools to estimate the combining ability variance and effects for selecting the desirable parents and crosses for exploitation of heterosis. Combining ability variance is usually used for estimate of genetic control of a specific trait. Mainly two types of gene action determine the combining ability *viz*., additive and non-additive. The additive effects are mainly due to polygenes that act in additive manner, producing fixable effects. The non-additive gene action results from dominance, epistasis and various other interaction effects that are non-fixable. The combining ability measures these effects in terms of general combining ability and specific combining ability.

Sprague and Tatum (1942) [11] defined the term ‘general combining ability’ as the average performance of a line or population in several hybrid combinations, General combining ability effect is used to select the desirable parents to be used in crosses and defined ‘specific combining ability’ to those effects in certain combinations that significantly depart from what would have been expected on the basis of average performance of the lines involved. They attributed *gca* to additive effects of gene and *sca* to dominant deviation and epistatic interactions. Among different methods to assess the combining ability, line x tester analysis is more useful for self-pollinated crops like rice for rapid evaluation of large number of germplasms with reasonable degree of confidence.

Combining ability is a powerful tool in identifying the best combiners that may be used in crosses either to exploit heterosis or to accumulate fixable genes and obtain desirable segregates that helps to understand the genetic architecture of various characters that enable the breeder to design effective breeding plan for future up-gradation of the existing materials. Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability. In breeding high yielding varieties of crop plant, the breeders often face with the problem of selecting parents and crosses. Line x tester analysis provides information about general combining ability (*gca*) effects of parents and is helpful in estimating various types of gene actions. (Virmani *et al.*, 2000, Chen *et al.*, 2002 and Islam 2009) [12, 3, 5]

Therefore, the present investigation was carried out to estimate combining ability effects for yield components involving varieties with various durations (very early, short, medium, long and very long). Considering the above idea the present investigation was undertaken

1. To determine the extent of general combining ability variances for selection of suitable parents.
2. To determine the extent of specific combining ability effects and per se performances for selection of suitable hybrids.

2. Materials and methods

The combining ability analysis consisted of 12 lines and 3 testers given in Table 1 were collected from various places of India. The line x tester evaluation conducted at Agricultural College and Research Institute, Madurai during *Rabi* 2016 in randomized block design with three replications. Twenty days old seedlings were transplanted in well ploughed main field applied with recommended dose of fertilizer. Each entries transplanted in two rows of three metre length with the spacing of 20 cm between rows and 15 cm between plants with in a row. Single plant observations were observed in ten plants selected randomly at every genotypes in both the replication and their means were used for statistical analysis. The different components taken for the study are days to panicle initiation, days to 50 per cent flowering, plant height(cm), total number of tillers per plant, number of productive tillers per plant, panicle length (cm), flag leaf length(cm), flag leaf width(cm), number of grains per panicle, 100 grain weight(cm) and Single plant yield(g). Estimates of combining ability were computed according to Kempthrone (1957) [6].

Table 1: The details of the lines and testers for hybridization programme

S. No.	Variety	Parentage	Duration (Days)	Special features	Status of the parent
1	IR 36	IR 1561-228/1 IR 244/O.NIVARA/CR 94-13	120- 125	Resistant to Brown Plant Hopper, Moderately resistant to stem borer and Bacterial Leaf Blight	Female (Line)
2	MDU 5	O.GLABERRIMA X POKKALI	95-100	Resistant to Drought, suitable for dry and transplanted condition. Cold tolerant variety	Female (Line)
3	MDU 6 (ACM 01010)	MDU 5/ ACM 96136	110-115	A short duration, high yielding, long slender grain type, moderately resistant to leaffolder, stem borer, GLH and WBPH.	Female (Line)
4	CO 41	CUL.2410 X IR 22	100 -105	Good quality fine rice, low nitrogen responsive	Female (Line)
5	CO 51	ADT 43 / RR 272 – 1745	105 -110	High yielding medium slender type, Moderately resistant to Blast, Brown Plant Hopper and Green Leaf hopper	Female (Line)
6	ADT (R) 36	TRIVENI X IR 20	110	Resistant to Blast and Brown Plant Hopper	Female (Line)
7	ADT (R) 37	BG 280-12/ PTB 33	105	Irrigated early short bold, resistant to leaf yellowing BS, blast, BPH, GLH, moderately resistant to BLB, RTV, GM & LH; Yield: 63 Q/ha. Seed dormancy for 60 days	Female (Line)
8	ADT (R) 45	IR 50/ADT 37	110	Resistant to Gall midge and moderately resistant to Brown Plant Hopper	Female (Line)
9	ADT (R) 48 (AD 951280)	IET 11412/ IR 64	94-99	Resistant to Green Leaf Hopper, Gall midge and Stem borer moderate tolerant to thrips, brown plant hopper, and white backed plant hopper. Tolerant to bacterial leaf blight, rice tungro virus, blast & Sheath blight	Female (Line)
10	ASD 17	ADT 31/RATNA/ASD 8/IR 8	95-101	Moderately resistant to Brown Plant Hopper, Susceptible to gall midge and suitable for semi dry condition	Female (Line)
11	CR 1009 Sub. 1	PANKAG X JAGANNATH (Sub. 1 LOCUS INTROGRESSED FROM FR 13A)	155-165	Resistant to brown plant hopper, high yielder.	Female (Line)
12	GEB 24	SPONTANEOUS MUTANT	150	Fine grain, good quality rice	Female (Line)
13	DHALA HEERA	CR 404-48/ CR 289-1208	80-85	Upland rice variety yields 3.5 t/ha. Resistant to Blight, Gall Midge, Rice Tungro Virus, Green Leaf Hopper, White Backed Plant Hopper. Susceptible to Gundhi Bug.	Male (Tester)
14	JALDHI DHAN -6	DULAR MUTANT/ NAGINA 22 MUTANT	65-75	Upland rice variety yields 3.0 t/ha. Moderate resistant to pest and diseases (White Backed Plant Hopper, Leaf Folder, Stem Borer, Blast, Neck Blast, Bacterial Leaf Blight, Sheath Rot and Brown Spot).	Male (Tester)
15	ANJALI	RR-19-2 X RR 149-1129	90-95	Upland rice variety yields 3.5 t/ha. Resistant to Brown Spot, Moderate resistant to drought Blast and Sheath Rot.	Male (Tester)

3. Results and Discussion

3.1 Gene action

The nature of gene action has a bearing on development of efficient breeding programme. General combining ability effects and additive x additive gene action are theoretically fixable. On the other hand, specific combining ability attributed to non additive gene action may be due to dominance or epistasis or both and is not fixable. The presence of non additive genetic variance is primary justification for initiating the hybrid programme. The success of hybrid programme based on the results of combining ability depends on the extent of genetic parameters remaining stable over environments.

3.2 Combining ability

Line x tester analysis is a modified form of a top cross used for measuring general and specific combining ability variances and effects in large number of germplasm lines at a time. The estimates of variances due to *gca* and *sca* provides an apt diagnosis of the predominant role of additive or non-allelic interaction effects of genes. The *gca* and *sca* effects help to locate the parents and crosses that are responsible in bringing about a particular type of gene action.

In the present study the analysis of variance for combining ability revealed highly significant differences among the hybrids with respect to all the characters (Table 2) studied. Results of combining ability analysis reveal the mean squares for general combining ability and specific combining ability are significant, this suggests significant differences among the general combining ability effects of 12 lines and 3 testers. The results also indicate role of additive genetic and non- additive genetic variance in the inheritance of this characters. 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 all the characters, indicating the importance of both additive and non-additive variance. Variances of SCA were higher than the GCA variances for these characters except for plant height which indicated preponderance of non-additive gene action in the inheritance of the traits. This was further supported by low magnitude of MS*gca*/MS*sca* ratios (Table 2). It suggested greater importance of non-additive gene action in its expression and indicated very good prospect for the exploitation of non-additive genetic variation for traits through hybrid breeding (Annadurai and Nadarajan, 2001; Bagheri and Jelodar 2010) [1, 2]

Magnitude of genetic variance for different traits revealed that the dominance genetic variance (σD2) was higher in magnitude than the additive genetic variance (σA2) revealed the importance of dominance gene action for all the eleven traits *viz.*, days to panicle initiation, days to 50 per cent flowering, plant height, total number of tillers per plant, number of productive tillers per plant, panicle length, flag leaf length, flag leaf width, number of grains per panicle, 100 grain weight and single plant yield. This finding is in conformation with the earlier reports of Shobhana *et al.*, 2018 [10] and Manish Kumar *et al.*, 2018 [8].

Table 2: Analysis of variance for combining ability in rice

Source of variation	df	Mean squares										
		DPI	**DFF**	**PHT**	**TNT**	**NPT**	**PL**	**FLL**	**FLW**	**NOG**	**100 GW**	**SPY**
Replication	1	0.0110	0.7833	0.5408	13.7113	9.5048	2.4127	10.7339	0.0470	54.7755	0.0019	0.4737
Hybrids	35	131.9907**	195.3486**	559.7031**	30.0899**	9.5777**	13.3468**	19.4871**	0.0228**	1223.5663**	0.5689**	57.2675**
Lines	11	345.7648**	532.6835**	1072.2609**	53.9623**	52.8025**	22.1700**	35.1214**	0.0255**	2194.8285**	1.0760**	60.2599**
Testers	2	57.9841**	63.1519**	1503.9636*	1.4124*	2.2663**	3.3606**	5.9545**	0.0462**	261.3216**	0.0414**	163.889**
L X T	22	31.8315**	38.6991**	217.5823**	20.7607**	20.4482**	9.8431**	12.9002**	0.0194**	825.4120**	0.3633**	46.0784**
Error	35	0.2764	0.2330	20.8468	1.6038	2.0270	1.0415	2.2423	0.0150	70.3607	0.0147	2.8231
σ^2 GCA		2.3654	3.6996	8.0798	0.2203	0.2156	0.0827	0.1556	0.0001	9.4031	0.0049	0.2643
σ^2 SCA		15.7776	19.2330	98.3677	9.5784	9.2106	4.4008	5.3290	0.0022	377.5256	0.1743	21.6277
σ^2 GCA / SCA		0.14992	0.19236	0.08214	0.02300	0.02341	0.01879	0.02920	0.04545	0.02491	0.02811	0.01222

*Significant at 5% level, **Significant at 1% level

Table 3: Magnitude of genetic variance for different traits

S. No.	Characters	GCA variance	SCA variance	σA2	σD2	σA2/ σD2
1.	Days to panicle initiation	2.365	15.778	4.731	15.778	0.300
2.	Days to 50 per cent flowering	3.700	19.233	7.399	19.233	0.385
3.	Plant height (cm)	8.080	98.368	16.160	98.368	0.164
4.	Total number of tillers per plant	0.220	9.578	0.441	9.578	0.046
5.	Number of productive tillers per plant	0.216	9.211	0.431	9.211	0.047
6.	Panicle length (cm)	0.083	4.401	0.166	4.401	0.038
7.	Flag leaf length (cm)	0.156	5.329	0.311	5.329	0.058
8.	Flag leaf width (cm)	0.0001	0.0022	0.0002	0.0022	0.0909
9.	Number of grains per panicle	9.403	377.526	18.806	377.526	0.050
10.	100 grain weight (g)	0.005	0.174	0.010	0.174	0.056
11.	Single plant yield (g)	0.264	21.628	0.529	21.628	0.024

The mean performance of parents in lines ASD 17 (67.72 and 73.48), CO 41 (68.29 and 74.59), MDU 5 (69.64 and 74.66), ADT (R) 48 (70.06 and 74.28), CO 51 (73.40 and 80.96), ADT (R) 37 (74.90 and 81.00), ADT (R) 36 (76.63 and 85.06), ADT (R) 45 (78.05 and 81.44) and tester JALDHI DHAN-6 (58.75 and 62.10) had registered significantly higher mean values for days to panicle initiation and days to 50 per cent flowering respectively. The mean performance of parents in lines IR 36 (37.97 g), ADT (R) 37 (33.06 g), ADT (R) 45 (34.84 g), ADT (R) 48 (29.15 g), CR 1009 sub. 1 (33.56 g) and tester ANJALI (25.27 g) had registered significantly higher mean of single plant yield.

For the earliness related characters like days to panicle initiation and days to 50 per cent flowering had registered significant mean values for 11 hybrids. For single plant yield eight hybrids were registered significantly higher mean values (Table 4).

3.3 General combining ability effects:

Significance of mean square for *gca* suggests significant differences among *gca* effects. It also implies that additive component of heritable variance is responsible for variation observed for the character. Analysis of mean performance of the parents and their *gca* effects revealed that *gca* is reflective of mean for most of the characters studied. The mean square for *gca* is found to be significant infer that there are significant differences among the *gca* effects. It also suggests that additive genetic variance is an important component of heritable variance for this attribute.

The negative estimates of *gca* effects are desirable for earliness and plant height. Among parents studied based on *per se* and *gca* effects MDU 5, CO 41, CO 51, ADT (R) 37, ADT (R) 45, ADT (R) 48, ASD 17 and JALDHI DHAN-6 were found good general combiner for days to panicle initiation (earliness). CO 41, CO 51, ADT (R) 36, ADT (R) 37, ADT (R) 45, ADT (R) 48, ASD 17 and JALDHI DHAN-6 was identified as good general combiner for days to 50 per cent flowering (earliness). Kishor *et al.*, 2017 [7] have also emphasized the same result regarding earliness related traits. IR 36, MDU 5, ADT (R) 48, CR 1009 Sub.1 and JALDHI DHAN-6 was identified as best combiners for plant height. ADT (R) 45 and ANJALI were found to be best general combiner for total number of tillers per plant and number of productive tillers per plant. IR 36, MDU 5, MDU 6 and ANJALI were best for the panicle length. IR 36, MDU 5 was the best general combiner for flag leaf length. ADT (R) 37, ADT (R) 45, CR 1009 sub.1 and ANJALI were identified as good general combiner for number of grains per panicle. MDU 5, CO 51, ADT (R) 36, ADT (R) 37, CR 1009 sub.1 and ANJALI were the best general combiner for the 100 grain weight. ADT (R) 45, ADT (R) 48 and ANJALI were identified as good general combiner for single plant yield.

According to the mean performance and *gca* effects of the various characters studied the following four lines *viz.*, ADT (R) 45, ADT (R) 48, MDU 5, ADT (R) 37 and two testers *viz.*, ANJALI and JALDHI DHAN-6 were identified as best combining parents among all the parents Table 3.

3.4 Specific combining ability effects:

Significance of mean square for specific combining ability indicates the significant differences exist among the *sca* effects and that non additive genetic variance is responsible for the inheritance of the character being studied.

High *sca* effect results mostly from the dominance and interaction effects existing between the hybridized parents. In the present study, positive significant of *per se* and *sca* effects were useful to identify the best cross combinations. Based on the *per se* and *sca* effects the crosses MDU 5 x ANJALI, MDU 6 x JALDHI DHAN-6, CO 41 x DHALA HEERA, CO 51 x DHALA HEERA, CO 51 x JALDHI DHAN-6, ADT (R) 37 x ANJALI, ADT (R) 45 x JALDHI DHAN-6, ADT (R) 48 x DHALA HEERA, ADT (R) 48 x JALDHI DHAN-6, ASD 17 x DHALA HEERA for earliness contributing traits like days to panicle initiation and days to 50 per cent flowering along with single plant yield except CO 41 x DHALA HEERA, CO 51 x JALDHI DHAN-6, ADT (R) 48 x DHALA HEERA, but it includes CR 1009 sub.1 x ANJALI for single plant yield only.

According to the mean performance and *sca* effects of the earliness, yield and yield related characters were studied, the following four cross combinations *viz.*, MDU 5 x ANJALI, ADT (R) 37 x ANJALI, ADT (R) 45 x JALDHI DHAN – 6 and ADT (R) 48 x JALDHI DHAN – 6 were identified as best specific combining crosses among all the 36 crosses Table 4.

The cross combinations having significant *sca* effects but failed to recoded high *per se* performance results from parents with low x low *gca* effects. The present findings also indicate that crosses had significant *sca* effects recorded the highest *per se* performance where either of the parent involved in the combination have high *gca* effects. In addition to single plant yield, the crosses had significant and positive *sca* effects for the earliness, yield and yield component traits (days to panicle initiation, days to 50 per cent flowering, number of productive tillers per plant, panicle length, number of grains per panicle, hundred grain weight and single plant yield)

Most of the crosses identified as desirable, on the basis of their *sca* effects have atleast one parent with significant and positive *gca* effects. A word regarding the choice of crosses is necessary. On the basis of simulation studies, Curnow (1980) [4] concluded that crosses should be selected on the basis of general combining ability effects of constituent parent.

The results also indicate role of additive genetic and non-additive genetic variance in the inheritance of this characters. The predominance of *gca* variance and *sca* variance for the observed characters was suggested that additive and non additive gene action was important for controlling these traits, confirming the earlier findings of Waza *et al.* (2015) [13], Priyanka *et al.* (2016) [9], Kishor *et al.* (2017) [7] and Shobhana *et al.* (2018) [10].

Table 4: General combining ability effects of lines and testers for earliness, yield and yield related traits

Parents		DPI	DFF	PHT	TNT	NPT	PL	FLL	FLW	NOG	100 GW	SPY
Lines												
IR 36	L_1	2.58 **	1.60 **	-7.82 **	-1.02 ns	-0.51 ns	4.73 **	-0.19 ns	-0.01 ns	-10.68 **	-0.01 ns	-3.75 **
MDU 5	L_2	-0.67 **	0.45 *	-3.85 *	-1.39 **	-1.36 *	1.27 **	2.09 **	0.09 ns	-11.28 **	0.12 *	-0.78 ns
MDU 6	L_3	3.85 **	1.74 **	-5.49 **	-2.69 **	-2.82 **	1.17 **	6.16 **	0.10 ns	-2.92 ns	-0.17 **	-0.47 ns
CO 41	L_4	-7.13 **	-8.06 **	2.26 ns	-0.15 ns	-0.51 ns	0.56 ns	1.06 ns	-0.03 ns	-2.08 ns	-0.80 **	-4.82 **
CO 51	L_5	-2.72 **	-3.08 **	0.74 ns	2.03 **	1.69 **	-0.82 ns	0.11 ns	0.04 ns	6.02 ns	0.43 **	-1.81 *
ADT (R) 36	L_6	1.46 **	1.68 **	-3.66 ns	-1.48 **	-1.44 *	-0.24 ns	-1.13 ns	-0.06 ns	8.25 *	0.76 **	-0.18 ns
ADT (R) 37	L_7	-3.11 **	-3.56 **	-0.09 ns	-0.79 ns	-1.27 *	-1.23 **	-0.45 ns	0.00 ns	7.55 *	0.29 **	-0.89 ns
ADT (R) 45	L_8	-9.36 **	-11.08 **	2.38 ns	5.97 **	5.63 **	-0.11 ns	-0.06 ns	0.07 ns	49.58 **	0.00 ns	6.47 **
ADT (R) 48	L_9	-6.31 **	-8.00 **	-13.20 **	4.93 **	5.43 **	-1.81 **	-0.88 ns	-0.06 ns	-27.25 **	-0.53 **	2.56 **
ASD 17	L_{10}	-3.57 **	-5.52 **	-4.90 *	-1.88 **	-1.64 **	-1.37 **	-2.56 **	-0.11 *	-16.85 **	-0.22 **	0.55 ns
CR 1009 Sub. 1	L_{11}	19.19 **	23.66 **	-6.35 **	0.70 ns	0.76 ns	-2.70 **	-3.40 **	0.20*	7.68 *	0.30 **	-1.15 ns
GEB 24	L_{12}	5.78 **	10.19 **	39.96 **	-4.23 **	-3.94 **	0.57 ns	-0.76 ns	-0.04 ns	-8.02 *	-0.17 **	4.28 **
SE		0.2146	0.1971	1.8640	0.5170	0.5812	0.4166	0.6113	0.0500	3.4244	0.0495	0.6859

Testers												
Dhala Heera	T_1	1.36 **	1.57 **	-1.00 ns	-1.68**	-1.63**	-0.29 ns	-0.30 ns	-0.02 ns	-10.72**	0.29**	-1.58 **
Jaldhi Dhan – 6	T_2	-1.69 **	-1.67 **	-7.37 **	0.23 ns	0.30 ns	-1.24**	-3.43**	-0.12*	-3.07 ns	-0.23**	-1.44 **
Anjali	T_3	0.34 **	0.10 ns	8.37 **	2.41**	1.69**	0.42 *	2.08**	0.05 *	3.49 *	0.30**	3.02 **
SE		0.1073	0.0985	0.9320	0.2585	0.2906	0.2083	0.3057	0.0250	1.7122	0.0247	0.3430

*****Significant at 5% level, **Significant at 1% level

Table 5: Best parents based on *per se* performance and *gca* effects for various characters

S. No.	Characters	*Per se*	*gca*	Both *per se* and *gca*
1	Days to panicle initiation	L_2, L_4, L_5, L_6, L_7, L_8, L_9, L_{10}, T_2	L_2, L_4, L_5, L_7, L_8, L_9, L_{10}, T_2	L_2, L_4, L_5, L_7, L_8, L_9, L_{10}, T_2
2	Days to 50 percent flowering	L_2, L_4, L_5, L_6, L_7, L_8, L_9, L_{10}, T_2	L_4, L_5, L_7, L_8, L_9, L_{10}, T_2	L_4, L_5, L_6, L_7, L_8, L_9, L_{10}, T_2
3	Plant height	L_1, L_2, L_6, L_7, L_8, L_9, L_{11}, T_2	L_1, L_2, L_3, L_9, L_{10}, L_{11}, T_2	L_1, L_2, L_9, L_{11}, T_2
4	Total number of tillers per plant	L_1, L_6, L_8, L_{12}, T_1, T_3	L_5, L_8, L_9, T_3	L_8, T_3
5	Number of productive tillers per plant	L_1, L_2, L_6, L_8, L_{11}, L_{12}, T_3	L_5, L_8, L_9, T_3	L_8, T_3
6	Panicle length	L_1, L_2, L_3, L_5, L_{10}, L_{12}, T_1, T_3	L_1, L_2, L_3, T_3	L_1, L_2, L_3, T_3
7	Flag leaf length	L_2, L_3, L_6, L_8, T_2	L_2, L_3, T_3	L_2, L_3
8	Flag leaf width	L_4, L_7, L_8, L_9, L_{12}, T_1	L_{11}, T_3	-
9	Number of grains per panicle	L_5, L_7, L_8, L_{11}, T_1, T_3	L_6, L_7, L_8, L_{11}, T_3	L_7, L_8, L_{11}, T_3
10	100 grain weight	L_1, L_2, L_5, L_6, L_7, L_9, L_{10}, L_{11}, T_1, T_3	L_2, L_5, L_6, L_7, L_{11}, T_3	L_2, L_5, L_6, L_7, L_{11}, T_3
11	Single plant yield	L_1, L_7, L_8, L_9, L_{11}, T_3	L_8, L_9, L_{12}, T_3	L_8, L_9, T_3

L_1- IR 36, L_2- MDU 5, L_3- MDU 6, L_4- CO 41, L_5- CO 51, L_6- ADT (R) 36, L_7- ADT (R) 37, L_8- ADT (R) 45, L_9- ADT (R) 48, L_{10}- ASD 17, L_{11}- CR 1009 Sub. 1, L_{12}- GEB 24, T_1- DHALA HEERA, T_2- JALDHI DHAN -6, T_3- ANJALI

4. Conclusion

Significant genotypic variances for yield related traits indicated that there were significant variations among the genotypes. Significant *gca* variances along with additive variance component for the biometrical traits indicated the accessibility of additive gene action. The significant interaction of line x tester indicated the higher estimates for *sca* variances. Seven lines showed significant negative effects for days to panicle initiation and 50 per cent flowering which were responsible for earliness. Eleven crosses showed significant negative *sca* estimates for days to panicle initiation and days to 50 per cent flowering. Among 36 crosses eight crosses showed significant positive sca effects along with above average *per se* performances for grain yield. (Table 5.)

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