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Original Research Paper

Heterosis and combining ability for yield and its related traits in ridge gourd [*Luffa acutangula* (L.)Roxb.]

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ABSTRACT

Line × Tester analysis involving three lines and four testers was carried out in ridge gourd [*Luffa acutangula* (Roxb.) L.]. Significant variation was noticed in the mean performance of the parents and hybrids for all the characters studied except for vine length and fruit girth. The results from GCA and SCA variance indicated the predominance of non-additive gene action for all the traits except fruit girth. Significant heterosis of 177.78% over standard check, Arka Sumeet for fruit weight per plant was expressed by the cross GARG-1 × CO-1. The best general combiners were GARG-1 and Pusa Nutan among the lines, and Jaipur long and CO-1 among testers. Best specific combining ability effects for fruit length and yield (t/ha) were recorded by the crosses Pusa Nasdar × Arka Sumeet and GARG-1 × CO-1.

Key words: Heterosis, combining ability, gca, sca, ridge gourd.

INTRODUCTION

Ridge gourd [*Luffa acutangula* (L.) Roxb.] is a commercially important vegetable crop because it has good yield potential and good medicinal properties as well. Ridge gourd can be grown throughout the year. It is cultivated from central and eastern Asia to south-eastern Asia. Of late, exploitation of hybrid vigour and selection of parents on the basis of combining ability has become crucial in crop improvement. It is a monoecious and cross pollinated crop, thus exhibits considerable heterozygosity, but does not have inbreeding depression. This results in the presence of natural variability in the population. This provides sufficient scope for utilization of heterosis on commercial scale which increases the production potential and productivity of ridge gourd. Combining ability helps in identifying the best general and specific combiners for yield and yield contributing characters. Hence the present study was undertaken to estimate the heterosis of different cross combinations and also to estimate the general and specific combining ability to identify the best performing parents and hybrids respectively in ridge gourd.

MATERIAL AND METHODS

The experimental material comprised of 7 parents (3 lines and 4 testers) *viz*; GARG-1, Pusa Nutan, Pusa Nasdar used as lines and four testers namely Arka Sumeet, Arka Sujat, Jaipur Long and CO-1 and twelve F_1s produced during 2013 by crossing these parents in Line × Tester mating design. These hybrids along with seven parents were evaluated for yield and yield related traits in randomized block design with three replications in the Vegetable Farm, ICAR-IIHR, Bengaluru during summer and kharif seasons of 2014-15 and 2015-16. Plant to plant spacing was maintained at 50 cm and row to row was 150 cm. Data were recorded on five randomly selected plants in each treatment (hybrids and parents) for ten characters *viz;* node number for first female flower appearance, days taken for first female flower appearance, vine length, number of branches, fruit length, fruit girth, fruit number/plant, fruit weight, fruit weight/plant and fruit yield/ha. Heterosis over better parent and standard check, Arka Sumeet was calculated for each character and significance was tested. The covariance of half-sibs and full-sibs were used for obtaining the estimates of general and specific combining ability effects as per the procedure outlined by Kempthorne (1957).

RESULT AND DISCUSSION

The mean performance of parents and hybrids for various traits has been presented in **Table 1**. The analysis of variance showed highly significant differences for all the characters studied except for vine length and fruit girth **(Table 2)**. Similarly variance due to parents was also highly significant for all the characters except for vine length indicating presence of sufficient variability among the parents for the characters studied. The variance due to parents versus crosses differed significantly for most of the characters except for vine length, fruit girth and per fruit weight indicating the presence of heterosis for the characters. Significant differences were observed among the crosses and Line × tester for all the characters except for vine length, fruit length and fruit girth. Similarly Narasannavar *et al* (2014b) observed a non-significant variance due to Line × Tester for vine length in ridge gourd. The magnitude of variance due to SCA was higher than the GCA variance and also the GCA : SCA was less than a unity for all the characters except for fruit girth, confirming the predominance of non additive gene action indicating the exploitation of heterosis for all these characters. The findings are in conformation with Ladom *et al.,* (2009) and Narasannavar *et al* (2014b). But the GCA variance was higher than that of SCA variance and also negative for fruit girth.

Among all the crosses it has been observed that ten crosses for node to first female flower appearance and nine crosses for days to flowering showed negative and significant heterosis over the better parent, similarly Kantharaj (2003) and Sarkar *et al* (2015) also reported the negative and significant heterosis for these characters. Only one cross each for fruit length, fruit girth and fruit weight showed significant positive heterosis over the better parent value. Whereas 11 crosses for number of fruits per plant and all crosses for fruit weight per plant and yield (t/ha) showed significantly positive heterosis over the better parent. These results are in confirmation with Narasannavar *et al* (2014a), Mole *et al* (2001), Kumar *et al* (1999) for number of fruits per plant and fruit weight per plant. However, for vine length and number of branches there is no significant favorable heterosis over the better parent. Previously Kumar *et al* (1999) also reported non-significant heterosis for number of branches in bottle gourd.

Significant heterosis has been observed over the standard check, Arka Sumeet in ten crosses for node to first female flower appearance, eight crosses for days to first female flower appearance and all crosses for fruit number per plant, fruit weight per plant and yield (t/ha) **(Table 3)** in the favorable direction. For fruit weight per plant and yield (t/ha) the cross GARG-1 x CO-1 has recorded significant standard heterosis i.e. 177.78% for fruit weight per plant and 173.22% for yield (t/ha) over the standard check Arka Sumeet **(Table 4)**. For node to first female flower appearance (70.61%) and days to first female flower appearance (24.48%) the cross Pusa Nutan x Arka Sujat recorded significant heterosis in favorable direction. Hence, these hybrids can be exploited for commercial purpose. Similarly Mole *et al* (2001) in ridge gourd and Kumar *et al.*,(1999) in bottle gourd reported standard heterosis for node to first female flower appearance, number of fruits per plant and fruit yield per plant.

The perusal of the data on GCA effects of lines indicated that GARG-1 and Pusa Nutan were found to be best general combiner for node to first female flower appearance, days to first female flower appearance, vine length, fruit length, fruit number per plant, per fruit weight and yield (t/ha) **(Table 5)**. These lines can be utilized in evolving highly productive hybrids. The significant heterotic crosses for various characters in the present study had these lines as one of the parents. Among the testers Jaipur long and CO-1 were proved to be good general combiners for days to first female flower appearance, vine length, number of fruits per plant, per fruit weight and yield (t/ha). Heterosis study also indicated the importance of these testers because of their involvement in majority of the significant heterotic crosses for various characters.

Promising crosses based on significant SCA effects and per se performance revealed that the cross Pusa Nutan x Arka Sujat was most promising for days taken for first female flower appearance. The cross GARG-1 x Jaipur Long was promising for vine length (Table 6). Pusa Nasdar x Arka Sumeet had the high SCA along with superior performance for fruit length and per fruit weight **(Table 6 & 7).** For fruit number per plant only the cross

Table 1. *Per se* performance of parents, their hybrids for yield and related traits

Parents / Hybrids	NFF	DFF	Vine length (cm)	Number of branches/ plant	Fruit length (cm)	Fruit girth (cm)	Number of fruits/ plant	Fruit weight (g)	Yield/ Plant (kg)
GARG-1	5.83	54.30	335.00	8.00	28.30	15.97	3.33	180.80	0.60
Pusa Nutan	3.80	50.40	180.67	7.67	27.93	15.27	3.50	151.27	0.50
Pusa Nasdar	10.87	62.10	308.33	7.00	27.20	13.27	3.33	184.37	0.60
Arka Sumeet	11.00	58.00	283.00	9.33	34.80	15.60	3.43	267.90	0.90
Arka Sujat	12.33	73.33	282.67	9.00	27.33	14.93	5.27	183.10	0.97
Jaipur Long	6.10	56.83	294.00	11.00	23.33	12.40	6.93	157.07	1.13
CO-1	13.83	62.50	322.33	7.00	28.60	13.20	5.77	224.53	1.27
GARG-1 × Arka Sumeet	6.37	49.83	264.67	5.33	30.60	15.40	14.40	149.87	2.10
GARG-1 × Arka Sujat	6.17	53.33	282.67	7.00	26.87	14.53	8.17	165.90	1.33
GARG-1 × Jaipur Long	7.10	53.67	349.00	8.33	27.93	13.07	11.00	192.70	2.10
GARG-1 × CO-1	6.33	56.60	285.00	6.33	30.53	14.53	11.73	214.73	2.50
Pusa Nutan × Arka Sumeet	5.77	49.10	233.00	5.00	32.53	13.27	9.00	211.07	1.90
Pusa Nutan × Arka Sujat	3.23	43.80	217.00	6.33	34.73	13.93	10.23	176.73	1.80
Pusa Nutan × Jaipur Long	7.60	52.97	256.67	7.67	32.33	14.13	12.27	171.77	2.10
Pusa Nutan × CO-1	7.20	53.07	183.33	4.00	32.00	14.13	9.87	196.73	1.93
Pusa Nasdar × Arka Sumeet	7.90	53.60	251.33	8.33	36.87	15.07	5.57	261.77	1.50
Pusa Nasdar × Arka Sujat	9.60	58.83	324.33	6.33	29.93	14.63	6.07	218.30	1.30
Pusa Nasdar × Jaipur Long	7.53	56.07	267.00	7.67	29.73	15.17	10.50	186.73	1.97
Pusa Nasdar × CO-1	9.70	59.83	282.33	8.33	31.20	15.73	8.30	222.30	1.83
Mean value of Parents	9.11	59.64	286.57	8.43	28.21	14.38	4.51	192.72	0.85
Mean value of hybrids	7.04	53.39	266.36	6.72	31.27	14.47	9.76	197.38	1.86
S.Em +/-	1.02	1.93	40.01	0.90	2.19	0.92	0.68	13.41	0.13
CD *(P=0.05)*	2.92	5.55	114.75	2.58	6.28	2.63	1.94	38.48	0.37

Note: NFF: node number for first female flower appearance, DFF: days taken for first female flower appearance

Table 2. Mean sum of squares for ten quantitative characters in L × T analysis in ridge gourd

	Characters	Replications	Genotype	Crosses	Parents	Parents Vs Crosses	Lines	Testers	L x T	Error
	df	2	18	11	6	1	2	3	6	36
1	NFF	0.56	23.17**	8.94**	43.67**	56.71**	25.13**	3.79NS	6.12*	3.10
2	DFF	21.85	118.45**	57.83**	163.10**	517.43**	162.08**	56.48**	23.76*	11.23
3	Vein length (cm)	4511.91	6504.53NS	5952.15NS	7698.41NS	5417.43NS	17909.19**	3629.29NS	3127.90NS	4801.65
4	Number of Branch	1.91	7.98**	6.11**	6.30**	38.62**	11.03**	5.67*	4.69*	2.43
5	Fruit length (cm)	30.48	32.14*	22.43NS	34.62*	124.04**	49.96**	19.34NS	14.80NS	14.36
6	Fruit girth (cm)	6.82	3.16NS	1.98NS	5.82*	0.11NS	5.00*	0.76NS	1.59NS	2.53
7	Fruit number/plant	0.89	34.21**	19.23**	6.49**	365.40**	44.50**	14.59**	13.12**	1.38
8	Fruit weight (g)	1092.43	3368.93**	2770.73**	4979.02**	288.54NS	5781.87**	1772.26**	2266.24**	539.88
9	Fruit weight/plant	0.09	1.06**	0.36**	0.26**	13.57**	0.43**	0.71**	0.16**	0.05
10	Fruit yield (t/ha)	15.22	185.92**	65.01**	43.42**	2370.96**	76.30**	126.01**	30.74**	8.47

Note: NFF: node number for first female flower appearance, DFF: days taken for first female flower appearance

Table 3. Heterobeltiosis of the promising crosses in ridge gourd

Cross	NFF	DFF	Vine length (cm)	Number of branches/ plant	Fruit length (cm)	Fruit girth (cm)	Number of fruits/ plant	Fruit weight (g)	Yield/ Plant (kg)	Fruit yield (t/ha)
GARG-1 × Arka Sumeet	-42.12**	-14.08**	-21	-42.86**	-12.07	-3.55	319.42**	-44.06**	133.33**	130.06**
GARG-1 × Arka Sujat	-50**	-27.27**	-15.62	-22.22*	-5.07	-8.98	55.06**	-9.39	37.93*	36.88*
GARG-1 × Jaipur Long	16.39	-5.57	4.18	-24.24**	-1.3	-18.16**	58.65**	6.58	85.29**	91.53**
GARG-1 × CO-1	-54.22**	-9.44**	-14.93	-20.83	6.76	-8.98	103.47**	-4.37	97.37**	93.05**
Pusa Nutan × A Sumeet	-47.58**	-15.35**	-17.67	-46.43**	-6.51	-14.96*	157.14**	-21.21**	111.11**	107.38**
Pusa Nutan × Arka Sujat	-73.78**	-40.27**	-23.23	-29.63**	24.34**	-8.73	94.3**	-3.48	86.21**	87.53**
Pusa Nutan × Jaipur Long	24.59	-6.8	-12.7	-30.3**	15.75	-7.42	76.92**	9.36	85.29**	92.91**
Pusa Nutan × CO1	-47.95**	-15.09**	-43.12**	-47.83**	11.89	-7.42	71.1**	-12.38	52.63**	49.81**
Pusa Nasdar × Arka Sumeet	-28.18**	-13.69**	-18.49	-10.71	5.94	-3.42	62.14**	-2.29	66.67**	60.66**
Pusa Nasdar × Arka Sujat	-22.16*	-19.77**	5.19	-29.63**	9.51	-2.01	15.19	18.41*	34.48*	37.4*
Pusa Nasdar × Jaipur Long	-30.68**	-9.72**	-13.41	-30.3**	9.31	14.32	51.44**	1.28	73.53**	79.18**
Pusa Nasdar × CO-1	-29.88**	-4.27	-12.41	19.05	9.09	18.59*	43.93**	-1	44.74**	42.28**

Note: NFF: node number for first female flower appearance, DFF: days taken for first female flower appearance

Table 4. Standard heterosis of the promising crosses in ridge gourd

Cross	NFF	DFF	Vine length (cm)	Number of branches/ plant	Fruit length (cm)	Fruit girth (cm)	Number of fruits/ plant	Fruit weight (g)	Yield/ Plant (kg)	Fruit yield (t/ha)
GARG-1 × Arka Sumeet	-42.12**	-14.08**	-6.48	-42.86**	-12.07	-1.28	319.42**	-44.06**	133.33**	130.06**
GARG-1 × Arka Sujat	-43.94**	-8.05*	-0.12	-25*	-22.8**	-6.84	137.86**	-38.07**	48.15**	43.99**
GARG-1 × Jaipur Long	-35.46**	-7.47*	23.32	-10.71	-19.73**	-16.24*	220.39**	-28.07**	133.33**	128.69**
GARG-1 × CO-1	-42.42**	-2.41	0.71	-32.14**	-12.26	-6.84	241.75**	-19.85**	177.78**	173.22**
Pusa Nutan × A Sumeet	-47.58**	-15.35**	-17.67	-46.43**	-6.51	-14.96*	162.14**	-21.21**	111.11**	107.38**
Pusa Nutan × Arka Sujat	-70.61**	-24.48**	-23.32	-32.14**	-0.19	-10.68	198.06**	-34.03**	100**	97.27**
Pusa Nutan × Jaipur Long	-30.91**	-8.68*	-9.31	-17.86	-7.09	-9.4	257.28**	-35.88**	133.33**	130.33**
Pusa Nutan × CO1	-34.55**	-8.51*	-35.22*	-57.14**	-8.05	-9.4	187.38**	-26.57**	114.82**	112.02**
Pusa Nasdar × Arka Sumeet	-28.18**	-7.59*	-11.19	-10.71	5.94	-3.42	62.14**	-2.29	66.67**	60.66**
Pusa Nasdar × Arka Sujat	-12.73	1.44	14.61	-32.14**	-13.99*	-6.2	76.7**	-18.51**	44.44**	44.54**
Pusa Nasdar × Jaipur Long	-31.52**	-3.33	-5.65	-17.86	-14.56*	-2.78	205.83**	-30.3**	118.52**	113.93**
Pusa Nasdar × CO-1	-11.82	3.16	-0.24	-10.71	-10.35	0.86	141.75**	-17.02**	103.7**	101.37**

Note: NFF: node number for first female flower appearance, DFF: days taken for first female flower appearance

Table 5. Estimates of general combining ability effects of seven parents for 10 quantitative characters in L × T analysis

Parents	NFF	DFF	Vine length (cm)	Number of branches/ plant	Fruit length (cm)	Fruit girth (cm)	Number of fruits/ plant	Fruit weight (g)	Yield/ Plant (kg)	Fruit yield (t/ha)
Lines										
GARG-1	-0.55	-0.03	28.97**	0.03	-2.29**	-0.08	1.57**	-16.58**	0.14	1.88**
Pusa Nutan	-1.09*	-3.66**	-43.86**	-0.97	1.63**	-0.6	0.58	-8.31**	0.07	0.99
Pusa Nasdar	1.64**	3.69**	14.89**	0.94	0.66	0.68	-2.15**	24.89**	-0.21	-2.87**
SEm ±	0.51	0.97	20.00	0.45	1.09	0.46	0.34	6.71	0.06	0.84
Testers										
Arka Sumeet	-0.36	-2.55**	-16.69**	-0.5	2.06**	0.11	-0.1	10.18**	-0.03	-0.52
Arka Sujat	-0.71	-1.40*	8.31**	-0.17	-0.76	-0.1	-1.6**	-10.41**	-0.39	-5.09**
Jaipur Long	0.37	0.84	24.53**	1.17	-1.27*	-0.34	1.5*	-13.65**	0.19	2.53**
CO-1	0.70	3.11**	-16.14**	-0.5	-0.03	0.33	0.21	13.87**	0.23	3.08**
SEm ±	0.59	1.12	23.10	0.52	1.26	0.53	0.39	7.75	0.07	0.97

Note: NFF: node number for first female flower appearance, DFF: days taken for first female flower appearance

Table 6. Estimates of specific combining ability effects of 12 crosses for 10 quantitative characters in L × T analysis

Cross	NFF	DFF	Vine length (cm)	Number of branches/ plant	Fruit length (cm)	Fruit girth (cm)	Number of fruits/ plant	Fruit weight (g)	Yield/ Plant (kg)	Fruit yield (t/ha)
GARG-1 × Arka Sumeet	0.24	-0.98	-13.97**	-0.92	-0.44	0.91	3.18**	-41.12**	0.12	1.87
GARG-1 × Arka Sujat	0.38	1.38	-20.97**	0.42	-1.36	0.25	-1.56	-4.49**	-0.29	-4.06**
GARG-1 × Jaipur Long	0.24	-0.53	29.14**	0.42	0.22	-0.97	-1.82	25.55**	-0.1	-1.34
GARG-1 × CO-1	-0.86	0.13	5.81**	0.08	1.58	-0.18	0.2	20.06**	0.27	3.54**
Pusa Nutan × A Sumeet	0.18	1.91	27.19**	-0.25	-2.43*	-0.71	-1.24	11.81**	0	-0.01
Pusa Nutan × Arka Sujat	-2.01	-4.53**	-13.81**	0.75	2.59*	0.17	1.49	-1.94	0.25	3.32**
Pusa Nutan × Jaipur Long	1.28	2.39*	9.64**	0.75	0.71	0.61	0.43	-3.66**	-0.03	-0.26
Pusa Nutan × CO1	0.55	0.23	-23.03**	-1.25	-0.87	-0.07	-0.68	-6.21**	-0.23	-3.05**
Pusa Nasdar × Arka Sumeet	-0.42	-0.94	-13.22**	1.17	2.87**	-0.19	-1.94	29.31**	-0.12	-1.86
Pusa Nasdar × Arka Sujat	1.63	3.15**	34.78**	-1.17	-1.24	-0.42	0.06	6.43**	0.04	0.74
Pusa Nasdar × Jaipur Long	-1.52	-1.86	-38.78**	-1.17	-0.93	0.36	1.39	-21.89**	0.13	1.6
Pusa Nasdar × CO-1	0.31	-0.36	17.22**	1.17	-0.71	0.25	0.48	-13.85**	-0.04	-0.49
SEm ±	1.02	1.93	40.01	0.90	2.19	0.92	0.68	13.41	0.13	1.68

Note: NFF: node number for first female flower appearance, DFF: days taken for first female flower appearance

Table 7. Best crosses based on SCA effects and per se performance in ridge gourd

	Cross	SCA	Per se performance (mean)
Days to Flowering	Pusa Nutan × Arka Sujat	-4.53**	43.80
Vein length (cm)	GARG-1 × Jaipur Long	29.14**	349.00
	Pusa Nasdar × Arka Sujat	34.78**	324.33
	GARG-1 × CO-1	5.81**	285.00
Fruit length (cm)	Pusa Nasdar × Arka Sumeet	2.87**	36.87
	Pusa Nutan × Arka Sujat	2.59*	34.73
Fruit number/plant	GARG-1 × Arka Sumeet	3.18**	14.40
Fruit weight (g)	Pusa Nasdar × Arka Sumeet	29.31**	261.77
	GARG-1 × CO-1	20.06**	214.73
	Pusa Nutan × A Sumeet	11.81**	211.07
	GARG-1 × Jaipur Long	25.55**	192.70
Fruit yield (t/ha)	GARG-1 × CO-1	3.54**	33.33
	Pusa Nutan × Arka Sujat	3.32**	24.07

GARG-1 x CO-1 had high SCA along with superior performance for the yield (t/ha). These crosses can be directly utilized for improvement of these characters through the exploitation of heterosis or can be exploited for the development of better transgressive segregants, since the parents Pusa Nutan, GARG-1, Jaipur Long and CO-1 involved in these crosses also exhibited high GCA. Similar results were reported by Narasannavar *et al* (2014b), Niyaria and Bhalala (2001), Mole *et al* (2001), Sarkar *et al* (2015), Lodam *et al* (2009) and Tyagi *et al* (2010).

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