



## Heterosis and combining ability analysis for productivity traits in ridge gourd [*Luffa acutangula* (L.) Roxb.]

Shivanand Koppad<sup>\*1</sup>, Mukesh Chavan<sup>2</sup>, Jyoti Patil, R.C. Jagadeesha and Shantappa T.

Department of Crop Improvement and Biotechnology, University of Horticultural Sciences, Bagalkot-591 310,  
KR College of Horticulture, Arabhavi, Tq. Gokak, District Belagavi, India

\*e-mail: shivu.643@gmail.com

(Received: January 23, 2016; Revised received: September 03, 2016; Accepted: September 06, 2016)

**Abstract:** The Line x Tester analysis was done with six lines and four testers of ridge gourd to study the heterosis and combining ability effects for growth, yield and yield attributing traits. The lines found to be good general combiners were  $L_4$  (12.18) and  $L_5$  (11.56) for vine length;  $L_4$  for number of branches (0.54) and number of leaves per vine (6.42), total chlorophyll content (0.05), average fruit weight (20.49), proline content (12.91), leaf area (41.61) and total fruit yield per vine (139.24);  $L_3$  (-4.82) and  $L_4$  (-2.60) for days to 50% flowering and days to first harvest. The best specific combiner for vine length was  $L_5 \times T_2$  (33.69). For numbers of leaves (6.32) and leaf area (41.82) the specific combiner was  $L_4 \times T_2$ . The hybrid  $L_2 \times T_4$  was earliest as it was specific combiner for days to 50% flowering (-3.53). Highly positive significant heterosis was observed for number fruits per vine (25.00%), total chlorophyll content of leaf (84.01%), leaf area (235.07%) and total fruit yield per vine (58.5%). Highly negative significant heterosis was observed with the days to 50% flowering (-15.38%) over the better parents. Three hybrids possessed significantly useful heterobeltiosis for fruit weight.

**Key words:** Better parent, Ridge gourd, Combining ability, Heterosis, Leaf area

### Introduction

Ridge gourd [*Luffa acutangula* (Roxb.) L.] is an important warm season cucurbitaceous vegetable crop grown in different parts of India and in the tropical countries of Asia and Africa (Reddy *et al.*, 2013). Being a warm season crop, it has the ability to tolerate hotter conditions, which makes it suitable for widespread cultivation throughout the tropics. Combining ability studies are more reliable as they provide useful information for the selection of parents in terms of performance the hybrids and elucidate the nature of magnitude of various types of gene actions involved in the expression of quantitative traits (Griffing, 1956). As such, so far there is no public sector or institutional commercial hybrids in ridge gourd in India, though few private hybrids from leading seed companies are being cultivated by growers. Hence, the present investigation was undertaken to its precision and versatility with an objective to select elite parental lines which can be utilized for future hybridization programmes and the best performing hybrids for commercial cultivation.

### Materials and Methods

The study was conducted with six lines and four testers and mated as per Line x Tester mating model of Kempthorne (1957). Thus a total of 24 hybrids of ridge gourd were synthesized at Dept. of Crop Improvement and Biotechnology, Kittur Rani Channamma College of Horticulture, Arabhavi during 2012-14. The experiment was conducted in RCB design with three replications. The

intercultural practices were followed as per the package of practices of horticultural crops of University of Agricultural Sciences, Dharwad (Anon., 2010). The vines were staked individually using wooden sticks and were trained uniformly. This helped the plants for better spreading and easy harvesting. Observations were recorded on vine length, number of leaves, number of branches, days to 50% flowering, days to first harvest, leaf area, total chlorophyll content, proline content of leaf, number of fruits per vine, average fruit weight and fruit yield per vine. Leaf area was estimated using the formula by Vivekanandan *et al.* (1972). Leaf extract proline content of the sample was calculated by using the formula given by Bates *et al.* (1973). Chlorophyll content of leaf tissue was estimated as suggested by Hiscox and Israelstom (1971). The biometrical analysis of the data and heterosis was carried out using Indostat programme. The combining ability analysis was done using Griffing's (1956) and Hayman's (1954) approach.

### Results and Discussion

Heterosis is the superiority of  $F_1$  over the mean of the parents or over the better parent (BP) or over the standard check (Hayes *et al.*, 1956) with respect to agriculturally useful traits. The primary objective of heterosis breeding is to achieve a quantum jump in yield and quality aspects of crop plants. Analysis of variance for general (gca) and specific (sca) combining ability showed highly significant differences for all the traits under the study (Table 1), suggesting both additive and non additive components of gene

**Table-1:** Analysis of variance for combining ability and genetic components of variation for growth, yield and yield attributing traits in ridge gourd

Source of variation	Vine length	No. of branches	No. of leaves	Days to 50% flowering	Days to 1 <sup>st</sup> harvest	No. of fruits/vine	Average fruit weight	Total chlorophyll content of leaf	Proline content of leaf	Leaf area	Total yield/vine
GCA	758.38**	4.33**	6.98**	47.8**	74.33**	1.25**	14353.1415**	156.841**	6.927**	11.240**	39.32**
SCA	432.07**	2.96**	1.93**	9.87**	12.96**	1.36**	15026.43**	43.021**	1.929**	6.392**	37.89**
Error	23.27	1.029	0.05	0.33	1.03	0.11	173.71	03.61	0.044	0.050	0.294
Genetic variance components											
Vg	73.51	3.73	0.69	4.75	7.33	0.15	1417.94	15.32	0.688	1.119	3.903
Vs	402.79	1.19	1.89	9.53	11.93	1.25	14852.72	39.41	1.885	6.342	37.59
VG/Vs	0.17	0.416	0.37	0.49	0.65	0.09	0.095	0.389	0.365	0.176	0.103
VA	147.02	14.66	1.89	9.50	14.66	0.23	2835.88	30.64	1.885	2.238	7.806
VD	408.79	11.93	3.31	9.53	11.93	1.25	14852.72	39.41	3.305	6.342	37.59
VA/VD	0.35	1.22	0.58	0.99	1.23	0.18	0.190	0.77	0.570	0.352	0.207
H <sup>2</sup> NS	0.25	0.53	0.45	0.49	0.53	0.14	0.158	0.416	0.416	0.259	0.170

**Table-2:** Estimation of gca effects of parents with respect to growth, yield and yield contributing characters

Source of variation	Vine length	No. of branches	No. of leaves	Days to 50% flowering	Days to 1 <sup>st</sup> harvest	No. of fruits/vine	Average fruit weight	Total chlorophyll content of leaf	Proline content of leaf	Leaf area	Total yield/vine
Lines											
L1	-3.12	-0.39*	-2.07*	0.99	2.33**	0.15	-17.76**	0.03	-8.34**	-5.17	-99.53
L2	7.81*	0.42*	1.49	-3.26**	-4.04**	-0.17	8.46	0.02	0.41	19.77**	40.26
L3	-29.81**	-0.79**	-9.07	-4.82**	0.21	0.15	-28.39**	0.02	-5.41**	-24.82**	-187.56**
L4	12.18**	0.54**	6.42**	-1.69**	-2.60**	-0.04	20.49**	0.05*	12.91**	41.61**	139.24*
L5	11.56**	0.35*	0.67	2.98**	1.02	0.02	11.59*	0.06*	12.33**	10.96**	82.95
L6	1.37	-0.14	2.55*	5.86**	3.27**	-0.10	5.80	-0.07*	-1.89	-20.43**	24.63
S.Em. ±	2.65	0.11	0.57	0.40	0.36	0.21	5.57	0.02	1.26	2.62	55.97
CD @ 5%	7.81	0.33	1.67	1.18	1.07	0.44	11.53	0.05	3.70	7.72	115.78
CD @ 1%	10.59	0.44	2.28	1.60	1.44	0.59	15.65	0.07	5.03	10.48	157.13
Testers											
T1	-3.85	-0.224	-0.74	0.24	-1.41**	-0.21	-5.64	0.005	-0.98	1.75	-52.43
T2	-1.31	-0.016	-0.57	-0.43	-1.58**	0.021	6.65	0.044*	-0.78	9.57**	47.15
T3	1.52	-0.016	1.34	0.16	0.42	-0.021	-12.13*	-0.034	2.19	-2.62	-86.76
T4	3.64	0.255	-0.03	0.03	2.58**	0.021	11.12*	-0.015	-0.42	-8.70**	92.04
S.Em. ±	2.16	0.09	0.46	0.47	0.33	0.12	3.19	0.02	1.46	2.14	32.17
CD @ 5%	6.38	0.27	1.36	0.96	0.88	0.36	9.41	0.04	3.02	6.31	94.54
CD @ 1%	8.65	0.36	1.85	1.30	1.20	0.49	12.78	0.06	4.10	8.56	128.30

action. Though the ratio of  $Vg/Vs$  indicated greater role of non additive gene effects in the inheritance for all the characters. The estimates of effects due to gca of parents and sca of crosses have been presented in Table 2 and 3, respectively. The best heterotic hybrids for important traits were presented in Table 4. The lines  $L_5$  and  $L_4$  were found to be good general combiners for vine length and can be used for breeding long vine cultivars. The cross combination  $L_5 \times T_2$  (33.69) exhibited the highest positive sca estimates. The variance ratio of general combining ability and specific combining ability ( $Vg/Vs$ ) was less than unity, indicating the preponderance non additive gene effects for vine length. These results are in agreement with findings of Sharma and Sharma (2010) in tomato, Singh *et al.* (2013) in ridge gourd and Pujer *et al.* (2014) in cherry tomato.

General combining ability of the parents revealed that the line  $L_3$  (-4.82) found to be good general combiners for days to 50%

flowering and these parents will therefore be of use in breeding for earliness, however the cross combination  $L_3 \times T_1$  (-3.53) exhibited highest negative sca estimates for the days to first harvest followed by  $L_2 \times T_1$  (-1.53) which are in the desired direction. Similar results have been reported by Mole *et al.*, 2001 and Laxuman *et al.*, 2012 in ridge gourd.

For the trait number of fruits per vine,  $L_3$  &  $L_1$  were showed with positive general combining ability. The crosses  $L_2 \times T_1$  (0.53) &  $L_2 \times T_2$  (0.27) were the best two specific combiners for number of fruits per vine. Number of fruits per vine directly contributes to the total yield per vine in case of ridge gourd. Preponderance of non additive effects for these traits was observed as the variance ratio of general combining ability and specific combining ability ( $Vg/Vs$ ) was less than unity. Similar results were put forth by Singh *et al.* (2013).

The general combining ability estimates of the lines  $L_4$  &  $L_5$  were positive and significant which intern appeared to be good

**Table-3:** Estimation of sca effects of parents with respect to growth, yield and yield contributing characters

Source of variation	Vine length	No. of branches	No. of leaves	Days to 50% flowering	Days to 1 <sup>st</sup> harvest	No. of fruits/vine	Average fruit weight	Total chlorophyll content of leaf	Proline content of leaf	Leaf area	Total yield/vine
L <sub>1</sub> x T <sub>1</sub>	-6.83	-0.15	2.24	-2.74*	-5.01**	0.27	1.67	-0.15**	-5.89	-14.95	47.34
L <sub>1</sub> x T <sub>2</sub>	-3.37	-0.36	-4.68**	2.17	1.08	0.23	-21.20	0.07	-3.06	1.99	-129.45
L <sub>1</sub> x T <sub>3</sub>	-0.96	0.39	1.16	1.84	2.08	0.20	38.48**	-0.04	4.62	17.71*	-2297.00*
L <sub>1</sub> x T <sub>4</sub>	11.67	0.12	1.28	-1.28	1.91	-0.52	-18.94	0.12*	4.33	-4.76	-214.87
L <sub>2</sub> x T <sub>1</sub>	2.23	0.04	2.43	5.77**	0.54	-0.17	6.79	-0.17**	-0.37	20.83*	24.13
L <sub>2</sub> x T <sub>2</sub>	-7.56	-0.17	0.26	-1.07	3.96**	0.04	1.77	0.03	0.22	-14.12	17.45
L <sub>2</sub> x T <sub>3</sub>	3.11	-0.17	-0.91	-1.16	-0.79	-0.41	0.71	0.18**	-0.94	18.12*	-64.26
L <sub>2</sub> x T <sub>4</sub>	2.23	0.31	-1.78	-3.53**	-3.71**	0.54	-9.27	-0.04	1.09	-24.84**	22.69
L <sub>3</sub> x T <sub>1</sub>	17.10*	0.25	-0.51	-0.68	-2.27*	0.27	-8.79	0.001	-3.68	3.53	-21.41
L <sub>3</sub> x T <sub>2</sub>	-1.94	-0.20	-4.43*	-0.01	-1.10	-0.02	14.34	-0.06	0.89	-16.08*	109.61
L <sub>3</sub> x T <sub>3</sub>	-10.02	0.05	1.16	-0.09	3.39**	0.27	-11.27	-0.01	8.45*	-7.86	-53.22
L <sub>3</sub> x T <sub>4</sub>	-5.15	-0.09	3.78*	0.78	-0.02	-0.52	5.73	0.06	-5.34	20.41*	-35.27
L <sub>4</sub> x T <sub>1</sub>	-9.89	-0.09	-1.26	-1.80	1.60	0.21	-9.71	0.16**	-2.22	-19.77*	-30.81
L <sub>4</sub> x T <sub>2</sub>	-6.19	0.45	6.32**	0.11	0.77	-0.08	16.98	0.9	6.27	41.82**	107.61
L <sub>4</sub> x T <sub>3</sub>	12.98	-0.5	-0.59	0.78	-1.97	-0.04	5.77	-0.15**	-1.05	-22.37**	37.27
L <sub>4</sub> x T <sub>4</sub>	3.10	-0.32	-4.47*	0.91	-0.37	-0.08	-13.03	-0.11*	-3.00	-9.68	-114.27
L <sub>5</sub> x T <sub>1</sub>	-8.27	0.09	-1.01	-0.68	2.47*	-0.60	31.94**	-0.09	-0.12	5.31	121.98
L <sub>5</sub> x T <sub>2</sub>	33.69**	0.14	2.83	1.24	-1.85	0.10	-17.47	0.03	3.01	-0.55	-100.52
L <sub>5</sub> x T <sub>3</sub>	-4.65	-0.11	-1.09	-0.59	-1.35	0.14	-29.62*	0.08	-192	3.23	-189.53
L <sub>5</sub> x T <sub>4</sub>	-20.77*	-0.13	-0.72	0.03	0.72	0.35	15.11	-0.01	-0.98	-8.04	168.07
L <sub>6</sub> x T <sub>1</sub>	5.67	-0.15	-1.89	0.14	2.73*	0.02	-21.88	0.25**	12.58**	-4.95	-141.53
L <sub>6</sub> x T <sub>2</sub>	-14.63	0.14	-0.30	-2.45*	-2.85*	-0.27	5.59	-0.16**	-7.33	-13.06	-4.68
L <sub>6</sub> x T <sub>3</sub>	-0.46	-0.11	0.28	-0.78	-1.35	0.02	-4.06	-0.07	-9.15*	-8.87	-27.27
L <sub>6</sub> x T <sub>4</sub>	9.42	0.12	1.96	3.10*	1.48	0.23	20.35	-0.02	3.89	26.90**	173.48
S.Em ±	5.30	0.22	1.14	0.80	1.04	0.40	7.82	0.03	2.51	6.99	78.56
C.D. @ 5%	15.61	0.66	3.35	2.36	2.16	0.88	23.07	0.10	7.42	15.46	231.57
C.D. @ 1%	21.19	0.89	4.55	3.20	2.93	1.20	31.31	0.14	10.05	20.98	314.26

**Table-4:** Best heterotic hybrids for important traits in ridge gourd lines

Vine length		No. of branches		No. of harvest		Days to 50% flowering		Days to 1 <sup>st</sup> harvest		No. of fruits/vine	
Crosses	BP	Crosses	BP	Crosses	BP	Crosses	BP	Crosses	BP	Crosses	BP
L <sub>5</sub> x T <sub>1</sub>	31.49	L <sub>4</sub> x T <sub>2</sub>	28.57	L <sub>4</sub> x T <sub>2</sub>	23.28	L <sub>3</sub> x T <sub>1</sub>	-15.38	L <sub>1</sub> x T <sub>1</sub>	-10.70	L <sub>2</sub> x T <sub>2</sub>	25.00
L <sub>5</sub> x T <sub>4</sub>	27.27	L <sub>3</sub> x T <sub>4</sub>	28.57	L <sub>4</sub> x T <sub>3</sub>	15.65	L <sub>3</sub> x T <sub>2</sub>	-14.66	L <sub>3</sub> x T <sub>1</sub>	-8.61	L <sub>5</sub> x T <sub>2</sub>	20.83
L <sub>3</sub> x T <sub>3</sub>	21.96	L <sub>4</sub> x T <sub>3</sub>	19.05	L <sub>4</sub> x T <sub>1</sub>	11.45	L <sub>3</sub> x T <sub>3</sub>	-14.16	L <sub>5</sub> x T <sub>2</sub>	-7.78	L <sub>5</sub> x T <sub>4</sub>	20.00
L <sub>4</sub> x T <sub>1</sub>	20.93	L <sub>4</sub> x T <sub>4</sub>	19.05	L <sub>6</sub> x T <sub>4</sub>	11.45	L <sub>2</sub> x T <sub>2</sub>	-10.31	L <sub>2</sub> x T <sub>1</sub>	-4.40	L <sub>2</sub> x T <sub>4</sub>	20.00
L <sub>4</sub> x T <sub>2</sub>	20.53	L <sub>5</sub> x T <sub>2</sub>	19.05	L <sub>6</sub> x T <sub>3</sub>	11.07	L <sub>3</sub> x T <sub>4</sub>	-7.73	L <sub>6</sub> x T <sub>2</sub>	-3.79	L <sub>4</sub> x T <sub>2</sub>	16.67
S.Em ±	4.78	S.Em ±	0.31	S.Em ±	1.60	S.Em ±	1.13	S.Em ±	1.03	S.Em ±	0.42
CD @ 5%	13.86	CD @ 5%	0.93	CD @ 5%	4.74	CD @ 5%	3.33	CD @ 5%	3.05	CD @ 5%	1.24

Average fruit weight		Total chlorophyll content of leaf		Proline content of leaf		Leaf area		Total yield per vine	
Crosses	BP	Crosses	BP	Crosses	BP	Crosses	BP	Crosses	BP
L <sub>1</sub> x T <sub>3</sub>	34.84	L <sub>4</sub> x T <sub>2</sub>	84.01	L <sub>6</sub> x T <sub>1</sub>	59.72	L <sub>4</sub> x T <sub>2</sub>	235.57	L <sub>4</sub> x T <sub>2</sub>	58.59
L <sub>5</sub> x T <sub>1</sub>	33.52	L <sub>3</sub> x T <sub>3</sub>	45.76	L <sub>3</sub> x T <sub>2</sub>	55.21	L <sub>4</sub> x T <sub>1</sub>	141.40	L <sub>5</sub> x T <sub>4</sub>	53.86
L <sub>5</sub> x T <sub>4</sub>	33.50	L <sub>4</sub> x T <sub>3</sub>	23.54	L <sub>3</sub> x T <sub>3</sub>	48.11	L <sub>2</sub> x T <sub>1</sub>	136.06	L <sub>2</sub> x T <sub>4</sub>	48.93
L <sub>2</sub> x T <sub>4</sub>	21.97	L <sub>6</sub> x T <sub>1</sub>	5.33	L <sub>2</sub> x T <sub>2</sub>	39.07	L <sub>1</sub> x T <sub>2</sub>	134.33	L <sub>5</sub> x T <sub>1</sub>	44.02
L <sub>2</sub> x T <sub>3</sub>	19.29	L <sub>4</sub> x T <sub>1</sub>	1.06	L <sub>5</sub> x T <sub>2</sub>	27.37	L <sub>2</sub> x T <sub>3</sub>	125.63	L <sub>1</sub> x T <sub>3</sub>	41.74
S.Em ±	13.07	S.Em ±	0.06	S.Em ±	5.66	S.Em ±	7.41	S.Em ±	11.11
CD @ 5%	39.21	CD @ 5%	0.18	CD @ 5%	10.48	CD @ 5%	21.86	CD @ 5%	32.49

BP : Better parent

genetic combiners. Hybrid  $L_5 \times T_1$  exhibited high sca effects for average fruit weight. The parents  $L_4$  and  $L_5$  showed good general combiners for total chlorophyll content and proline content of leaf and leaf area. The hybrids  $L_5 \times T_1$  and  $L_4 \times T_1$  performed high positive significant sca effects for proline content and chlorophyll content respectively. The similar findings are with Simuzu *et al.* (2005) in cauliflower. The lines involved in production of more amount of chlorophyll in the leaf were contributed more to the hybrids.

The analysis of variance in treatments for in eleven characters in heterosis namely vine length, number of branches per vine, number of leaves, days to 50% flowering, days to first harvest, number of fruits per vine, average fruit weight, fruit yield per vine, leaf area, total chlorophyll content and proline content showed significant results. Variance due to parents showed significant difference for all the characters. Parents versus hybrids interaction showed significant difference for all the characters studied.

The heterosis for vine length showed highly positive significant in a crosses,  $L_5 \times T_1$  (31.49),  $L_5 \times T_4$  (27.27) and  $L_3 \times T_3$  (21.96). The extent of heterosis was exhibited by hybrids in case of number of branches per vine revealed that, eight hybrids exhibited positive significant heterosis over better parent from them three hybrids shown same level it was at 19.09 ( $L_4 \times T_3$ ,  $L_4 \times T_4$  and  $L_5 \times T_2$ ). Similarly, in case of number of leaves per vine, positive significant heterosis over a better parent and which ranged between 1.12 ( $L_1 \times T_1$ ) to 23.28 ( $L_4 \times T_2$ ). The cross  $L_3 \times T_1$  (-15.38) found to be highly negative significant heterosis followed by the crosses,  $L_3 \times T_2$  (-14.66) and  $L_3 \times T_3$  (-14.16) which shows the early flowering. For days to 1<sup>st</sup> harvest the significant negative heterosis from  $L_1 \times T_1$  (-10.70) followed by  $L_3 \times T_1$  (-8.61) and  $L_5 \times T_2$  (-7.78). Number of fruits per vine is one of the important yield components among 24 hybrids, 14 hybrids found to be positive significant heterosis for this trait. The highest heterobeltiosis found by the hybrids,  $L_2 \times T_2$  (25.00),  $L_5 \times T_2$  (20.83) and  $L_5 \times T_4$  (20.00). Number of fruits per vine indicated the percent fruit set. These results are online with Purohit *et al.* (2007), Laxuman *et al.* (2012), Singh *et al.* (2013) and Pujer *et al.* (2014).

Average fruit weight showed high positive significant heterosis over the better parent. The extent of heterosis was ranged from 2.00 ( $L_5 \times T_2$ ) to 34.84 ( $L_1 \times T_3$ ) for the yield per vine. The results are controversy with Pujer *et al.* (2014) who got the high negative significant heterosis over the better parent for the trait average fruit weight in cherry tomato. For the total yield per vine highest better parent heterosis was seen in the hybrid  $L_4 \times T_2$  (58.59) followed by  $L_5 \times T_4$  (54.36) and  $L_2 \times T_4$  (48.93). The fore going discussion on yield and yield component indicated the role of non additive and additive gene effects in governing these traits.

The total chlorophyll content of leaf is an important trait responsible for high photosynthesis and production of more photosynthates in ridge gourd. The positive heterosis ranged between 1.06 ( $L_4 \times T_1$ ) to 84.01 ( $L_4 \times T_2$ ) for production of more chlorophyllus materials in their leaves. The proline is one of the important amino acid, which accumulate in the leaves during less

irrigation condition or drought condition, which contributes for long duration of the crop. For this trait, 6 hybrids were performed positive significant heterosis over better parent and it ranged from 0.16 ( $L_2 \times T_3$ ) to 177.64 ( $L_3 \times T_3$ ). Thus showing additive gene action for the said trait and selection for this trait will produce the drought tolerant lines for the rain fed areas. For the trait leaf area of the plant among the 24 hybrids, 22 crosses expressed significant positive heterosis (desired direction) over better parent its ranged from 11.73 ( $L_3 \times T_3$ ) to 35.57 ( $L_4 \times T_2$ ) confirming more additive gene effects. The hybrid ( $L_4 \times T_2$ ) which are having more number of leaves are directly contributing high amount of chlorophyll and large leaf area. The combining ability analysis revealed the preponderance of additive gene action for the expression of this trait. Similar findings were coated by Reddy *et al.* (2013).

The combining ability analysis revealed that, both additive and non additive components of variation were important for all the traits. The Preponderance of additive action was observed for all the traits. Hence heterosis breeding would be the best option for improvement of these traits studied.

### Reference

- Anonymous: Package of practices for agricultural crops (Kannada), Univ. Agril. Sci., Dharwad, p. 273-276 (2010).
- Bates, L.S., Walderen, R.P. and Teare, I.D.: Rapid determination of free proline in water stresses studies. *Plant and Soil.*, **39**: 205-207 (1973).
- Griffings, B.: Concept of general and specific combining ability in relation to diallele crossing system, *Aust. J. Biol. Sci.*, **9**: 463-493 (1956).
- Hayes, H.K., Immer, F.F. and Smith, D.C.: Methods of Plant Breeding. McGraw Hill Book Publishing Company, Inc., New Delhi (1956).
- Hayman, B.I.: The analysis of variance of diallele tables. *Biometrics*, **10**: 235-244 (1954).
- Hiscox, J.D. and Israelstom, G.F.: A method of extraction of chlorophyll content from leaf tissue without maceration. *Canadian J. Bot.*, **57**: 1332-1334 (1979).
- Laxuman, Patil S.A., Salimath, P.M., Dharmatti, P.R., Byadagi, A.S. and Yenagi, N.: Heterosis and combining ability analysis for productivity traits in bitter gourd (*Momordica charantia* L.). *Karnataka J. Agric. Sci.*, **25**: 9-13 (2012).
- Mole, T.J., Nirmala, D., Rajan, S. and Sadhankumar, P.G.: Heterosis and combining ability in ridge gourd (*Luffa acutangula* roxb.). *Veg. Sci.*, **28**: 165-167 (2001).
- Pujer, P., Jagadeesha, R.C. and Mahesh, B.: Combining ability analysis and heterosis for growth, yield and quality traits in cherry tomato (*Solanum lycopersicum*). *Green Farming*, **5**: 758-761 (2014).
- Purohit, V.L., Mehta, O.R., Dhaduk, L.K. and Gajipara, N.N.: Combining ability for fruit yield and its attributes in ridge gourd [*Luffa acutangula* (roxb.) L.]. *Veg. Sci.*, **34**: 84-85 (2007).
- Reddy, R.P., Reddy, V.S.K. and Padma, S.S.V.: Performance of parents and hybrids for yield and yield attributing characters in ridge Gourd (*Luffa acutangula* (Roxb.) L.). *The Bioscan.*, **8**: 1373-1377 (2013).
- Sharma, D. and Sharma, H.R.: Combining ability analysis for yield and other horticultural traits in tomato. *Ind. J. Hort.*, **67**: 402-405 (2010).
- Singh, S.K., Singh, B., Kumar, U. and Rai, M.: Heterosis analysis in bitter gourd through Line  $\times$  Tester design. *Veg. Sci.*, **34**: 95 (2013).
- Simuzu, A.G., Demirsoy, H. and Demirsoy, L.: A validated physiology prediction model sunflower. *Pak. J. Bot.*, **35**: 361-367 (2005).
- Vivekandan, A.S., Gunasena, H.P.M. and Shiavnygam, T.: Statistical evaluation of the techniques used in the estimation of leaf area of crop plants. *Ind. J. Agric. Sci.*, **42**: 857-860 (1972).
- Kemphorne, O.: An introduction to genetic statistics. *John Wiley and Sons*. New York, p. 408-711 (1957).