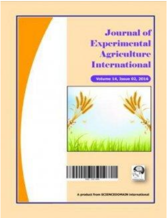

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Combining Ability Studies in Lentil for Yield and Its Related Attributes

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Authors' contributions

This work was carried out in collaboration between all authors. Author SM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MSJ, NBS and PRS managed the analyses of the study. Author EVDS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

To study the inheritance of some important yield contributing characters and yield through combining ability analysis, the eight parents of lentil genotypes were selected and crossed in diallel without reciprocals. The analysis of variance for combining ability revealed highly significant differences among crosses for all the characters studied. The σ^2gca/σ^2sca ratio was shown to be less than unity for most of the characters indicating the predominant role of non-additive gene action in the inheritance of these characters. However, for the characters days to first flowering and days to 50% flowering, the ratio was found to be more equal to unity indicating the importance of both additive and non-additive gene action in the expression of these characters. In case of GCA effects, DKL 50, L4147 and IPL 406 were identified as the most promising parents. On the basis of SCA effects, RLG 161 × IPL 406 was the most promising cross combinations for improvement of seed yield and no. of pods/plant. This heterotic cross having highly significant SCA effects for seed yield

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involved both the parents either as good general combiners or at least one good general combiner for seed yield. The manifestation of heterosis for seed yield was evidenced by superiority of hybrids ranging from 1.02 to 91.18% in the 24 crosses over better parent and from 1.02 to 46.94% in 21 crosses over standard check variety (PL 4). Out of 28 cross combinations, 20 crosses exhibited significant heterosis over their better parent as well as standard check. Overall on the basis of results of mean performance, including GCA and SCA effects and standard heterosis, PL 166 × DKL 50 and L 4147 × PL 4 were identified as the most promising cross combinations for improvement of seed yield in lentil.

Keywords: Gene action; heterosis; seed yield; lentil.

ABBREVIATIONS

GCA	:	*General Combining Ability*
SCA	:	*Specific Combining Ability*
RBD	:	*Randomized Block Design*

1. INTRODUCTUION

Pulses are also an excellent feed as fodder for livestock. Pulses contain 18 to 32% protein and 1 to 5% fat, which is almost twice the protein in wheat and thrice that of rice [1]. Pulses are considerably richer in calcium than most cereals and contain about 100 to 200 mg of calcium/100 g of grain. They are also rich in iron, thiamine, riboflavin, and niacin as compared to cereals. Endowed with the unique ability of biological nitrogen fixation, carbon sequestration, low water requirement and capacity to withstand abiotic stresses, pulses are a major component of sustainable crop production, especially in rainfed system. Though India the second largest producer [2] and [3] of pulses in the world, with 22.52% share in the global production, it is also the largest importer and consumer of pulses.

Lentil is one of the major *rabi* pulse crop grown in India since time immemorial and contributes significantly to food, feed and sustainable farming systems. It contains a high amount of digestible protein (up to 35%), macro and micronutrients, particularly, iron, zinc and vitamins, thus provides nutritional security to its consumers the straw is a valued animal feed [4, 5] and [6].

Lentil (2n=2x=14) is an annual, herbaceous and short growing self-pollinated crop. It has low-bushy, sub-erect or erects growing habit. Plant height ranges from 15-75 cm depending upon the genotype and growing conditions. The leaves are light green, alternate, pinnate with 1 to 8 pairs of leaflets. Lentil is mostly consumed as dry seed (whole decorticated, decorticated and split). High yielding variety is the main objectives in most of the crop improvement programmes. Yield as such is the most complex character and is contributed by several components, most of which are polygenically inherited.

Hence, improvement in the grain yield on the basis of *per se* performance is rather difficult. Therefore, determination of association among important metric traits, would enable the breeders to design appropriate breeding strategies for effective selection programme in this crop. The other objectives in lentil breeding programme including high harvest index, response to high plant density, input use of efficiency and early maturity in the improved cultivars. In Manipur, ample area is available for growing lentil during the *rabi* season. Developing suitable variety for the rice fallow condition is essential.

2. MATERIALS AND METHODS

The experimental field is situated at 24° 51 'N latitude 93° 56 'E longitudes and at an altitude of 790 metre above mean sea level. The soil is clay type having acidic pH of 5.4 with available N (326 kg/ha), P_2O_5(26.4) and K_2O (324 kg/ha). The total rainfall during the crop growth period was 61.9 cm spread over in 28 rainy days with the temperature range from 3.7°c to 29.2°c. In the present investigation, eight genetically diverse varieties of lentil processing different morphological and productive attributes were used. The experiment took two crop seasons. In the first season of *rabi* 2015-2016, F1 hybrid seeds were produced following diallel cross analysis without reciprocals using eight parental lines by hand emasculation and pollination technique and obtained 28 F1 seeds. In the next crop season of *rabi* 2016-2017, all the seeds of 28 F1 cross combination with eight parental lines totally 36 treatments were grown in the RBD with three replication.

Table A. Parents used in the present study

Genotypes	Pedigree	Sources
VL 147	VL 501 x VL 133	VPKAS, Almora
PL 166	PL 5 x DPL 15	GPUAT, Pantnagar
IPL 406	DPL 35 x EC 157634/382	IIPR, Kanpur
RLG161	RLG 14 x L 4076	Durgapura, Rajasthan
VL 146	VL 4 x PL 406	VPKAS, Almora
DKL 50	Sehore 74-3 x PL 4	Dhaulakaun, H.P.
L4147	(L3875 x P4) PKVL 1	IARI, New Delhi
PL 4	UPL 175 (PL 184 x P288)	GPUAT, Pantnagar

The experimental material was sown in a randomized block design with three replication having one row of 1.5 m length. All the 36 treatments were sown with 22.5 cm row to row and 10 cm plant to plant spacing by using a fertilizer dose of 20:40:20 kg NPK/ha. Observations were recorded on five randomly taken plants from each entry and in each replication for seven traits *viz.,* days to first flowering, days to 50% flowering, plant height, number of pods/plant, number of secondary branches/plant, seed yield/plant and 100 seed weight. The data were analysed using method given by Griffing (1956) [7] and the PBtools software (IRRI,2013).

3. RESULTS AND DISCUSSION

The analysis of variance to test the differences between sets of progenies included in the study in a diallel set of 28 f_1s (without reciprocals) and eight parents for the characters *viz*., days to first flowering, days to 50% flowering, number of secondary branches/plant, plant height, number of pods/plant, seed yield/plant and 100 seed weight. The differences among genotypes were found to be highly significant for all the characters studied. The *per se* performance of the parents was good indicator of their gca effects. The parent l4147 and ipl 406 having good *per se* performance for seed yield/plant with no. Of pods/plant. Dkl 50 for number of pods/plant, days to first flowering and days to 50% flowering, plant height. The superior specific cross combinations rlg 161 × ipl 406 had positive gca effects for seed yield/plant and no. Of pods/plant. The crosses pl 166 × vl 146 and rlg 161 × dkl 50 was shown good *per se* performance for 100 seed weight and no. Of secondary branches/plant. The crosses rlg 161 × l 4147 and rlg 161 × pl 4 were shown positive significance for days to first flowering and plant height respectively. These results were corroboration with the results of [8] reported in field pea that most of the traits were influenced the yield.

3.1 General and Specific Combining Ability Effects

The magnitude and direction of combining ability effects provide guidelines for selecting parents and their utilization. The general combining ability (GCA) effects represents the fixable components of genetic variance which include both additive and additive × additive interactions. The parent IPL 406 recorded significantly positive GCA effects for number of pods/plant and 100 seed weight. DKL 50 was found to be good general combiners for days to first flowering, days to 50% flowering and plant height. [9] studied diallel analysis in black gram and found that some of the parents were good general combiner for most of the trait under study. On the basis of overall performance across 7 characters, the DKL 50, L 4147 and IPL 406 were identified as the most promising parents because this parents were noticed either good or average general combiners for seed yield and other yield contributing characters. These parents may serve as valuable parents for hybridization programme or multiple crossing programmes to achieve good sergeants. [10] has done similar experiment for genetic variability studies in black gram and found that high genotypic coefficient of variation in plant height and 100 seed weight which contribute more for seed yield and its component traits. The significant GCA effects for seed yield in positive direction resulted from similar GCA effects of some yield components indicating that the combining ability of seed yield was influenced by the combining ability of its component traits [11]. Therefore, simultaneous improvement in important yield contributing traits along with seed yield may be better approach for raising yield potential in lentil. The magnitude of SCA effects is of prime importance in selecting the cross combinations with higher probability of obtaining transgressive segregates. SCA indicates the deviation in performance of a cross combination for the performance expected on the basis of general combining ability. It may be desirable to consider both the SCA effect and mean performance when selection is made. Out of 28 cross combinations, one for days to first flowering (RLG 161 × L 4147), one for plant height (RLG 161 × PL 4), eight for number of pods/plant (DKL 50 × L 4147, PL 166 × DKL 50, PL 166 × L 4147 etc.), six for number of secondary branches/plant (VL 147 × RLG 161, PL 166 × VL 146, L 4147 × IPL 406 etc.), three for seed yield/plant (VL 147 × DKL 50, L 4147 × PL 4 and VL 146 × IPL 406), two for 100 seed weight (PL 166 × L 4147 and RLG 161 × DKL 50) exhibited desirable and highly significant SCA effects. Similar results were also obtained while studied by [12] for combining ability in cow pea and found that SCA variances were highly significant for all the character and these characters were influenced the yield. In general, maximum crosses showing significant SCA effects, were invariably associated with better *perse* performance for respective traits. The results were in agreement with those obtained by [13] and [14] in pea, whom concluded that mean performance of the crosses were closely associated with SCA effects. Hence selection of the crosses on the basis of heterotic response should prove effective. On the basis of both SCA effects, the cross RLG 161 × IPL 406 appeared to be the best combination for seed yield with no. of pods/plant. Other researchers [15] in pea for seed yield with one other trait from half diallel analysis) also reported similar results.

From the Table 3 it is revealed that most of the good specific cross combinations for different characters involved parents of low × low, average × average, high × average, average × high and high × high general combining ability. However, in majority of cases, the crosses exhibiting high SCA effects were found to have either or both of the parents as good general combiner for the character under reference. In black gram [16] was also reported that most of the promising cross is the one that involves parents with high GCA. The major part of such variance would be fixable in later generations. Such crosses were RLG 161 × L 4147 for days to first flowering, RLG × PL 4 for plant height, VL 147 × RLG 161 for number of pods/plant and PL 166 × L 4147 for 100 seed weight. Recombination breeding through multiple crosses involving these hybrids would be desirable to breed genotypes combining these characters. Similar findings were also reported for non-additive gene action while studied for seed yield/plant, 100 seed weight, number of secondary branches/plant and number of pods/plant in lentil by [17]. Out of 28 cross combinations, 24 combinations exhibited significant heterosis over their better parent and 21 crosses over its standard check, while nineteen crosses, *viz.*, VL 147 × DKL 50, PL 166 × DKL 50, PL 166 × PL 4, RLG 161 × DKL 50, DKL 50 × IPL 406, L4147 × PL4 etc. were common in heterobeltiosis and standard heterosis for seed yield along with other of its components. These results were found in agreement with the study of [12] in pigeon pea some of the crosses were which exhibited significant heterosis over their better parent and standard check variety.

A perusal of Table 4 and 5 reveals that heterosis in seed yield was almost proportional to the heterosis observed for yield components. In majority of cases, one or three components registered heterosis in seed yield. Twenty four crosses showing significant positive heterobeltiosis for seed yield also exhibited significantly positive heterobeltiosis for days to first flowering, number pods/plant, plant height, number of secondary branches/plant and 100 seed weight. Similarly in pea [18] was also reported significant positive heterobeltiosis for number of pods/plant and seed yield/plant. Substantial amount of heterosis over better parent for plant height, no. of pods/plant and seed yield/plant in pea was revealed [19]. In case of standard heterosis, most of the crosses showing heterosis for seed yield were found to register significant positive heterosis for number of pods/plant, plant height, no. of secondary branches/plant and 100 seed weight. Similar results were reported by [20] In lentil from heterosis studies. The majority of crosses with significant positive heterosis for seed yield over better parent or check parent also had desirable heterosis for plant height, no. of pods/plant, no. of secondary branches/plant and 100 seed weight. This results were supported by [21] and [22] for heterosis and inbreeding depression studies in pea. The highest significant and positive percent heterosis over the standard variety was found in cross PL 166 × L 4147 and PL 166 × VL 146. Thus from the point of 100 seed weight these crosses having positively significant values can be selected. The significant heterosis for days to first flowering was observed by [23] for diallel analysis In lentil. However, number of pods/plant,

Table 1. Estimates of general combining ability effects for different traits in a half-diallel cross of lentil

Parents	Days to first flowering	Days to 50% flowering	Plant height (cm)	No. of pods/plant	No. of secondary branches/plant	Seed yield/plant (g)	100 seed weight (g)
VL 147	3.84**	3.44**	0.93	-5.12**	0.02	-0.08**	-0.18*
PL 166	0.18	-0.09	-1.20	3.26**	0.04	0.02	0.08
RLG 161	0.27	0.92	0.16	-9.25**	-0.23	0.00	-0.01
DKL 50	-1.98**	-1.94**	-1.62*	3.55**	-0.19	-0.06**	0.03
L 4147	0.07	0.26	0.78	5.44**	0.31	0.07**	-0.07
PL 4	0.02	-0.52	0.38	1.54*	0.30	-0.00	-0.02
VL 146	-1.27*	-0.94	-0.19	-1.72*	0.29	0.00	-0.15
IPL 406	-1.11	-1.13	0.76	2.29**	-0.54**	0.04**	0.30**
S.E. (g_I)	0.41	0.42	0.49	0.46	0.12	0.01	0.05
S.E. (g_I-g_J)	0.62	0.64	0.74	0.69	0.19	0.01	0.08
C.D. (5%)	1.23	1.27	1.47	1.37	0.38	0.02	0.16
C.D. (1%)	1.64	1.70	1.96	1.83	0.50	0.03	0.21

, Significant at 5% and 1% levels, respectively*

Table 2. Estimates of Specific combining ability effects for different traits in a half-diallel cross of lentil

Crosses	Days to first flowering	Days to 50% flowering	Plant height (cm)	No. of pods/plant	No. of secondary branches/plant	Seed yield/plant (g)	100 seed weight (g)
VL 147 × PL 166	-2.81	0.01	0.97	-7.54**	-0.10	-0.07	0.18
VL 147 × RLG 161	1.70	0.64	1.50	2.30	2.70**	-0.03	-0.07
VL 147 × DKL 50	4.08*	3.05	2.33	-3.00	0.07	0.13**	0.14
VL 147 × L 4147	-0.50	-3.09	0.54	1.28	0.07	-0.00	0.25
VL 147 × PL 4	-1.52	-0.48	0.50	0.34	-2.59**	-0.03	-0.06
VL 147 × VL 146	1.89	1.22	-1.43	5.22*	0.65	-0.11*	0.11
VL 147 × IPL 406	3.62	3.36	-2.17	0.05	-1.72**	0.01	-0.22
PL 166 × RLG 161	-0.68	-2.56	-1.61	-8.92**	-2.51**	-0.01	0.06
PL 166 × DKL 50	0.49	-0.42	-0.09	10.73**	0.17	0.02	-0.15
PL 166 × L 4147	1.21	1.30	-1.44	9.12**	-0.72	-0.02	0.72**
PL 166 × PL 4	0.06	-0.28	-0.72	4.78*	1.69**	0.04	-0.08
PL 166 × VL 146	1.69	1.78	-0.57	-4.95*	2.25**	-0.03	0.60*

Crosses	Days to first flowering	Days to 50% flowering	Plant height (cm)	No. of pods/plant	No. of secondary branches/plant	Seed yield/plant (g)	100 seed weight (g)
PL 166 × IPL 406	0.94	1.55	0.92	-2.34	-0.43	0.06	-0.75**
RLG 161 × DKL 50	-0.52	0.24	2.60	-5.65**	1.66**	0.02	0.55*
RLG 161 × L 4147	-3.75*	-0.63	1.70	-9.76**	-0.45	0.03	-0.12
RLG 161 × PL 4	3.52	2.32	-5.61*	-5.81**	-2.11**	-0.02	0.27
RLG 161 × VL 146	0.62	0.41	2.79	-0.58	-1.60**	0.05	-0.14
RLG 161 × IPL 406	-0.18	-0.90	0.39	8.56**	-0.83	-0.02	0.21
DKL 50 × L 4147	-1.16	1.74	-3.85	15.77**	-0.55	-0.08	0.03
DKL 50 × PL 4	-1.94	0.40	-3.84	-6.66**	0.51	-0.08	0.18
DKL 50 × VL 146	-2.33	-2.62	-1.88	-3.51	-1.53**	0.00	0.21
DKL 50 × IPL 406	-1.78	-2.54	-0.67	-6.13**	0.13	-0.02	0.13
L 4147 × PL 4	0.86	-0.63	-0.15	0.91	0.01	0.10*	-0.08
L 4147 × VL 146	0.66	-0.04	-0.34	0.71	-0.03	0.04	-0.21
L 4147 × IPL 406	2.21	2.98	0.54	-8.63**	2.00**	0.06	-0.27
PL 4 × VL 146	0.50	1.55	4.20	5.06*	1.00	0.00	0.07
PL 4 × IPL 406	0.83	0.65	4.00	5.59**	1.57**	0.04	-0.31
VL 146 × IPL 406	-0.39	1.93	-2.15	-3.47	0.04	0.10*	-0.25
S.E. (s_{ij})	1.26	1.29	1.50	1.41	0.38	0.02	0.16
S.E. (s_{ij}-s_{ik})	1.87	1.91	2.22	2.08	0.57	0.04	0.24
S.E. (s_{ij}-s_{kl})	1.76	1.80	2.09	1.96	0.53	0.03	0.23
C.D. (5%)	3.72	3.80	4.42	4.14	1.13	0.08	0.48
C.D. (1%)	4.96	5.06	5.88	5.51	1.51	0.11	0.64

, Significant at 5% and 1% levels, respectively*

Table 3. Top crosses showing significant desirable SCA effects, their GCA effects and mean *per se* performance in lentil

Character	SCA effects	GCA effects	*Per se* performance
Days to first flowering	RLG 161 × L4147(-3.75)	A×A	RLG 161 × L4147(69.72)
Days to 50% flowering	-	-	-
Plant height (cm)	RLG 161 × PL 4(-5.61)	A×A	RLG 161 × PL 4(18.67)
Number of pods per plant	DKL 50 × L 4147(15.77)	H×H	DKL 50 × L 4147(51.33)
	PL 166 × DKL 50(10.73)	H×H	PL 166 × DKL 50(44.11)

Character	SCA effects	GCA effects	*Per se* performance
Number of secondary branches per plant	VL 147 × RLG 161(2.70)	A×A	VL 147 × RLG 161(8.08)
	PL 166 × VL 146(2.25)	A×A	PL 166 × VL 146(8.17)
Seed yield per plant (g)	VL 147 × DKL 50(0.13)	L×L	VL 147 × DKL 50(0.25)
	L 4147 × PL 4(0.10)	H×A	L 4147 × PL 4(0.42)
	VL 146 × IPL 406(0.10)	A×H	VL 146 × IPL 406(0.40)
100 seed weight (g)	PL 166 × L4147(0.72)	A×A	PL 166 × L4147(2.40)
	PL166 × VL 146(0.60)	A×A	PL166 × VL 146(2.20)
	RLG 161 × DKL 50(0.55)	A×A	RLG 161 × DKL 50(2.24)

Table 4. Estimates of heterobeltiosis for different traits in the intervarietal cross of lentil

Crosses	Days to first flowering	Days to 50% flowering	Plant height (cm)	No. of pods/plant	No. of secondary branches/plant	Seed yield/plant (g)	100 seed weight (g)
VL 147 × PL 166	1.78	5.67*	8.11**	0.98	1.01	-8.68**	54.41**
VL 147×RLG 161	7.68**	3.76	13.53**	-14.7**	32.27**	8.68**	23.53**
VL 147× DKL 50	11.76**	11.68**	9.33**	29.41**	10.00**	78.13**	47.06**
VL 147× L 4147	4.13	1.22	6.12*	65.69**	-0.92	67.55**	47.06**
VL 147× PL 4	4.81	7.23**	4.31	37.25**	-45.45**	4.15**	23.53**
VL 147× VL 146	12.01**	10.82**	0.00	46.73**	13.48**	-49.06**	27.35**
VL 147 × IPL 406	16.40**	16.44**	-5.10	39.88**	-18.66**	60.75**	38.24**
PL 166× RLG 161	-0.57	-4.91	-9.08**	-35.19**	-56.85**	5.39**	42.11**
PL 166× DKL 50	1.51	1.90	-10.29**	34.11**	12.22**	71.88**	35.73**
PL 166× L 4147	1.47	2.37	-18.34**	35.54**	-13.76**	-2.32**	75.61**
PL 166× PL 4	1.92	2.64	-12.29**	31.12**	23.60**	42.50**	1.02**
PL 166× VL 146	6.43**	6.65**	-5.54	-3.03	41.35**	6.57**	88.03**
PL 166× IPL 406	7.11**	8.78**	-2.46	-13.27**	12.75**	75.64**	-56.67**
RLG 161× DKL 50	0.21	4.23	7.31*	-15.43**	36.67**	61.72**	86.43**
RLG 161× L 4147	-4.90*	1.15	13.77**	-27.78**	-13.76**	39.57**	15.79**
RLG 161× PL 4	6.85**	7.62**	-19.52**	-27.48**	-42.34**	7.50**	50.00**
RLG 161× VL 146	5.03*	6.15*	14.94**	-16.54**	-29.81**	32.04**	16.81**
RLG 161× IPL 406	-3.31	-3.36	14.47**	65.69**	-23.40**	94.72**	91.18**
DKL 50× L 4147	-0.98	5.39*	-17.94**	56.74**	3.33**	31.64**	38.50**
DKL 50× PL 4	-2.16	2.44	-19.62**	-9.28**	24.44**	-17.97**	53.74**

Crosses	Days to first flowering	Days to 50% flowering	Plant height (cm)	No. of pods/plant	No. of secondary branches/plant	Seed yield/plant (g)	100 seed weight (g)
DKL 50× VL 146	-2.49	-2.10	-13.01**	4.19	-16.67**	41.80**	51.00**
DKL 50× IPL 406	-0.04	0.24	-4.31	-20.11**	20.81**	59.38**	77.29**
L 4147× PL 4	2.89	2.64	-2.20	25.08**	2.75**	90.50**	9.76**
L 4147× VL 146	4.79	4.59	4.10	29.76**	6.73**	57.75**	5.41**
L 4147× IPL 406	8.82**	11.33**	3.98	-21.63**	78.15**	96.92**	19.51**
PL 4× VL 146	0.52	3.98	11.14**	14.16**	16.67**	18.50**	-4.08**
PL 4× IPL 406	1.20	2.49	14.14**	30.60**	12.43**	51.50**	0.00
VL 146× IPL 406	3.03	8.10**	-3.86	-0.93	30.20**	84.36**	33.90**
S.E.	2.42	2.47	2.86	2.69	0.73	0.05	0.31
Range	-4.90 to 16.40	-4.91 to 16.44	-19.62 to 14.94	-35.19 to 65.69	-56.85 to 78.15	-49.06 to 96.92	-56.67 to 91.18
C.D. (5%)	4.82	4.91	5.69	5.35	1.45	0.01	0.62
C.D. (1%)	6.41	6.55	7.58	7.13	1.93	0.13	0.82

, Significant at 5% and 1% levels, respectively*

Table 5. Estimates of standard heterosis for different traits in the intervarietal cross of lentil

Crosses	Days to first flowering	Days to 50% flowering	Plant height (cm)	No. of pods /plant	No. of secondary branches/ plant	Seed yield/plant (g)	100 seed weight (g)
VL 147 × PL 166	3.24	8.50**	-3.40	-37.70**	-9.91**	-39.50**	7.14**
VL 147×RLG 161	9.65**	10.75**	4.06	-47.38**	31.08**	-28.00**	-14.29**
VL 147× DKL 50	9.81**	10.14**	0.33	-20.16**	-10.81**	14.00**	2.04**
VL 147× L 4147	6.30*	4.71*	2.74	2.21	-2.70**	11.00**	2.04**
VL 147× PL 4	4.81*	7.23**	0.99	-15.33**	-45.95**	-31.00**	-14.29**
VL 147× VL 146	7.75**	8.99**	-8.89**	-9.48**	6.32**	-66.25**	-11.63**
VL 147 × IPL 406	10.38**	11.67**	-8.12**	-13.71**	-45.41**	6.50**	-4.08**
PL 166× RLG 161	1.25	1.49	-16.66**	-57.66**	-53.15**	21.20**	10.20**
PL 166× DKL 50	-0.25	0.50	-17.67**	60.07**	-9.01**	10.00**	0.00
PL 166× L 4147	3.59	5.89**	-13.50**	61.09**	-15.32**	47.50**	46.94**
PL 166× PL 4	1.92	2.64	-12.29**	31.12**	23.60**	42.50**	1.02**
PL 166× VL 146	2.39	4.90*	-13.94**	-15.93**	32.43**	13.50**	34.69**

Crosses	**Days to first flowering**	**Days to 50% flowering**	**Plant height (cm)**	**No. of pods /plant**	**No. of second-dary branches/ plant**	**Seed yield/plant (g)**	**100 seed weight (g)**
PL 166× IPL 406	1.57	4.32*	-4.28	8.06**	-24.32**	71.25**	-20.41**
RLG 161× DKL 50	-1.53	2.79	-1.65	-44.76**	10.81**	3.50**	37.35**
RLG 161× L 4147	-3.16	4.63*	4.28	-52.82**	-15.32**	60.50**	-10.20**
RLG 161× PL 4	6.85**	7.62**	-26.23**	-52.63**	-42.34**	7.50**	16.33**
RLG 161× VL 146	1.04	4.40*	4.72*	-45.48**	-34.23**	40.63**	-16.33**
RLG 161× IPL 406	0.15	2.33	-0.99	2.21	-35.14**	29.00**	32.65**
DKL 50× L 4147	-2.70	3.94	-24.70**	86.28**	-16.22**	-15.75**	2.04**
DKL 50× PL 4	-3.86	1.03	-26.23**	-9.28**	0.90	-47.50**	13.27**
DKL 50× VL 146	-6.19**	-3.71	-20.75**	-9.68**	-32.43**	-9.25**	8.16**
DKL 50× IPL 406	-5.21*	-3.87	-12.18**	-4.64*	-18.92**	2.00**	30.61**
L 4147× PL 4	2.89	2.64	-2.20	25.08**	0.90	90.50**	-8.16**
L 4147× VL 146	0.81	2.87	-5.16*	12.50**	0.00	68.00**	-24.49**
L 4147× IPL 406	3.19	6.77**	2.04	-6.86**	19.57**	92.00**	0.00
PL 4× VL 146	0.52	3.98	11.14**	14.16**	16.67**	18.50**	-4.08**
PL 4× IPL 406	1.20	2.49	14.14**	30.60**	12.43**	51.50**	0.00
VL 146× IPL 406	-2.29	3.67	-12.40**	-14.12**	-12.61**	79.75**	-4.08**
S.E.	1.97	2.02	2.34	2.20	0.60	0.04	0.25
Range	-6.19 to 10.38	-3.87 to 11.67	-26.23 to 14.14	-57.66 to 86.28	-53.15 to 32.43	-66.25 to 92.00	-24.49 to 46.94
C.D. (5%)	3.92	4.02	4.66	4.38	1.19	0.08	0.50
C.D. (1%)	5.22	5.35	6.20	5.83	1.59	0.11	0.66

, Significant at 5% and 1% levels, respectively* seed yield/plant and 100 seed weight appears as most common important components associated with manifestation of heterosis for seed yield. Manifestation of considerable heterosis for such yield components have also been reported by [24] from heterosis and combining ability studies in field pea for number of pods/plant and seed yield/plant.

4. CONCLUSION

The analysis of variance revealed a significant difference for all the characters studied indicating the materials chosen were adequate. The overall picture from combining ability analysis revealed the predominant role of additive and non-additive genetic variance for yield and yield components. Thus. It can be suggested that there is a considerable scope for improving yield of lentil through heterosis breeding. On the basis general combining ability effects, DKL 50, L 4147 and IPL 406 were identified as most promising parents for involving in hybridization programme for generating desirable segregants. On the basis of specific combining ability effects, RLG 161 × IPL 406 were the most promising cross combinations for improvement of seed yield and no. of pods/plant. This heterotic cross having highly significant SCA effects for seed yield involved both the parents either as good general combiners or at least one good general combiner for seed yield. The manifestation of heterosis for seed yield was evidenced by the superiority of hybrids ranging from 1.02 to 91.18% in the 24 crosses over better parent and from 1.02 to 46.94% in 21 crosses over standard check variety (PL 4). The crosses which exhibited superiority over better parent or standard parent for seed yield also exhibited significant heterosis for one to three yield components. The no. of pods/plant, plant height and 100 seed weight appeared most common components associated with the manifestation of better parent as well as standard parent for seed yield. Overall on the basis of results of mean performance, SCA effects and standard heterosis, PL 166 × DKL 50 and L 4147 × PL 4 were identified as the most promising cross combinations to give transgressive segregants in later generations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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