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Heterosis and Combining Studies for Growth, Yield and Quality Traits in Garden Pea (*Pisum sativum* L.)

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ABSTRACT

The present study entitled "Line × Tester analysis in garden pea" was undertaken to estimate the extent of heterosis and combining ability effects for growth, yield and quality traits in pea. Experimental materials comprise five lines viz., Arka Uttam, IIHR-48, IIHR-34, IIHR-41, Arka Tapas and three testers viz., Arka Ajith, Arka Sampoorna and Arka Priya with their fifteen crosses along with one check Arka Pramodh. The parents and hybrids were randomized separately and sown using a Randomized Block Design with two replications during 2019-20. The results revealed that the female parent Arka Tapas recorded a significant GCA effect for most growth and yield parameters. The cross Arka Tapas × Arka Priya exhibited a high percentage of mid-parent (38.74 %), better parent (16.70 %) and heterosis over the commercial check (9.96 %) for the character pod yield per hectare.

Keywords Combining ability, Heterosis, Line × Tester, *Pisum sativum.*

INTRODUCTION

The Garden pea (*Pisum sativum* L.) is a legume crop belonging to the family Leguminosae, with a chromosome number of 2n=14, which originated in the Mediterranean region. It is one of the important vegetables having a high percentage of protein (7.2 g / 100g), carbohydrate (15.8 g), vitamin C (9 mg), phosphorus (139 mg), and minerals. The peas are notably used in the tinned and frozen meals enterprise to deliver the necessary proteins for human nutrition. Moreover, pea contributes to enhancing the yield of succeeding crops in rotation by enhancing the soil's nitrogen content.

The major concern in pea breeding is to get a higher yield which gives better profit to the farmers. Apart from yield, there is a wide scope for improvement of other characteristics like earliness, good quality and resistance to pests and disease by exploiting the phenomenon of hybrid vigor or heterosis.

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Heterosis breeding has been identified as a practical tool that helps to provide the breeder with increasing yield and economic traits.

Improvement in yield of self-pollinated crops like a garden pea is effected mainly through a selection of genotypes with desirable characters from the existing variation and recombination breeding followed by selection. Heterosis in the F_1 generation is very important in vegetable crops as heterotic crosses may yield better transgressive segregants for economic traits in advanced generations. Line × Tester analysis provides information about combining the ability effects of genotypes and knowledge regarding genetic mechanisms controlling yield components. Information on general and specific combining abilities influencing yield and its components has become increasingly important to plant breeders to select appropriate parents for developing hybrid cultivars.

MATERIALS AND METHODS

The present investigation was carried out at the research field unit of the Department of Vegetable Science, College of Horticulture, Mudigere, during the *rabi* season 2019-20. The experimental material consists of five diverse lines viz., Arka Uttam, IIHR-48, IIHR-34, IIHR-41, Arka Tapas and three testers viz., Arka Ajith, Arka Sampoorna and Arka Priya, along with their fifteen crosses and one check Arka Pramodh. The parents, hybrids and check were grown and evaluated in Randomized Block Design in two replications. Seeds were sown in each replication with 1.5 m × 1.3 m plot size at 60 cm × 15 cm spacing and all recommended packages of practices were followed during the crop season. Data were recorded on five randomly selected plants from each treatment for several characters Seed germination (%), Plant height at harvest (cm), number of primary branches at harvest, node at which the first flower appears, days to 50 % flowering, pod yield per hectare (t/ha), shelling percentage, TSS (°brix) and total sugars (mg/g).

RESULTS AND DISCUSSION

The results of ANOVA for various characters are presented in Table 1, and the results revealed that the mean sum of squares for treatments was highly significant for all the characters. Whereas variance due to the lines and testers was highly significant for all the traits except for seed germination (%).

The mean sum of squares for Line × Tester interaction was highly significant for all the characters except for characters like TSS and seed germination (%). Variance due to parents vs. hybrids was significant for all the characters except for seed germination (%). This indicates the presence of variability among treatments. The contribution of the total crosses or hybrid variance was higher from the females than males for all the characters under study. Females were regarded as more genetically diverse than males. Similar findings were also reported by Shiwani and Sharma (2019).

Table 1. Analysis of variance (mean sum of squares) for various characters in garden pea.

Characters	Replications	Treatments (genotypes)	Parents	Lines	Testers	Lines × Tester	Parents vs Crosses	Crosses	Error
Degrees of freedom	1	22	7	4	2	8	1	14	22
Seed germination (%)	1.10	48.83*	23.53	13.63	35.19	36.81	57.85	60.83 *	20.20
Plant height (cm) at harvest	7.28	48.41**	14.26**	8.48*	7.10	20.31**	50.61**	65.33**	2.17
Number of primary branches at harvest	0.03	3.65**	1.81*	2.26*	1.38	4.32**	10.21**	4.11**	0.67
Node at which first flower appears	0.18	12.10**	11.11**	15.26**	6.72**	7.92**	5.77**	13.05**	0.13
Days to 50% flowering	25.13	77.37**	113.77**	61.35**	168.16**	2.09	41.91**	61.70**	1.17
Pod yield per hectare (t/ha)	0	5.34**	4.81**	0.46**	4.95**	0.54**	9.47**	5.31**	0.04
Shelling percentage	6.38	56.90**	33.39**	37.93**	27.00*	15.18*	40.07**	69.85**	4.41
TSS (°brix)	0.13	2.51**	3.94**	1.66**	0.42	0.26	4.59**	1.64**	0.14
Total sugars (mg/g)	0.283	0.70 **	1.48 **	0.02 **	0.26 **	0.05 **	0.43 **	0.33**	0.004

* and **, Indicate, Significance at 5% and 1% levels, respectively. DAS – Days after sowing.

Heterosis

Heterosis is the superiority of F_1 over its parents. Traditionally, the deviation of F_1 performance from the parents' mean is considered the estimate of heterosis. However, only the superiority of the hybrid over the superior parent is of practical value. Therefore only the heterosis over the superior parent is discussed.

Per se performance and magnitude of heterosis for various characters in garden pea are presented in Table 2. Seed germination is one of the highly signified parameters, and it influences crop yield and total biomass. Germination per cent decides how many seeds of a particular plant species, variety, or seed lot are likely to germinate over a given period. The germination rate helps to calculate the seed rate for

Table 2. *Per se* performance and magnitude of heterosis for various characters in garden pea.

Crosses	Seed germination (%)			Plant height (cm) at harvest			Number of primary branches at harvest		
	MP	BP	SC	MP	BP	SC	MP	BP	SC
Arka Uttam × Arka Ajith	9.24 *	6.43	22.10 **	4.68 **	0.48	7.36 **	9.35 **	8.01 *	5.26
Arka Uttam × Arka Sampoorna	8.42	7.72	23.58 **	6.84 **	3.45 *	10.53 **	10.54 **	9.59 **	8.66 **
Arka Uttam × Arka Priya	-1.91	-3.73	14.71 *	3.19 *	1.13	8.06 **	0.18	-4.05	-3.57
IIHR-48 × Arka Ajith	5.44	5.44	14.74 *	9.21 **	5.21 **	11.57 **	-3.11	-6.19 *	-4.75
IIHR-48 × Arka Sampoorna	7.30	5.21	19.13 **	9.38 **	6.29 **	12.72 **	2.37	1.17	2.72
IIHR-48 × Arka Priya	7.11	2.47	22.10 **	13.46 **	11.61 **	18.35 **	-0.50	-1.00	0.51
IIHR-34 × Arka Ajith	1.37	0.00	8.82	-6.24 **	-8.71 **	-5.29 **	5.26	3.57	-1.53
IIHR-34 × Arka Sampoorna	3.36	0.00	13.24 *	-8.19 **	-9.82 **	-6.44 **	2.15	-1.52	-2.36
IIHR-34 × Arka Priya	1.95	-3.72	14.72 *	2.34	1.77	5.58 **	-7.03 *	-8.45 **	-7.98 *
IIHR-41 × Arka Ajith	8.73	8.00	19.13 **	1.65	0.34	1.21	0.54	0.18	-4.75
IIHR-41 × Arka Sampoorna	-2.64	-3.90	8.82	4.18 *	3.76 *	4.66 *	8.42 **	5.82	4.92
IIHR-41 × Arka Priya	-0.02	-3.73	14.71 *	-1.07	1.91	0.63	6.27 *	3.04	3.57
Arka Tapas × Arka Ajith	4.05	4.05	13.24 *	4.52 **	0.98	6.44 **	1.41	0.00	-2.21
Arka Tapas × Arka Sampoorna	-7.28	-9.09	2.94	-0.87	-3.38	1.84	6.55 *	5.82	4.92
Arka Tapas × Arka Priya	-12.27 *	-16.08**	0.00	1.41	0.05	5.47 **	6.51 *	5.07	5.60
SssssssEm ±	`3.89	4.49	4.49	1.27	1.47	1.47	0.71	0.82	0.82
CD @ 5 %	8.34	9.64	9.64	2.74	3.16	3.16	1.52	1.76	1.76
CD @ 1 %	11.58	13.38	13.38	3.80	4.39	4.39	2.11	2.44	2.44

Table 2. Continued.

Crosses	Node at which first flower appears			Days to 50% flowering		
	MP	BP	SC	MP	BP	SC
Arka Uttam × Arka Ajith	-3.87	-2.24	-35.55	-23.23 **	4.10 **	-14.60 **
Arka Uttam × Arka Sampoorna	-20.49 **	-8.42 **	-39.62 *	-16.56 **	-6.84 **	-23.50 **
Arka Uttam × Arka Priya	-22.58 **	-5.61 **	-37.77	-12.28 **	2.73**	-15.73 **
IIHR-48 × Arka Ajith	10.64 **	13.04 *	-22.96 **	-15.89 **	1.12**	1.12
IIHR-48 × Arka Sampoorna	38.68 **	53.12 **	8.88**	-1.68	-1.12	-1.12
IIHR-48 × Arka Priya	-16.96 **	-3.12 **	-31.11	-0.53	4.49 *	4.49
IIHR-34 × Arka Ajith	-18.55 **	-2.17 **	-33.33	-6.91 **	9.78 **	13.48 **
IIHR-34 × Arka Sampoorna	-24.90 **	-20.68**	-31.85	13.19 **	11.96 **	15.72**
IIHR-34 × Arka Priya	-27.63 **	-27.34**	-31.11	8.42 **	11.96*	15.72**
IIHR-41 × Arka Ajith	20.51 **	53.26	4.44 **	-15.49 **	2.27**	1.12
IIHR-41 × Arka Sampoorna	8.53 **	20.68	3.70 **	-1.12	0	-1.12
IIHR-41 × Arka Priya	-3.70	1.56 **	-3.70 **	1.08	6.81	5.61
Arka Tapas × Arka Ajith	16.87 **	54.34 *	5.18 **	-11.79 **	-2.88 **	13.48 **
Arka Tapas × Arka Sampoorna	-22.84 **	-11.20 **	-23.70	1.03	8.88 *	10.11**
Arka Tapas × Arka Priya	-0.36	8.59 **	2.96**	-2.9	1.02 *	10.11 **
SEm ±	0.31	0.36	0.36	0.93	1.08	1.08
CD @ 5 %	0.67	0.77	0.77	2.01	2.32	2.32
CD @ 1 %	0.93	1.08	1.08	2.79	3.22	3.22

Table 2. Continued.

Crosses	Pod yield per hectare (t/ha)			Shelling percentage		
	MP	BP	SC	MP	BP	SC
Arka Uttam × Arka Ajith	-9.54 **	-16.09 **	-39.14 **	-3.92	-4.34	-3.62
Arka Uttam × Arka Sampoorna	-6.03 *	-12.95 **	-36.68 **	9.00 *	2.51	3.28
Arka Uttam × Arka Priya	-14.62 **	-29.55 **	-32.81 **	-5.72	-12.42 **	-11.76 *
IIHR-48 × Arka Ajith	-2.67	-13.22 **	-37.06 **	4.10	-2.36	-2.49
IIHR-48 × Arka Sampoorna	5.15 *	-6.36 *	-31.89 **	9.45 *	8.66	-3.56
IIHR-48 × Arka Priya	-6.82 **	-25.66 **	-29.10 **	3.38	2.76	-10.11 *
IIHR-34 × Arka Ajith	7.13 **	-1.15	-28.30 **	-2.54	-11.46 *	-11.58 *
IIHR-34 × Arka Sampoorna	7.71 **	-0.74	-27.80 **	-10.66 *	-14.27 **	-23.91 **
IIHR-34 × Arka Priya	-2.37	-19.80 **	-23.51 **	-10.86 *	-13.36 *	-25.12 **
IIHR-41 × Arka Ajith	11.20 **	-2.13	-29.01 **	-3.33	-12.53 **	-12.65 **
IIHR-41 × Arka Sampoorna	16.75 **	2.64	-25.34 **	-0.32	-4.76	-15.47 **
IIHR-41 × Arka Priya	6.67 **	-15.82 **	-19.72 **	-3.86	-6.96	-19.59 *
Arka Tapas × Arka Ajith	24.08 **	17.70 **	-14.63 **	32.17 **	19.72 **	19.56 **
Arka Tapas × Arka Sampoorna	41.14 **	33.70 **	-2.75	17.41 **	12.32 *	-0.31
Arka Tapas × Arka Priya	38.74 **	16.70 **	9.96 **	19.36 **	15.65 **	-0.05
SEm ±	0.18	0.21	0.21	1.81	2.10	2.10
CD @ 5%	0.39	0.45	0.45	3.90	4.50	4.50
CD @ 1%	0.55	0.63	0.63	5.41	6.25	6.25

Table 2. Continued.

Crosses	TSS (°brix)			Total sugars (mg/g)		
	MP	BP	SC	MP	BP	SC
Arka Uttam × Arka Ajith	5.65 *	4.06	-15.09 **	-4.33 **	-13.47 **	-0.46
Arka Uttam × Arka Sampoorna	2.45	-1.88	-19.94 **	-3.81 **	-13.49 **	1.74 *
Arka Uttam × Arka Priya	3.81	0.00	-18.41 **	-7.31 **	-13.95 **	-5.67 **
IIHR-48 × Arka Ajith	3.89	-2.24	-12.26 **	-5.70 **	-14.11 **	-0.29
IIHR-48 × Arka Sampoorna	7.44 **	-1.56	-11.65 **	-4.68 **	-13.69 **	1.51
IIHR-48 × Arka Priya	3.62	-4.55	-14.33 **	-8.70 **	-14.63 **	-6.43 **
IIHR-34 × Arka Ajith	6.34 **	-1.24	-8.85 **	-5.77 **	-14.11 **	-0.29
IIHR-34 × Arka Sampoorna	10.69 **	0.14	-7.57 **	-4.97 **	-13.88 **	1.27
IIHR-34 × Arka Priya	9.04 **	-0.83	-8.47 **	-7.76 **	-13.68 **	-5.39 **
IIHR-41 × Arka Ajith	10.95 **	3.04	-4.90 *	-4.54 **	-12.42 **	1.68 *
IIHR-41 × Arka Sampoorna	10.53 **	0.00	-7.70 **	2.08 **	-6.89 **	9.50 **
IIHR-41 × Arka Priya	6.00 *	-3.59	-11.01 **	-6.70 **	-12.10 **	-3.65 **
Arka Tapas × Arka Ajith	-0.36	-4.08	-17.95 **	-4.32 **	-12.22 **	1.91 *
Arka Tapas × Arka Sampoorna	4.53	-2.09	-16.24 **	2.40 **	-6.60 **	9.84 **
Arka Tapas × Arka Priya	3.16	-2.83	-16.88 **	-3.67 **	-9.24 **	-0.52
SEm ±	0.33	0.38	0.38	0.05	0.06	0.06
CD @ 5%	0.71	0.82	0.82	0.11	0.13	0.13
CD @ 1 %	0.99	1.15	1.15	0.16	0.19	0.19

MP- Mid parent value, BP-Better parent value, SC- Standard check, * and ** indicate. Significant at 5% and 1%, respectively.

a given area or desired number of plants. Among the hybrids, only 1 cross showed heterosis over the mid parent and 11 crosses over the standard check. The highest significant positive heterosis was exhibited by the cross Arka Uttam × Arka Sampoorna (23.58 %) over the check. High heterosis was observed due to the high GCA effect of the parents Arka Uttam. Identical results were also reported by Yadav *et al.* (2015) and Shiwani and Sharma (2019) in garden pea.

Plant height is one of the important growth parameters that give a strong framework to the plants, which directly gives rise to primary branches and contributes to the total yield of the crop. Out of 15

hybrids, 10 hybrids showed a positive and 2 hybrids showed negative heterosis over a mid-parent. Significant positive heterosis was noticed by the cross IIHR-48 × Arka Priya (18.35 %) followed by IIHR-48 × Arka Sampoorna(12.72 %) over the check. Heterosis among these crosses might be due to the high GCA effect of the parents IIHR-48, Arka Uttam and Arka Priya. Similar results were reported by Yadav *et al.* (2015) in garden pea.

A number of primary branches per plant also play a vital role in increasing crop yield by giving more bearing nodes. Out of 15 crosses, 6 exhibited heterosis over the mid parent and 2 and 1 crosses over better and standard check, respectively. The cross Arka Uttam × Arka Sampoorna (8.66 %) followed by Arka Uttam × Arka Ajith (5.26 %) showed significant positive heterosis over check Arka Pramodh. Heterosis among these crosses might be due to the significant positive GCA effect of Arka Sampoorna. These results are in line with the earlier findings of Daheriya (2012) in garden pea.

Nodes are the important points on the stem where buds, leaves and flowers appear and help in healing and give structural support, which intern to give early flowering. For the character node at which the first flower appears and days to 50 % flowering, the cross Arka Uttam × Arka Sampoorna (-39.62 and -23.50%) showed significant negative heterosis in the desirable direction. High negative heterosis was observed due to the negative GCA effect of Arka Uttam, IIHR – 34 and Arka Sampoorna. Similar trends were also noticed by Buckseth (2013) in garden pea.

Improvement of yield is one of the prime importance in the breeding program. Among 15 hybrids studied, the highest significant positive heterosis was exhibited by the cross Arka Tapas × Arka Priya (9.96 %) and the lowest significant negative heterosis was shown by cross Arka Uttam × Arka Ajith (-39.14 %) over the standard check, reason for higher heterosis is mainly due to the positive GCA effect of parents Arka Tapas and Arka Priya. Earlier reports by Sharma and Bora (2013) and Kumar *et al.* (2019) explain the above results in garden pea.

Shelling percentage estimates is an important trait from the consumer's point of view in garden pea; among the hybrids, 5 crosses showed heterosis over the mid parent and 3, 1 cross showed heterosis over the better parent and standard check Arka Pramodh. The cross Arka Tapas × Arka Ajith (19.56 %) over the commercial check showed significant positive heterosis for the shelling per cent. High heterosis was observed due to the high GCA effect of the parents like Arka Tapas, Arka Uttam and Arka Ajith. Similar results were also reported by Sharma and Bora (2013) in garden pea.

Total soluble solid is an indicator of the sugar level in garden pea; generally, the highest TSS contained variety fetch a good price in the market. The above trait 8 crosses exhibited positive heterosis over mid-parent only, but none exhibited positive heterosis over better parent and standard check. The presence of high heterosis is mainly due to the positive GCA effect of the parents like IIHR -41 and IIHR -34. These results are close to those of Buckseth (2013) and Kumar *et al.* (2019) in garden pea.

For total sugar, significant positive heterosis is desirable, and the hybrids displayed a good amount of variation for total sugar, 2 crosses showed significant positive heterosis over the mid parent and 3 crosses showed positive heterosis and the highest was recorded in the cross Arka Tapas × Arka Sampoorna (9.84 %) over the standard check. Positive heterosis occurs mainly due to the high GCA effect of the parents like Arka Tapas and Arka Sampoorna. The above results conform with the garden pea of Sharma and Bora (2013).

Combining ability

The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using a single cross of maize. Combining ability is defined as the relative ability of a genotype to transmit its desirable trait to its progenies. Combining ability analysis is one of the most powerful tools available, which gives the estimates of combining ability effect and aids in selecting desirable parents and crosses and also elucidates the nature and magnitude of different types of gene actions. According to Sprague and Tatum, combining ability mainly involves general

Table 3. Estimates of general combining ability (GCA) effects of parents for 24 characters in garden pea.

Traits / Parents	Seed germination (%)	Plant height (cm) at harvest	Number of primary branches at harvest	Node at which first flower appears	Days to 50% flowering	Pod yield per hectare (t/ha)	Shelling percentage	TSS (°brix)	Total sugars (mg/g)
				Females (Lines)					
Arka Uttam	4.85 *	2.72**	0.40	-0.64**	-2.62**	-1.41 **	1.94 *	-0.99**	-0.13**
IIHR-48	3.66	7.56**	-0.32	-1.26**	0.42 *	-0.99**	1.24	0.04	-0.18**
IIHR-34	-1.51	-6.57**	-0.90	0.18	-1.87**	-0.25*	-6.33 **	0.87**	-0.15**
IIHR-41	0.07	-2.90**	0.19	0.30**	2.65**	-0.03	-4.13**	0.95**	0.18**
Arka Tapas	-7.07**	-0.80	0.64	1.42**	1.42**	2.68**	7.28 **	-0.83 **	0.29**
SEm±	1.83	0.60	0.33	0.10	0.14	0.08	0.85	0.15	0.02
CD at 5%	3.93	1.29	0.71	0.22	0.31	0.18	1.83	0.33	0.05
CD at 1%	5.46	1.79	0.99	0.30	0.44	0.26	2.55	0.46	0.07
				Males (Testers)					
Arka Ajith	1.19	-1.09*	-2.56**	-0.64*	0.23	-0.62 **	2.90**	0.18	0.02
Arka Sampoorna	-0.47	-0.74	-1.06*	0.93**	0.027	-0.05	-0.08	0.02	0.37**
Arka Priya	-0.71	1.83**	3.63**	-0.28	-0.263*	0.67**	-2.81**	-0.21	-0.40 **
SEm±	1.42	0.46	0.49	0.25	0.11	0.06	0.66	0.12	0.02
CD at 5%	3.04	1.00	1.05	0.55	0.24	0.14	1.42	0.26	0.04
CD at 1%	4.23	1.38	1.46	0.77	0.34	0.20	1.97	0.36	0.06

combining ability (GCA) and specific combining ability (SCA).

The estimation of general and specific combining ability effects of the parents and hybrids involved in the present investigations are presented in Tables 3–4, respectively. For the trait seed germination (%) highest significant GCA effect was recorded by the line Arka Uttam (4.85) and the lowest was observed in the line Arka Tapas (-7.70).

None of the testers showed a significant GCA effect for this trait. Similarly, none of the crosses recorded a significant SCA effect for this character. The cross Arka Tapas × Arka Ajith (5.15) showed a positive SCA effect in a desirable direction. The previous studies of Singh (2013) revealed that estimates of GCA variances were lesser than SCA variances for the above traits studied in garden pea.

For the trait plant height at final harvest, 2 lines IIHR-48 (7.56) and Arka Uttam (2.72) showed a positive GCA effect. In contrast, IIHR-34 (-6.57) and IIHR -41(-2.90) showed a negative GCA effect. Among the testers, the GCA effect ranges from -1.09 (Arka Ajith) to 1.83 (Arka Priya). Among 15 crosses, a Significant positive SCA effect was shown by IIHR-34 × Arka Priya (4.80) followed by IIHR-41 × Arka Sampoorna (2.90). These results closely conform with the findings of Dalia and EI-Rawy (2013) in garden pea.

For the character number of primary branches at harvest, only one tester showed significant positive GCA effects of 0.93 (Arka Sampoorna) and none of the lines showed significant GCA effects. Number of primary branches at harvest, the highest positive SCA effect was observed in the cross Arka Uttam × Arka Ajith (1.61) and this trait showed the role of non-additive gene action due to low GCA to SCA ratio. These results were supported by Brar et al. (2012) in garden pea.

For the trait node at which the first flower appears, out of 5 lines, 2 lines showed a significant negative GCA effect recorded in Arka Uttam (-2.62) and IIHR-34 (-1.87) and are considered as a good general combiner. Whereas the hybrid Arka Tapas × Arka Sampoorna (-3.19) followed by IIHR-48 × Arka Priya (-1.90) was found to be a good specific

Table 4. Estimates of specific combining ability (SCA) effects for various characters in 15 garden pea hybrids.

Traits / Crosses	Seed germination (%)	Plant height (cm) at harvest	Number of primary branches at harvest	Node at which first flower appears	Days to 50% flowering	Pod yield per hectar (t/ha)	Shelling percentage	TSS (°brix)	Total sugars (mg/g)
Arka Uttam × Arka Ajith	0.4	-0.027	0.56	0.04	0.43	0.27	-2.69	0.34	0.11*
Arka Uttam × Arka Sampoorna	3.27	2.37*	-1.93	-0.29	-1.36*	-0.001	3.83*	-0.44	-0.12*
Arka Uttam × Arka Priya	-3.67	-2.34*	1.36	0.24	0.63	-0.27	-1.14	0.09	0.01
IIHR-48 × Arka Ajith	-4.36	-1.21	3.06*	-1.30**	-0.23	0.09	-1.41	-0.08	0.09
IIHR-48 × Arka Sampoorna	0.86	-0.56	0.06	3.20**	-0.23	0.15	1.02	0.19	-0.09*
IIHR-48 × Arka Priya	3.5	1.77	-3.13*	-1.90**	0.46	-0.24*	0.39	-0.1	0.002
IIHR-34 × Arka Ajith	-3.97	-1.72	-1.93	-0.40	-0.73	0.41*	1.51	-0.29	0.07
IIHR-34 × Arka Sampoorna	1.26	-3.07*	3.06*	0.007	1.26	-0.09	-1.81	0.11	-0.14**
IIHR-34 × Arka Priya	2.70	4.80**	-1.13	0.39	-0.53	-0.31	0.29	0.17	0.06
IIHR-41 × Arka Ajith	2.78	0.25	1.06	0.16	-0.4	0.10	-1.23	0.39	-0.09*
IIHR-41 × Arka Sampoorna	-3.89	2.90*	0.06	0.27	-0.4	-0.02	0.30	0.00	0.22**
IIHR-41 × Arka Priya	1.11	-3.16**	-1.13	-0.43	0.8	-0.08	0.92	-0.40	-0.12*
Arka Tapas × Arka Ajith	5.15	2.70*	-2.76*	1.49**	0.93	-0.88**	3.83*	-0.36	-0.18**
Arka Tapas × Arka Sampoorna	-1.50	-1.64	-1.26	-3.19**	0.43	-0.03	-3.35*	0.12	0.14**
Arka Tapas × Arka Priya	-3.64	-1.06	4.03**	1.69**	-1.06	0.91**	-0.48	0.23	0.03
SEm±	3.17	1.04	1.10	0.256	0.76	0.15	1.48	0.27	0.04
CD at 5%	6.81	2.23	2.36	0.55	1.64	0.32	3.18	0.58	0.09
CD at 1%	9.46	3.10	3.28	0.76	2.28	0.45	4.42	0.81	0.135

* and ** indicate, Significant at 5% and 1%, respectively. DAS – Days after sowing.

combiner and showed maximum significant negative SCA effects, earlier researchers like Kumar *et al.* (2017) recorded similar negative effect in garden pea.

Among the parents, line Arka Uttam (-9.43) and tester Arka Sampoorna (-0.93) exhibited significant negative GCA effect and were considered the best general combiner and the cross Arka Uttam × Arka Sampoorna (-1.36 and -2.56) recorded highest negative SCA effect for the trait days to 50 % flowering and act as a good specific combiner. The results follow the findings of Brar *et al.* (2012) and Singh (2013) in garden pea.

For the trait pod yield per hectare, line Arka Tapas (2.68) exhibited a desirable significant and positive GCA effect. Among the tester, Arka Priya (0.67) showed a significant and positive GCA effect. Out of 15 crosses, cross Arka Tapas × Arka Priya (0.91) followed by IIHR-34 × Arka Ajith (0.41) displayed maximum significant SCA effect and acted as a good specific combiner. The above results agreed with the findings of Dalia and EI-Rawy (2013) and Kumar *et al.* (2017) in garden pea.

GCA effect for the trait shelling percentage was significant and positive in the lines Arka Tapas (7.28) and Arka Uttam (1.94). Among the testers, Arka Ajith (2.90) was considered a good general combiner and showed a significant positive GCA effect. Similarly, the significant positive SCA effect was exhibited by the hybrids Arka Tapas × Arka Sampoorna and Arka Uttam × Arka Sampoorna (3.83), which act as the best specific combiner. These findings are in consonance with the reports of Brar *et al.* (2012) on garden pea.

For this trait of total soluble solids, two lines, IIHR-41 (0.95) and IIHR-34 (0.87), showed a significant positive GCA effect and none of the testers showed significant GCA effects for this trait. Among the 15 hybrids studied, none of the crosses showed a significant SCA effect. The results of this investigation closely conform with the reports of Dalia and EI-Rawy (2013) on garden pea.

For the trait total sugars, among the five females, line Arka Tapas (0.29) and IIHR-41 (0.18) had a sig-

nificant positive GCA effect in a desirable direction. Among the 15 crosses, 3 showed a positive significant SCA effect. Among these crosses, IIHR-41 × Arka Sampoorna (0.22) was a good specific combiner, the similar results were observed by Singh (2013) in garden pea.

The present investigation has provided useful information regarding the magnitude of heterosis and combining ability effects of growth, yield and quality traits in garden pea. Among the lines, Arka Tapas and among the testers, Arka Priya is found to be good general combiners for the characters Pod yield (t/ha), Shelling percentage and Total sugars (mg/g) and Plant height at harvest, Number of primary branches at harvest, Days to 50% flowering respectively. The hybrid Arka Tapas × Arka Priya acts as a good specific combiner for the traits number of primary branches at harvest, pod yield per hectare and node at which the first flower appears. From the overall study, it is concluded that the cross Arka Tapas × Arka Priya exhibited a high percentage of mid-parent (38.74 %), better parent (16.70 %) and heterosis over the commercial check (9.96 %) for the character pod yield per hectare.

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