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Heterosis Studies for Yield and Quality Traits in Garden Peas (*Pisum sativum* L.)

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ABSTRACT: Hybridization is challenging in pea crop due its flower structure. Present study was carried out with 51 genotypes (36 hybrids developed by crossing 12 lines and 3 testers) of garden pea (*Pisum sativum* L). The per cent heterosis over mid-parent and better parent was worked out for yield and yield related attributes. Heterosis was valued in this study. Heterosis values were significant over better parent and mid parent in desirable direction in most crosses for yield and quality characters under studies. The crosses involving Palam Priya × Azad Pea-1 and Palam Priya × VL-Ageti Matar-7 exhibited maximum magnitude of positive and significant heterosis over mid-parent and better parent for fruit yield per plant and fruit yield per hectare in garden pea indicating the potential of selected hybrids over existing homozygous parental lines and exploitation of dispersion of alleles between the parents and mean directional dominance gene action in crop improvement. The F_2 population can be utilized in pea improvement programme.

Keywords: Yield, Heterosis, Garden pea.

INTRODUCTION

Due to its high nutritive value, Garden pea (*Pisum sativum* L.) is an important vegetable crop. It is a leading vegetable grown in India on a large scale. Exploitation of heterosis is a cheap and easy method for increasing yield in many crops. Cross combinations showing heterotic vigour can be utilized for developing high yielding pure lines of garden pea. Therefore, in the present investigation analysis for heterosis was also done for yield and its components. In self pollinated crops like pulses, the development of pure line varieties has been only the option. However, the extent of heterosis manifested works as an indicator for the successful development of improved cultivars. Therefore, the present investigation was carried out for suggesting breeding strategy on the basis of above parameters.

Two cross combinations namely Palam Priya × Azad Pea-1 and Palam Priya × VL-Ageti Matar-7 were identified as superior hybrids selected for yield, as these crosses exhibited significant heterosis and sca effects for yield per hectare.

MATERIALS AND METHODS

Experimental material comprised of twelve lines and three testers. The testers were crossed with each line and thus 36 F_1s were produced during 2016-17 and evaluation was done in 2017-18. The 15 parents along with 36 F_1s were grown in a Randomized Complete Block Design with three replications at the Experimental Farm-I, Division of Vegetable Science & Floriculture, Faculty of Agriculture, Sher-e Kashmir University of Agricultural Sciences and Technology Jammu, Main Campus, Chatha, Jammu (J & K) during 2017-18. The distance between the plants was maintained at 10 cm while the rows were spaced 45 cm apart. The standard plant protections and other cultural practices were followed to raise a healthy crop. Five plants of each entry in each replication were randomly selected as per package of practices of Division of Vegetable Science & Floriculture (Anonymous, 2020) from mid rows to avoid border row effect for recording the observations on parameters namely plant height (cm), days to 50 per cent flowering, node at which first flower appears, inter nodal distance (cm), number of pods per node, days to first picking, pod length (cm), pod width (cm), number of pods per plant, number of seed per pod, number of primary branches per plant, shelling per cent age, total sugar content (%), crude protein (%), total soluble solids (B°), pod yield per plant (g) and pod yield per heacter (q). Heterosis over mid parent and better parent were calculated for the above traits as per the model suggested by Kempthorne, (1957).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences among the crosses for all the traits except for ascorbic acid content (Table 1). Mean squares due to crosses were further partioned into lines, testers and line × testers interactions. Mean square due to lines were found significant for traits namely plant height, days to 50 per cent flowering, ascorbic acid content, total sugar

content, crude protein, total soluble solids, pod yield per plant and pod yield per hectare. Mean squares due testers were found to be significant for eleven traits namely plant height, days to 50 per cent flowering, internodal distance, days to first picking, pod length, number of seed per pod, shelling percentage, total sugar content, crude protein, pod yield per plant and pod yield per hectare. Line × tester interactions were found significant for all the traits under study except for days to first picking.

For plant height positive and significant heterosis over mid parent was observed for crosses viz., Matar Ageta-7 × VL-Ageti Matar-7 (137.80%), Arka Ajit × VL-Ageti Matar-7 (112.46%), Mithi Phali × VL-Ageti Matar-7(84.74%), Arka Apoorva × VL-Ageti Matar-7 (75.90%) and Matar Ageta-7 × P-89 (59.56%), whereas Matar Ageta-7 × VL-Ageti Matar-7 (86.93%), Arka Ajit × VL-Ageti Matar-7 (72.27%), Matar Ageta-7 × P-89 (56.64%), Matar Ageta-7 × Azad pea-1 (46.55%), Mithi Phali × Azad Pea-1 (40.40%), showed positive and significant heterosis over better parent (Table 2). These findings are similar to observations of earlier workers, like Katoch *et al*., (2017); Kushwah and Sharma (2015); Patil *et al*., (2011); Punia *et al*., (2011); Borah, (2009).

For days taken to 50% flowering Palam Triloki × Azad Pea-1 (-40.94%), Palam Triloki × VL-Ageti Matar-7 (-20.69%), Arkel × VL-Ageti Matar-7 (-19.49%), Vivek Matar-11 × VL-Ageti Matar-7 (-17.39%), Palam Triloki × P-89 (-11.97%) exhibited significant negative heterosis over mid parent, whereas Palam Triloki × Azad Pea-1 (-42.48%), Palam Triloki × VL-Ageti Matar-7 (-36.55%), Arkel × VL-Ageti Matar-7 (-36.24%), Vivek Matar-11 × VL-Ageti Matar-7 (-33.57%) and Vivek Matar-10 × Azad Pea-1 (-23.53%) showed significant and negative heterosis over better parents (Table 2). Heterosis for days taken to 50% flowering was also reported by Katoch *et al*., (2017); Rebika, (2017); Sharma and Bora (2013); Patil *et al*., (2011); Punia *et al*., (2011); Shah and Mohammed (2005).

For node at which first flower appears, Azad Pea-3 × P-89 (-21.07%), Matar Ageta-7 × Azad Pea-1 (-16.09%), Arka Priya × Azad Pea-1 (-15.67%), Matar Ageta-7 × P-89 (-14.26%) and Azad Pea-3 × Azad Pea-1 (-7.59%) exhibited significant negative relative heterosis, whereas Azad Pea-3 × P-89 (-35.65%), Azad Pea-3 × VL-Ageti Matar-7 (-33.86%), Matar Ageta-7 × P-89 (-21.59%), Arka Priya × VL-Ageti Matar-7 (-18.00%), Azad Pea-3 × Azad Pea-1 (-17.71%), (Table 2). These results are in accordance with the findings of Katoch *et al*., (2017).

For inter nodal distance Mithi Phali × P-89 (-14.51%) exhibited significant and negative heterosis over mid parent whereas the cross combinations showing significant negative heterosis over better parent were Mithi Phali × P-89 (-27.70%), Vivek Matar-11 × P-89 (-18.55%), Mithi Phali × Azad Pea-1 (-18.37%) and Mithi Phali × VL-Ageti Matar-7 (-16.22 %) (Table 2). The findings of heterosis are in accordance with early work of Rebika, (2017); Sharma and Bora (2013); Shah and Mohammed (2005).

For number of pods per node Vivek Matar-11 × VL-Ageti Matar-7 (65.22%), Palam Triloki × VL-Ageti Matar-7 (56.52%), Vivek Matar-10 × VL-Ageti Matar-7 (42.86%), Palam Triloki × P-89 (37.93%) and Palam Priya × VL-Ageti Matar-7 (37.93%) exhibited significant positive relative heterosis whereas cross combinations namely Vivek Matar-11 × VL-Ageti Matar-7 (46.15%), Palam Triloki × VL-Ageti Matar-7 (38.46%), Vivek Matar-10 × VL-Ageti Matar-7 (33.33%), Palam Priya × VL-Ageti Matar-7 (25.00%) and Matar Ageta-7 × VL-Ageti Matar-7 (11.11 showed significant positive heterosis over better parent (Table 3). Rebika, (2017); Sharma and Bora (2013); Shah and Mohammed (2005); reported similar findings for heterosis in number of pods per node.

For days to first picking cross combinations Palam Triloki × Azad Pea-1 (-29.57%), Palam Triloki × VL-Ageti Matar-7 (-15.52%), Vivek Matar-11 × VL-Ageti Matar-7 (-15.37%), Arkel × VL-Ageti Matar-7 (-14.05%) and Arka Ajit × P-89 (-10.77%) exhibited significant negative relative heterosis whereas cross combinations Palam Triloki x Azad Pea-1 (-29.90%), Palam Triloki × VL-Ageti Matar-7 (-24.10%),Vivek Matar-11 × VL-Ageti Matar-7 (-23.44%), Arkel × VL-Ageti Matar-7 (-21.69%) and Arka Ajit × P-89 (-15.91%) showed significant negative heterosis over better parent (Table 3). for pod length Arka Karthik × P-89 (41.29%), Palam Triloki × P-89 (26.82%), Mithi Phali × P-89 (26.55%), Azad Pea-3 × P-89 (24.85%) and Vivek Matar-10 × VL-Ageti Matar-7 (22.43%) exhibited significant positive relative heterosis whereas cross combinations namely Arka Karthik × P-89 (35.72%), Palam Triloki × P-89 (25.06%), Azad Pea-3 × P-89 (23.77%), Mithi Phali × P-89 (22.90%) and Vivek Matar-10 × VL-Ageti Matar-7 (18.21%) showed significant positive heterosis over better parent (Table 3). Heterosis for days to first picking was also reported by Katoch *et al*., (2017); Rebika, (2017); Sharma and Bora (2013); Shah and Mohammed (2005).

For pod length Arka Karthik × P-89 (41.29%), Palam Triloki × P-89 (26.82%), Mithi Phali × P-89 (26.55%), Azad Pea-3 × P-89 (24.85%) and Vivek Matar-10 × VL-Ageti Matar-7 (22.43%). exhibited significant positive relative heterosis. Whereas Arka Karthik × P-89 (35.72%), Palam Triloki × P-89 (25.06%), Azad Pea-3 × P-89 (23.77%), Mithi Phali × P-89 (22.90%) and Vivek Matar-10 × VL-Ageti Matar-7 (18.21%). showed significant positive heterosis over better parent (Table 3). Similar results for heterosis were reported by Katoch *et al*., (2017); Kushwah and Sharma (2015); Patil *et al*., (2011); Punia *et al*., (2011); Borah, (2009); Sofi *et al.*, (2006).

Table 1: Analysis of variance for Line × tester including parents.

Source of variation	d.f.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Replicates	2.00	106.01	0.59	17.30	5.22	0.01	0.07	0.12	0.03	92.84	0.24	0.024	3.84	0.01	0.86	0.55	0.24	23.59	117.58
Parents	14.00	2030.86*	485.914*	11.07*	2.14**	0.34**	421.20**	1.20**	0.21**	224.47*	4.46*	1.31*	78.54*	0.31**	14.63**	15.81**	5.48**	571.77*	2825.70*
Lines	11.00	1737.48**	467.06*	6.98**	1.77**	0.36*	468.18*	1.27*	0.23*	212.03*	5.30*	0.92**	81.44*	0.31*	18.24**	14.03*	4.95*	489.70**	2420.59*
Testers	2.00	1583.87*	825.75**	25.71*	0.34	0.43*	326.75*	0.80*	0.23*	129.96*	2.11**	3.16**	92.97*	0.07	1.07**	32.64**	1.03**	1168.85**	5772.13**
Lines vs testers	1.00	6151.98*	13.61*	26.76**	9.85*	0.02*	89.28*	1.32**	0.01*	550.27*	0.09	1.01**	17.86**	0.95**	1.99*	1.79**	20.21**	280.48*	1389.05*
Crosses	35.00	1152.34**	313.69*	4.09**	1.21*	0.02*	330.87**	2.11*	4.25**	821.02*	2.73**	2.24**	9.01*	0.29**	15.82**	13.50**	4.23**	452.89*	2237.06*
Parents vs crosses	1.00	2279.70*	638.48**	4.18**	0.98	2.05**	897.85	7.45*	0.01*	41343.39*	17.76*	56.94*	435.77*	0.01	3.36**	36.75**	0.10	4778.92**	23632.21**
Error	100.00	24.48	0.44	0.33	0.43	0.00	2.28	0.10	0.02	32.21	0.037	0.04	0.83	0.02	0.06	0.06	0.05	6.107	30.25

*Significant at 5% level of significance **Significant at 1% level of significance

1=Plant height, 2=Days to 50% flowering, 3=Node at which first flower appears, 4=Inter nodal distance (cm), 5=Number of pods per node, 6=Days to first picking, 7= Pod length (cm), 8=Pod width (cm), 9=Number of pods per plant, 10=Number of seed per pod, 11=Number of primary branches per plant, 12=Shelling percentage, 13=Ascorbic Acid content (mg/100g), 14=Total Sugar Content (%), 15= Crude Protein (%), 16=Total Soluble Solids (B^0), 17=Pod yield per plant (g) and 18=Pod yield per hectare (q).

Table 2: Estimation of heterosis (%) over mid- parent (MP) and over better parent (BP) for plant height, days to 50% flowering, node at which first flower appears and intermodal distance in pea (*Pisum sativum* L.).

Crosses	Plant Height (cm)		Days to 50% flowering		Node at which first flower appears		Inter nodal distance	
	MP	BP	MP	BP	MP	BP	MP	BP
Palam Priya × P-89	-0.79	-9.65	29.13**	16.67**	32.27**	28.39**	-5.74	-7.67
Palam Priya × VL-Ageti Matar-7	55.03**	29.52**	53.07**	48.91**	85.54**	49.41**	8.59	6.01
Palam Priya × Azad Pea-1	11.71*	-3.11	20.00**	-3.92**	-1.42	-13.27**	33.67**	28.73**
Arka Ajit × P-89	41.80**	33.76**	-7.58**	-18.67**	-1.19	-12.18**	12.58	10.14
Arka Ajit × VL-Ageti Matar-7	112.46**	72.27**	15.61**	-8.67**	21.52**	-12.09**	30.54**	27.59**
Arka Ajit × Azad Pea-1	30.41**	16.90**	0.33	-0.65	-7.51*	-9.20*	19.96*	15.66
Azad Pea-3 × P-89	4.57	-3.57	19.81**	8.77**	-21.07**	-35.65**	9.70	2.29
Azad Pea-3 × VL-Ageti Matar-7	57.52**	15.41**	5.56**	2.15	-2.91	-33.86**	7.44	-3.84
Azad Pea-3 × Azad Pea-1	30.21**	26.57**	26.83**	1.96**	-7.59*	-17.71**	12.49	-0.55
Arka Apoorva × P-89	12.70**	-4.03	14.62**	4.32**	7.14	4.64	-5.28	-14.01
Arka Apoorva × VL-Ageti Matar-7	75.90**	22.03**	32.74**	7.91**	26.43**	-2.15	8.46	-5.36
Arka Apoorva × Azad Pea-1	31.89**	17.80**	2.05**	-2.61**	-7.97	-15.03**	-0.93	-14.57
Arka Karthik × P-89	0.25	-18.69**	15.10**	7.63**	-3.17	-12.02**	-7.64	-14.91
Arka Karthik × VL-Ageti Matar-7	6.66	-28.39**	36.70**	13.74**	12.10*	-17.63**	11.14	-1.65
Arka Karthik × Azad Pea-1	-17.33**	-29.91**	6.34**	-1.31	5.66	5.01	28.78**	12.58
Palam Triloki × P-89	1.26	-17.74**	-11.97**	-21.38**	18.67**	7.46	-1.49	-9.70
Palam Triloki × VL-Ageti Matar-7	48.96**	0.12	-20.69**	-36.55**	14.79**	-15.85**	7.99	-4.90
Palam Triloki × Azad Pea-1	-26.05**	-37.19**	-40.94**	-42.48**	6.57	6.31	12.23	-2.35
Vivek Matar-11 × P-89	-22.58**	-32.49**	-5.84**	-15.38**	32.48**	31.34**	-14.55	-18.55*
Vivek Matar-11 × VL-Ageti Matar-7	18.42**	-16.51**	-17.39**	-33.57**	29.89**	2.92	-5.74	13.85
Vivek Matar-11 × Azad Pea-1	-8.21*	-15.93**	4.05**	0.65	-6.88	-16.51**	16.82*	5.43
Arka Priya × P-89	-1.45	-3.09	16.59**	7.89**	-2.29	-10.23*	17.42*	14.37
Arka Priya × VL-Ageti Matar-7	45.58**	14.29*	35.87**	28.87**	10.72*	-18.00**	10.45	3.06
Arka Priya × Azad Pea-1	9.04*	1.66	16.80**	-4.58**	-15.67**	-17.19**	23.64**	13.88
Mithi Phali × P-89	1.32	-5.91	4.64**	0.81	10.46*	4.18	-14.51*	-27.70**
Mithi Phali × VL-Ageti Matar-7	84.74**	36.01**	-3.81**	-17.89**	47.49**	11.31*	2.69	-16.22*
Mithi Phali × Azad Pea-1	43.38**	40.40**	7.97**	-2.61**	4.39	-0.28	1.14	-18.37**
Matar Ageta- 7 × P-89	59.56**	56.64**	39.34**	28.95**	-14.26**	-21.59**	29.30**	19.74*
Matar Ageta- 7 × VL-Ageti Matar-7	137.80**	86.93**	22.83**	16.49**	48.76**	9.81*	9.36	-2.75
Matar Ageta- 7 × Azad Pea-1	57.45**	46.55**	20.00**	-1.96**	-16.09**	-17.19**	24.46**	9.33
Vivek Matar-10 x P-89	-12.23**	-28.87**	18.63**	6.14**	27.92**	26.74**	5.02	3.29
Vivek Matar-10 × VL-Ageti Matar-7	-4.57	-35.95**	38.98**	36.67**	33.48**	5.82	2.46	-3.51
Vivek Matar-10 × Azad Pea-1	-5.33	-19.80**	-3.70**	-23.53**	13.11**	1.36	24.50**	15.72
Arkel × P-89	-3.57	-22.92**	-11.03	-21.48**	9.85*	4.80	-6.50	-12.16
Arkel × VL-Ageti Matar-7	14.98**	-23.54**	-19.49**	-36.24**	60.86**	22.41**	4.52	-5.78
Arkel × Azad Pea-1	23.02**	2.69	-2.65**	-3.92**	17.39**	10.85*	19.60*	6.48

*Significant at 5% level of significance **Significant at 1% level of significance

Table 3: Estimation of heterosis (%) over mid-parent (MP) and over better parent (BP) for number of pods per node, days to first picking, pod length and pod width in pea (*Pisum sativum* L.).

Crosses	Number of pods per node		Days to first picking		Pod length (cm)		Pod width (cm)	
	MP	BP	MP	BP	MP	BP	MP	BP
Palam Priya × P-89	2.86	-5.26*	11.06**	1.10	3.16	0.53	-19.68**	-27.54**
Palam Priya × VL-Ageti Matar-7	37.93**	25.00**	27.66**	24.86**	13.84**	10.68**	-27.87**	-34.13**
Palam Priya × Azad Pea-1	5.56*	-5.00*	16.38**	2.10	1.52	-2.29	-17.99**	-18.57**
Arka Ajit × P-89	5.26*	5.26*	-10.77**	-15.91**	5.67	1.26	-0.90	-0.90
Arka Ajit × VL-Ageti Matar-7	25.00**	5.26*	5.58**	-7.11**	0.98	-8.03*	-23.02**	-35.93**
Arka Ajit × Azad Pea-1	-2.56	-5.00*	2.64*	0.72	0.23	-2.76	-20.32**	-28.57**
Azad Pea-3 × P-89	5.26*	5.26*	20.77**	4.42**	24.85**	23.77**	-22.22**	-33.96**
Azad Pea-3 × VL-Ageti Matar-7	25.00**	5.26*	3.00*	-4.75**	10.25**	5.41	-21.47**	-23.35**
Azad Pea-3 × Azad Pea-1	2.56	0.00	24.06**	3.62**	10.00*	7.68*	-25.08**	-29.56**
Arka Apoorva × P-89	5.26*	5.26*	8.60**	5.76**	17.10**	7.43*	1.33	0.00
Arka Apoorva × VL-Ageti Matar-7	25.00**	5.26*	18.94**	7.85**	7.80**	-5.76	-7.47**	-22.16**
Arka Apoorva × Azad Pea-1	2.56	0.00	4.16**	2.60*	-9.71**	-16.19**	27.56**	15.71**
Arka Karthik × P-89	-5.26*	-5.26*	6.96**	6.73**	41.29**	35.72**	-10.67**	-20.42**
Arka Karthik × VL-Ageti Matar-7	25.00**	5.26*	16.27**	7.83**	18.07**	16.48**	-28.80**	-34.13**
Arka Karthik × Azad Pea-1	-7.69**	-10.00**	6.17**	2.10	14.25**	8.41*	-21.28**	-21.83**
Palam Triloki × P-89	37.93**	5.26*	-9.04**	-12.31**	26.82**	25.06**	-1.39	-19.77**
Palam Triloki × VL-Ageti Matar-7	56.52**	38.46**	-15.52**	-24.10**	5.19	1.09	-32.56**	-34.46**
Palam Triloki × Azad Pea-1	20.00**	-10.00**	-29.57**	-29.90**	14.58**	11.56**	-28.08**	-35.59**
Vivek Matar-11 × P-89	31.03**	0.00	-7.24**	-9.90**	15.27**	11.77**	15.35**	11.71**
Vivek Matar-11 × VL-Ageti Matar-7	65.22**	46.15**	-15.37**	-23.44**	-9.66**	-16.80**	-15.87**	-31.74**
Vivek Matar-11 × Azad Pea-1	26.67**	-5.00*	9.55**	8.19**	-15.69**	-17.21**	-8.20**	-20.00**
Arka Priya × P-89	-5.26*	-5.26*	6.02**	-2.76*	15.73**	13.50**	-29.60**	-36.69**
Arka Priya × VL-Ageti Matar-7	25.00**	5.26*	18.15**	16.49**	13.65**	9.81**	43.7**	39.2**
Arka Priya × Azad Pea-1	2.56	0.00	15.56**	2.10	0.09	-3.06	7.53**	7.14**
Mithi Phali × P-89	5.26*	5.26*	-0.28	-2.76*	26.55**	22.90**	-21.40**	-30.82**
Mithi Phali × VL-Ageti Matar-7	25.00**	5.26*	-4.70**	-9.30**	0.09	-7.68*	-8.63**	-14.37**
Mithi Phali × Azad Pea-1	2.56	0.00	9.52**	2.60*	-3.29	-4.88	-14.69**	-16.44**
Matar Ageta- 7 × P-89	8.11**	5.26*	21.19**	12.71**	3.73	-2.93	-21.74**	-24.37**
Matar Ageta- 7 × VL-Ageti Matar-7	29.03**	11.11**	6.74**	6.65**	-7.91**	-17.98**	-25.87**	-36.53**
Matar Ageta- 7 × Azad Pea-1	5.26*	0.00	14.60**	2.60*	4.73	-0.81	6.56**	-1.43
Vivek Matar-10 × P-89	5.88*	-5.26*	9.15**	-4.42**	12.95**	10.85**	1.89	-2.70*
Vivek Matar-10 × VL-Ageti Matar-7	42.86**	33.33**	21.49**	13.91**	22.43**	18.21**	-11.94**	-29.34**
Vivek Matar-10 × Azad Pea-1	14.29**	0.00	-0.26	-15.68**	11.15**	7.72*	-11.20**	-23.57**
Arkel × P-89	5.26*	5.26*	-9.73**	-11.64**	2.34	-0.58	-30.85**	-44.57**
Arkel × VL-Ageti Matar-7	25.00**	5.26*	-14.05**	-21.69**	-4.64	-12.02**	-47.58**	-50.00**
Arkel × Azad Pea-1	2.56	0.00	6.77**	4.64**	6.15*	4.42	-27.16**	-35.87**

*Significant at 5% level of significance **Significant at 1% level of significance

For pod width Arka Priya × VL-Ageti Matar-7 (43.7%), Arka Apoorva × Azad Pea-1 (27.56%), Vivek Matar-11 × P-89 (15.35%), Arka Priya × Azad Pea-1 (7.53%) and Matar Ageta-7 × Azad Pea-1 (6.56%) exhibited significant positive relative heterosis whereas Arka Priya × VL-Ageti Matar-7 (39.2%), Arka Apoorva ×Azad Pea-1 (15.71%), Vivek Matar-11 × P-89 (11.71%) and Arka Priya × Azad Pea-1 (7.14%) showed significant positive heterosis over better parent (Table 3). Rebika, (2017); Sharma and Bora (2013); Patil *et al*., (2011); Shah and Mohammed (2005); reported similar findings for heterosis with regard to pod width.

For number of pods per plant crosses namely Azad Pea-3 × Azad Pea-1 (175.38%), Matar Ageta-7 × P-89 (171.31%), Vivek Matar-10 × Azad Pea-1 (169.93%), Mithi Phali × VL-Ageti Matar-7 (163.44%) and Azad Pea-3 × VL-Ageti Matar-7 (159.53%) exhibited significant positive relative heterosis, whereas Azad Pea-3 × Azad Pea-1 (162.17%), Matar Ageta-7 × P-89 (159.74%), Vivek Matar-10 × Azad Pea-1 (154.79%), Arka Ajit × VL-Ageti Matar-7 (150.06%), Arka Karthik × VL-Ageti Matar-7 (143.77%) showed significant positive heterosis over better parent (Table 4). These findings are in accordance with early work of Katoch *et al*., (2017); Kushwah and Sharma (2015); Sharma and Bora (2013); Patil *et al*., (2011); Punia *et al*., (2011); Borah (2009); Ceyhan *et al*., (2008); Sofi *et al.*, (2006); Ceyhan and Avci (2005); Shah and Mohammed (2005).

For number of seed per pod crosses namely Arkel x VL-Ageti Matar-7 (77.22%), Arkel x P-89 (76.34%), Arka Apoorva × VL-Ageti Matar-7 (43.14%), Arka Karthik × P-89 (34.55%) and Mithi Phali × P-89 (33.33%) exhibited significant positive relative heterosis whereas Arkel × VL-Ageti Matar-7 (42.86%), Arka Apoorva × VL-Ageti Matar-7 (37.74%), Mithi Phali × P-89 (30.16%), Arkel × P-89 (30.16%) and Azad Pea-3 × P-89 (25.40%) showed significant positive heterosis over better parent (Table 4). The results are in accordance with the early work of Katoch *et al*., (2017); Rebika, (2017); Kushwah and Sharma (2015); Patil *et al*., (2011); Punia *et al*., (2011); Borah, (2009); Sofi *et al.*, (2006); Kumar and Tewatia (2005).

For number of primary branches per plant Arka Karthik × VL-Ageti Matar-7 (123.33%), Matar Ageta-7 × Azad Pea-1 (109.52%), Arka Priya × P-89 (95.45%), Matar Ageta-7 × P-89 (90.91%) and Mithi Phali × P-89 (81.82%) exhibited significant positive relative heterosis. whereas Arka Priya × P-89 (86.96%), Matar Ageta-7 × P-89 (82.61%), Arka Karthik × VL-Ageti Matar-7 (81.08%), Mithi Phali × P-89 (73.91%) and Vivek Matar-11 × VL-Ageti Matar-7 (70.83%) showed significant positive heterosis over better parent (Table 4). These results of heterosis are in accordance with early findings of Katoch *et al*., (2017); Kushwah and Sharma (2015); Patil *et al*., (2011); Punia *et al*., (2011); Borah, (2009); Ceyhan and Avci (2005); Salam, (2004) in garden pea.

For shelling percentage (%) the cross combinations namely Arkel × P-89 (24.27%), Arkel × VL-Ageti Matar-7 (23.10%), Azad Pea-3 × VL-Ageti Matar-7 (22.95%), Vivek Matar-10 × P-89 (21.46%) and Vivek Matar-10 × VL-Ageti Matar-7 (18.84%) exhibited significant positive relative heterosis whereas Azad Pea-3 × VL-Ageti Matar-7 (22.80%), Arkel × VL-Ageti Matar-7 (20.90%), Vivek Matar-10 × P-89 (20.45%), Arkel × P-89 (14.26%) and Mithi Phali × P-89 (12.40%) showed significant positive heterosis over better parent (Table 4). Similar results for heterosis were reported by earlier researchers namely Katoch *et al*., (2017); Sharma and Bora and (2013); Patil *et al*., (2011).

For ascorbic acid content Palam Triloki × P-89 (23.87%), Vivek Matar-11 × P-89 (22.73%), Palam Priya × P-89 (22.66%), Palam Priya × VL-Ageti Matar-7 (18.90%) and Azad Pea-3 × P-89 (16.22%) exhibited significant positive relative heterosis whereas Vivek Matar-11 × P-89 (20.25%), Palam Triloki × P-89 (19.98%), Palam Priya × P-89 (11.74%) and Palam Triloki × Azad Pea-1 (11.26%) showed significant positive heterosis over better parent (Table 5). Similar reports for heterosis were given by Sharma and Bora (2013); Borah, (2009); Ceyhan *et al*., (2008); Ceyhan and Avci (2005); Shah and Mohammed (2005).

For total sugar content Mithi Phali × Azad Pea-1 (46.36%), Mithi Phali × P-89 (42.13%), Mithi Phali × VL-Ageti Matar-7 (39.02%), Arka Apoorva × Azad Pea-1 (9.57%) and Azad Pea-3 × Azad Pea-1 (8.42%) exhibited significant positive relative heterosis, whereas Mithi Phali × Azad Pea-1 (42.88%), Mithi Phali × P-89 (41.02%), Mithi Phali × VL-Ageti Matar-7 (38.67%), Arka Apoorva × Azad Pea-1 (9.56%) and Azad Pea-3 × Azad Pea-1 (6.28%) showed significant positive heterosis over better parent (Table 5). Similar results for heterosis were reported by Katoch *et al*., (2017); Sharma and Bora (2013); Borah (2009); Ceyhan *et al*., (2008); Ceyhan and Avci (2005); Shah and Mohammed (2005).

For crude protein Arka Priya × Azad Pea-1 (34.36%), Arka Priya × VL-Ageti Matar-7 (21.46%), Arka Priya × P-89 (16.74%), Arka Apoorva × Azad Pea-1 (16.07%) and Azad Pea-3 × P-89 (13.87%) exhibited significant positive relative heterosis whereas Arka Priya × Azad Pea-1 (31.81%), Arka Priya × VL-Ageti Matar-7 (9.79%), Arka Apoorva × Azad Pea-1 (8.11%), Arka Apoorva × VL-Ageti Matar-7 (6.24%) and Arkel × Azad Pea-1 (5.68%) showed significant positive heterosis over better parent (Table 5). Yadav, (2013) reported similar findings for the trait.

Table 4: Estimation of heterosis (%) over mid-parent (MP) and over better parent (BP) for number of pods per plant, number of seed per pod , number of primary branches per plant and shelling percentage in pea (*Pisum sativum* L.).

Crosses	Number of pods per plant		Number of seed per pod		Number of primary branches per plant		Shelling percentage (%)	
	MP	BP	MP	BP	MP	BP	MP	BP
Palam Priya × P-89	62.57**	13.87	-18.03**	-20.63**	50.00**	44.00**	6.82**	6.00**
Palam Priya × VL-Ageti Matar-7	94.05**	54.09**	5.56*	-3.39	70.83**	64.00**	10.90**	2.95
Palam Priya × Azad Pea-1	122.59**	63.13**	-15.45**	-18.75**	13.43**	-9.52*	9.82**	5.64**
Arka Ajit × P-89	120.40**	91.19**	8.06**	6.35*	63.27**	53.85**	2.87*	-5.61**
Arka Ajit × VL-Ageti Matar-7	159.47**	150.06**	-1.82	-11.48**	59.18**	50.00**	5.95**	-8.54**
Arka Ajit × Azad Pea-1	112.30**	96.81**	-0.80	-3.13	55.88**	26.19**	-4.81**	-8.71**
Azad Pea-3 × P-89	128.61**	65.87**	26.40**	25.40**	69.57**	69.57**	15.49**	7.85**
Azad Pea-3 × VL-Ageti Matar-7	159.53**	115.66**	18.92**	6.45*	43.48**	43.48**	22.95**	22.80**
Azad Pea-3 × Azad Pea-1	175.38**	162.17**	20.63**	18.75**	53.85**	19.05**	9.03**	-2.44
Arka Apoorva × P-89	108.04**	106.31**	29.31**	19.05**	28.81**	5.56	2.42	-3.64**
Arka Apoorva × VL-Ageti Matar-7	148..48**	107.51**	43.14**	37.74**	52.54**	25.00**	4.12**	-8.01**
Arka Apoorva × Azad Pea-1	27.12*	17.35	-4.27	-12.50**	10.26**	2.38	-3.05*	-4.55**
Arka Karthik × P-89	68.93**	37.52**	34.55**	17.46**	16.67**	-5.41	3.82**	-3.38*
Arka Karthik × VL-Ageti Matar-7	153.70**	143.77**	20.83**	18.37**	123.33**	81.08**	4.78**	-8.36**
Arka Karthik × Azad Pea-1	85.34**	60.32**	26.13**	9.37**	6.33	0.00	-2.56*	-5.16**
Palam Triloki × P-89	131.28**	64.44**	9.63**	2.78	49.02**	35.71**	12.77**	12.19**
Palam Triloki × VL-Ageti Matar-7	124.62**	81.85**	5.79*	-11.11**	68.63**	53.57**	18.44**	11.27**
Palam Triloki × Azad Pea-1	115.20**	60.37**	14.71**	8.33**	22.86**	2.38	7.62**	2.26
Vivek Matar-11 × P-89	5.02	-9.05	27.87**	23.81**	40.43**	37.50**	7.97**	4.23**
Vivek Matar-11 × VL-Ageti Matar-7	112.06**	104.73**	7.41**	-1.69	74.47**	70.83**	12.01**	1.35
Vivek Matar-11 × Azad Pea-1	76.65**	63.47**	-8.94**	-12.50**	15.15**	-9.52*	2.09	0.94
Arka Priya × P-89	87.76**	35.10**	23.58**	20.63**	95.45**	86.96**	8.16**	6.85**
Arka Priya × VL-Ageti Matar-7	146.32**	102.49**	21.10**	10.00**	50.00**	43.48**	15.81**	7.06**
Arka Priya × Azad Pea-1	110.15**	58.68**	17.74**	14.06**	17.46**	-11.90**	3.89**	0.38
Mithi Phali × P-89	101.49**	44.31**	33.33**	30.16**	81.82**	73.91**	12.86**	12.40**
Mithi Phali × VL-Ageti Matar-7	163.44**	115.30**	-15.60**	-23.33**	54.55**	47.83**	12.99**	6.04**
Mithi Phali × Azad Pea-1	108.22**	56.43**	4.84*	1.56	4.76	-21.43**	-1.19	-6.02**
Matar Ageta- 7 × P-89	171.31**	159.74**	-12.75**	-24.42**	90.91**	82.61**	8.94**	8.26**
Matar Ageta- 7 × VL-Ageti Matar-7	136.65**	126.85**	-0.74	-22.09**	77.27**	69.57**	12.35**	5.65**
Matar Ageta- 7 × Azad Pea-1	48.22**	38.11**	-4.00*	-16.28**	109.52**	57.14**	1.58	-3.57**
Vivek Matar-10 × P-89	24.02*	9.39	5.60*	4.76	65.22**	65.22**	21.46**	20.45**
Vivek Matar-10 × VL-Ageti Matar-7	94.97**	84.44**	27.93**	14.52**	21.74**	21.74**	18.84**	11.97**
Vivek Matar-10 × Azad Pea-1	169.93**	154.79**	7.94**	6.25*	7.69	-16.67**	3.17*	-2.26
Arkel × P-89	40.63**	30.73**	76.34**	30.16**	51.11**	47.83**	24.27**	14.26**
Arkel × VL-Ageti Matar-7	79.77**	61.18**	77.22**	42.86**	20.00**	17.39*	23.10**	20.90**
Arkel × Azad Pea-1	127.06**	126.89**	10.64**	-18.75**	-18.75**	-38.10**	9.81**	-3.20*

*Significant at 5% level of significance **Significant at 1% level of significance

Table 5: Estimation of heterosis (%) over mid-parent (MP) and over better parent (BP) for ascorbic acid content, total sugar content, crude protein and total soluble solids in pea (*Pisum sativum* L.).

Crosses	Ascorbic Acid content (mg/100g)		Total Sugar Content (%)		Crude Protein (%)		Total Soluble Solids (Brix)	
	MP	BP	MP	BP	MP	BP	MP	BP
Palam Priya × P-89	22.66**	11.74**	1.80	-1.88	5.26**	2.84**	3.35**	-0.08
Palam Priya × VL-Ageti Matar-7	18.90**	7.74*	-2.28*	-4.86**	-5.35**	-10.06**	0.49	-0.78
Palam Priya × Azad Pea-1	4.50	-4.89	-0.87	-1.38	-1.08	-13.14**	0.06	0.06
Arka Ajit × P-89	-5.79*	-18.13**	2.05*	-1.94	1.93*	-0.51	-13.77**	-18.00**
Arka Ajit × VL-Ageti Matar-7	-6.88*	-19.49**	-1.77	-4.66**	5.03**	-0.10	-16.30**	-1875**
Arka Ajit × Azad Pea-1	0.92	-12.38**	4.28**	3.41**	3.76**	-8.81**	-15.50**	-16.95**
Azad Pea-3 × P-89	16.22**	8.43*	5.18**	3.92**	13.87**	-0.70	2.53*	-6.13**
Azad Pea-3 × VL-Ageti Matar-7	-7.47*	-14.15**	2.32*	2.16*	2.98**	-3.91**	-1.09	-7.64**
Azad Pea-3 × Azad Pea-1	-1.96	-8.62*	8.42**	6.28**	1.15	-0.38	-5.86**	-11.03**
Arka Apoorva × P-89	-2.00	-8.77*	7.38**	4.03**	8.49**	-0.39	-8.53**	-11.05**
Arka Apoorva × VL-Ageti Matar-7	10.53**	2.33	6.94**	4.66**	7.68**	6.24**	-24.76**	-25.27**
Arka Apoorva × Azad Pea-1	-8.12*	-14.55**	9.57**	9.56*	16.07**	8.11**	-12.36**	12.88**
Arka Karthik × P-89	-2.08	-3.47	0.60	0.30	1.06	-1.07	0.14	-11.24**
Arka Karthik × VL-Ageti Matar-7	-1.61	-3.58	-7.04**	-7.73**	-4.38**	-9.30**	8.42**	-2.05
Arka Karthik × Azad Pea-1	3.58	2.00	-3.36**	-6.11**	-2.37**	-14.41**	11.00**	1.43
Palam Triloki × P-89	23.87**	19.98**	-2.73**	-4.39**	3.12**	-1.41	15.63**	-0.50
Palam Triloki × VL-Ageti Matar-7	12.16**	8.01*	-7.87**	-10.36**	7.74**	4.61**	-1.25	-13.46**
Palam Triloki × Azad Pea-1	14.99**	11.26**	0.42	-4.32**	11.43**	-0.22	6.53**	-5.61**
Vivek Matar-11 × P-89	22.73**	20.25**	1.06	-1.95	1.73*	-4.70**	0.40	-5.77**
Vivek Matar-11 × VL-Ageti Matar-7	-2.56	-5.09	2.92**	0.87	-0.09	-0.92	-2.38*	-6.50**
Vivek Matar-11 × Azad Pea-1	3.34	1.14	3.52**	3.36**	2.64**	-6.30**	3.59**	0.45
Arka Priya × P-89	-3.57	-11.06**	-3.71**	-5.15**	16.74**	-1.11	-1.72	-9.88**
Arka Priya × VL-Ageti Matar-7	9.12**	0.09	-2.69**	-5.12**	21.46**	9.79**	4.34**	-2.41*
Arka Priya × Azad Pea-1	-4.96	-12.43**	0.25	-4.29**	34.36**	31.81**	-1.36	-6.63**
Mithi Phali × P-89	-2.51	-3.70	42.13**	41.02**	2.23*	-9.05**	4.90**	-4.61**
Mithi Phali × VL-Ageti Matar-7	-1.61	-3.38	39.02**	38.67**	-10.02**	-14.20**	5.51**	-2.15*
Mithi Phali × Azad Pea-1	4.55	3.17	46.36**	42.88**	2.67**	-1.14	-5.40**	-11.22**
Matar Ageta- 7 × P-89	-1.09	-4.62	1.44	-1.92	7.88**	-1.27	-16.74**	-21.38**
Matar Ageta- 7 × VL-Ageti Matar-7	-4.09	-8.04*	-2.89**	-5.15**	-12.92**	-14.38**	-10.30**	-13.58**
Matar Ageta- 7 × Azad Pea-1	4.23	0.40	0.10	-0.09	-4.33**	-10.61**	-7.69**	-9.93**
Vivek Matar-10 × P-89	6.44	6.39	2.30*	-1.60	10.35**	-1.06	2.98**	-0.40
Vivek Matar-10 × VL-Ageti Matar-7	5.01	4.44	3.91**	0.96	-0.66	-4.47**	-5.70**	-6.86**
Vivek Matar-10 × Azad Pea-1	1.90	1.84	0.75	0.02	3.44**	-1.24	0.73	0.70
Arkel ×P-89	1.32	-1.13	-12.75**	-25.15**	9.44**	-4.62**	-9.35**	-11.33**
Arkel × VL-Ageti Matar-7	3.72	0.62	-17.55**	-29.88**	3.75**	-3.26**	-5.88**	-5.96**
Arkel × Azad Pea-1	7.24*	4.53	-20.21**	-33.33**	7.23**	5.68**	1.13	-0.06

*Significant at 5% level of significance **Significant at 1% level of significance

For total soluble solids the cross combinations with significant positive relative heterosis were Palam Triloki × P-89 (15.63%), Arka Karthik × Azad Pea-1 (11.00%), Arka Karthik × VL-Ageti Matar-7 (8.42%), Palam Triloki × Azad Pea-1 (6.53%) and Mithi Phali × VL-Ageti Matar-7 (5.51%) whereas only one cross combination showed significant positive heterosis over better parent i.e. Arka Apoorva × Azad Pea-1 (12.88%) (Table 5). These findings are in accordance to the early reports by Katoch *et al*., (2017); Sharma and Bora (2013); Borah (2009); Ceyhan *et al*., (2008); Ceyhan and Avci (2005); Shah and Mohammed (2005).

For pod yield per plant the cross combinations *viz*., Palam Priya × Azad Pea-1 (99.51%), Palam Priya × VL-Ageti Matar-7 (76.29%), Palam Priya × P-89 (56.19%), Arka Priya × Azad Pea-1 (55.62%) and Azad Pea-3 × P-89 (42.14%) exhibited significant positive relative heterosis, whereas Palam Priya × Azad Pea-1 (96.37%), Palam Priya × VL-Ageti Matar-7 (55.04%), Arka Priya × Azad Pea-1 (54.57%), Vivek Matar-10 × Azad Pea-1 (40.53%) and Azad Pea-3 × VL-Ageti Matar-7 (24.67%) showed significant positive heterosis over better parent (Table 6). These results are in agreement with early work of Sharma and Bora (2013); Patil *et al*., (2011); Kumar and Tewatia (2005); Shah and Mohammed (2005)..

For pod yield per hectare the cross combinations *viz*., Palam Priya × Azad Pea-1 (99.50%), Palam Priya × VL-Ageti Matar-7 (76.28%), Palam Priya × P-89 (56.19%), Arka Priya × Azad Pea-1 (55.61%) and Azad Pea-3 × P-89 (42.25%) exhibited significant positive relative heterosis. whereas Palam Priya × Azad Pea-1 (96.36%), Palam Priya × VL-Ageti Matar-7 (55.03%), Arka Priya × Azad Pea-1 (54.57%), Vivek Matar-10 x Azad Pea-1 (40.52%) and Azad Pea-3 × VL-Ageti Matar-7 (24.66%) showed significant positive heterosis over better parent (Table 6). The results are in close agreement with the findings of Patil *et al*., (2011); Kumar and Tewatia (2005).

Table 6: Estimation of heterosis (%) over mid-parent MP) and over better parent (BP) for pod yield per plant and pod yield per hectare in pea (*Pisum sativum* L.).

Crosses	Pod yield per plant (g)		Pod yield per hectare (q)	
	MP	BP	MP	BP
Palam Priya × P-89	56.19**	16.62**	56.19**	16.62**
Palam Priya × VL-Ageti Matar-7	76.29**	55.04**	76.28**	55.03**
Palam Priya × Azad Pea-1	99.51**	96.37**	99.50	96.36**
Arka Ajit × P-89	14.61**	4.26	14.62**	4.26
Arka Ajit × VL-Ageti Matar-7	19.11**	6.80*	19.29**	6.97*
Arka Ajit × Azad Pea-1	26.44**	0.09	26.45**	0.09
Azad Pea-3 × P-89	42.14**	6.13*	42.25**	6.13*
Azad Pea-3 × VL-Ageti Matar-7	41.75**	24.67**	41.89**	24.66**
Azad Pea-3 × Azad Pea-1	23.71**	21.76**	23.87**	22.06**
Arka Apoorva × P-89	-6.42**	-9.32**	-6.42**	-9.32**
Arka Apoorva × VL-Ageti Matar-7	-12.29**	-29.41**	-12.30**	-29.41**
Arka Apoorva × Azad Pea-1	-7.18*	-32.79**	-7.18*	-32.79**
Arka Karthik × P-89	23.33**	-1.51	23.33**	-1.51
Arka Karthik × VL-Ageti Matar-7	18.83**	13.99**	18.82**	13.98**
Arka Karthik ×Azad Pea-1	28.71**	15.85**	28.70**	15.84**
Palam Triloki × P-89	11.06**	-8.32**	11.06**	-8.32**
Palam Triloki × VL-Ageti Matar-7	8.85*	8.76*	8.84*	8.76*
Palam Triloki × Azad Pea-1	0.29	-13.05**	0.30	-13.05**
Vivek Matar-11 × P-89	19.31**	0.63	19.30**	0.63
Vivek Matar-11 × VL-Ageti Matar-7	2.76	0.00	2.76	0.00
Vivek Matar-11 × Azad Pea-1	12.77**	-4.40	12.76**	-4.41
Arka Priya × P-89	40.58**	4.33	40.57**	4.33
Arka Priya × VL-Ageti Matar-7	28.65**	12.25**	28.65**	12.24**
Arka Priya × Azad Pea-1	55.62**	54.57**	55.61**	54.57**
Mithi Phali × P-89	8.41**	-14.12**	8.40**	-14.13**
Mithi Phali × VL-Ageti Matar-7	6.44	1.06	6.44	1.06
Mithi Phali × Azad Pea-1	4.87	-4.69	4.87	-4.69
Matar Ageta- 7 × P-89	12.24**	-8.63**	12.23**	-8.63**
Matar Ageta- 7 × VL-Ageti Matar-7	13.66**	11.75**	13.65**	11.74**
Matar Ageta- 7 × Azad Pea-1	-2.23	-13.94**	-2.24	-13.94**
Vivek Matar-10 × P-89	25.91**	-6.85*	25.91**	-6.85*
Vivek Matar-10 × VL-Ageti Matar-7	33.43**	15.94**	33.42**	15.93**
Vivek Matar-10 × Azad Pea-1	40.81**	40.53**	40.80**	40.52**
Arkel × P-89	20.82**	-8.31**	20.82**	-8.31**
Arkel × VL-Ageti Matar-7	15.78**	4.00	15.77**	4.00
Arkel × Azad Pea-1	18.29**	13.72*	18.29**	13.72*

*Significant at 5% level of significance **Significant at 1% level of significance

CONCLUSION

On the basis of present studies, it can be concluded that the hybrids namely Palam Priya × Azad Pea-1 and Palam Priya × VL-Ageti Matar-7 were found to be superior hybrids selected for yield since these crosses exhibited significant heterosis and sca effects for yield per hectare. These crosses can be further assessed for their yield stability to confirm their potentiality and also their adaptability to agro-climatic conditions of Jammu

region before exploiting them on commercial scale. The segregating material from further generation can be utilized for isolating potential material.

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Conflict of Interest. None.

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