

Original Research Article

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Combining Ability Studies for Various Horticultural Traits in Garden Pea (*Pisum sativum* L.)

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ABSTRACT

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Line x tester, Pea, Combining ability, Grain Yield, Protein content, GCA and SCA

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Combining ability effects were estimated for different characters in a line x tester crossing programme comprising 36 hybrids produced by crossing 12 lines and 3 testers. Parents and hybrids differed significantly for gca and sca effects, respectively. Among the lines, Palam Triloki, Vivek Matar-10, Palam Priya, Azad Pea-3, Arka Karthik and Arka Ajit and among the testers P-89 and VL-Ageti Matar-7 were found to be the best general combiners. Six cross-combiners viz., Palam Priya x VL-Ageti Matar-7, Palam Priya x Azad Pea-1, Arka Ajit x P-89, Arka Ajit x VL-Ageti Matar-7, Arka Ajit x Azad Pea-1 and Azad Pea-3 x P-89 were found to be the best specific crosses for yield per plant and other related traits. Result showed that non additive gene action is an integral component of the genetic architecture of different traits in the material used in pea.

Introduction

Garden pea (*Pisum sativum* L.) a diploid ($2n=2x=14$) cultivated species of genus *Pisum*, family Leguminosae, is native of region between Mediterranean and Near East. It is grown both for fresh market and for food processing industry across the world. India rank 2nd in area and production of green peas after China and rank 5th in terms of yield in world. In India, it is grown on an area of 540.5 thousand hectares with an annual production of 5422.1 thousand MT with a

productivity level of 10.0 MT/ha (Anonymous 2017-18). In Jammu & Kashmir, it covers an area of 2.38 thousand hectare as winter and off season crop with an annual production of 30.82 thousand MT. and productivity level of 12.95 MT/ha (Anonymous 2017-18). Hybridization is one of the important breeding methods for breaking yield barriers. It offers for great possibilities in crop improvement than any other breeding method and is the only effective means of combining together the desirable horticultural traits of two or more

varieties, by the concept of combining ability, it refers to capacity of genotype to transmit superior performance to its progeny (Sprague and Tatum, 1942).

Materials and Methods

Experimental material comprised of twelve lines and three testers (Table 1). The testers were crossed with each line and thus 36 F₁'s were produced (Table 2). The 15 parents along with 36 F₁'s were grown in a Randomized Block Design with three replications at the Experimental Farm, Division of Vegetable Science & Floriculture, Faculty of Agriculture, Sher-e Kashmir University of Agricultural Sciences and Technology Jammu, Main Campus, Chatha, Jammu (J&K). 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 maintain uniform experimental conditions. Five plants of each entry in each replication were randomly selected (excluding boarder rows) for recording the observations on various characters 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 (B⁰), pod yield per plant (g) and pod yield per hectare (q). The analysis of general and specific combining abilities for the above traits were calculated 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 3). Mean squares due to crosses were further portioned into lines, testers and line x 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, intermodal 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 x tester interactions were found significant for all the traits under study except days to first picking.

Estimates of general combining ability effects

The estimates of gca effects (Table 4) showed that the parental line Palam Triloki was found to be the best general combiner for pod yield per hectare, pod yield per plant, crude protein and total soluble solids; Vivek Matar-10 for pod yield per hectare, plant height, days to 50% flowering, number of pods per node, days to first picking, total sugar content; Palam Priya for pod yield per hectare, pod yield per plant, plant height, number of pods per plant, number of primary branches per plant, shelling percentage, crude protein; Azad Pea-3 for pod yield per hectare, pod yield per plant, node at which first flower appears, pod width, number of seeds per pod, crude protein; Arka Karthik for plant height, node at which first flower appears, number of pods per node, pod length, number of pods per plant, number of seeds per pod, number of primary branches per plant, total sugar content, crude protein; Arka Ajit for pod length, number of primary branches per plant, total sugar content; Arka Apoorva for days to 50% flowering, days to first picking, pod

length, number of seeds per pod, number of primary branches per plant, shelling percentage, ascorbic acid content, crude protein; Arka Priya for days to 50% flowering, node at which first flower appears, inter nodal distance, days to first picking, shelling percentage, total soluble solids; Arkel for number of pods per node, days to first picking, pod length, number of pods per plant,

number of seeds per pod, total sugar content; Vivek Matar-11 for plant height, node at which first flower appears, number of pods per node, number of pods per plant; Matar Ageta-7 for days to 50% flowering, days to first picking, pod length, number of seeds per pod, total soluble solids; Mithi Phali for plant height, number of pods per node, total soluble solids.

Table.1 List of parents (Males and Females)

S. No.	Genotype (s)
Female parents	
1	Palam Triloki
2	Palam Priya
3	Arka Karthik
4	Arka Ajit
5	Arka Apoorva
6	Arka Priya
7	Azad Pea-3
8	Arkel
9	Vivek Matar-10
10	Vivek Matar-11
11	Matar Ageta-7
12	Mithi Phali
Male parents	
1	P-89
2	Azad Pea-1
3	VL-Ageti Matar-7

Table.2 Hybrids (F₁'s) developed by crossing 12 lines and 3 testers

S. No.	Hybrids	S. No.	Hybrids
1	Palam Priya x P-89	19	Vivek Matar-11 x P-89
2	Palam Priya x VL-Ageti Matar-7	20	Vivek Matar-11 x VL-Ageti Matar-7
3	Palam Priya x Azad Pea-1	21	Vivek Matar-11 x Azad Pea-1
4	Arka Ajit x P-89	22	Arka Priya x P-89
5	Arka Ajit x VL-Ageti Matar-7	23	Arka Priya x VL-Ageti Matar-7
6	Arka Ajit x Azad Pea-1	24	Arka Priya x Azad Pea-1
7	Azad Pea-3 x P-89	25	Mithi Phali x P-89
8	Azad Pea-3 x VL-Ageti Matar-7	26	Mithi Phali x VL-Ageti Matar-7
9	Azad Pea-3 x Azad Pea-1	27	Mithi Phali x Azad Pea-1
10	Arka Apoorva x P-89	28	Matar Ageta- 7 x P-89
11	Arka Apoorva x VL-Ageti Matar-7	29	Matar Ageta- 7 x VL-Ageti Matar-7
12	Arka Apoorva x Azad Pea-1	30	Matar Ageta- 7 x Azad Pea-1
13	Arka Karthik x P-89	31	Vivek Matar-10 x P-89
14	Arka Karthik x VL-Ageti Matar-7	32	Vivek Matar-10 x VL-Ageti Matar-7
15	Arka Karthik x Azad Pea-1	33	Vivek Matar-10 x Azad Pea-1
16	Palam Triloki x P-89	34	Arkel x P-89
17	Palam Triloki x VL-Ageti Matar-7	35	Arkel x VL-Ageti Matar-7
18	Palam Triloki x Azad Pea-1	36	Arkel x Azad Pea-1

Table.3 Analysis of variance for combining ability for various traits in peas (*Pisum sativum* L.)

Source of variation	d.f.	Plant Height (cm)	Days to 50% 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
Replicates	2.00	101.15	1.36	15.91	4.81	0.01	0.56	0.04	0.03	213.87
Crosses	35.00	1152.35*	313.69*	4.09*	1.21*	0.02*	330.87*	2.11*	4.25*	821.02*
Lines	11.00	2373.78*	430.16*	4.42	1.39	0.03	413.01	1.65	4.34	870.42
Testers	2.00	1901.41*	1365.75**	1.46	3.90*	0.02	1277.06**	14.58**	4.47	84.33
Lines x Tester	22.00	23.75**	159.82*	4.16**	0.88**	0.02**	203.79	1.21*	4.19**	863.30**
Error	70.00	23.75	0.36	0.23	0.40	0.01	1.73	0.12	0.02	38.69

Source of variation	d.f.	Number of seed per pod	Number of primary branches per plant	Shelling percentage (%)	Ascorbic Acid content (mg/100g)	Total Sugar Content (%)	Crude Protein (%)	Total Soluble Solids (Brix=B ⁰)	Pod yield per plant (g)	Pod yield per hectare (q)
Replicates	2.00	0.11	0.16	8.12	0.00	0.99	0.63	0.21	19.89	98.04
Crosses	35.00	2.73*	224*	9.01*	0.29	15.82*	13.50*	4.23*	452.89*	2237.06*
Lines	11.00	2.80	2.96	8.40	0.53*	48.23*	13.06*	8.18*	466.35*	2305.47*
Testers	2.00	9.40*	1.52	42.93**	0.20	4.96**	133.30*	5.72	4983.05*	24602.94*
Lines x testers	22.00	2.09**	1.95**	6.24*	0.18**	0.61*	2.82**	2.11**	34.33**	169.59**
Error	70.00	0.04	0.04	0.78	0.02	0.05	0.06	0.05	5.22	25.87

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

Table.4 Estimates of General Combining Ability (GCA) effects of lines for various traits in peas (*Pisum sativum* L.)

Female Parent	Plant Height (cm)	Days to 50% 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
Palam Triloki	-22.09*	4.92**	0.85**	-0.39	-0.05*	4.96**	-0.49**	-0.27**	-14.64**
Palam Priya	6.62**	3.92*	-0.12	0.10	0.02	3.29**	-0.21	-0.29**	10.79**
Arkel	2.42	-2.08*	-0.28	0.13	0.05**	-1.21*	0.32**	-0.20**	14.48**
Arka Karthik	22.07*	9.42*	-0.85**	-0.22	0.05**	10.29**	0.42**	0.01	10.21*
Arka Ajit	-8.41**	8.92**	-0.25	0.26	-0.08*	7.12*	0.73**	-0.23**	-3.327
Arka Apoorva	0.28	-15.58**	0.61*	0.03	-0.08**	-15.21*	0.32**	-0.12**	-5.42**
Arka Priya	-19.30**	-2.92*	-0.32**	-0.71**	-0.05*	-2.54**	-0.74**	-0.18**	-11.59**
Azad Pea-3	-17.99**	1.08**	-1.14*	0.22	-0.01	1.62**	-0.17	2.19**	-7.72**
Vivek Matar-10	10.47**	-2.25**	0.57**	0.11	0.05**	-2.37**	0.10	-0.13**	-5.52**
Vivek Matar-1	27.97*	3.75**	-0.50*	0.87**	0.05**	3.96**	-0.15	-0.23**	12.41**
Matar Ageta-7	-11.40**	-4.42**	0.26	-0.22	-0.01	-5.37**	0.25*	-0.24**	0.51
Mithi Phali	9.36**	-4.75	1.17**	-0.18	0.05**	-4.54	-0.39**	-0.31	-0.19
SE (gi)+	1.65	0.22	0.19	0.22	0.02	0.50	0.11	0.01	1.90
SE(gi-gj)+	2.33	0.31	0.27	0.31	0.03	0.71	0.15	0.01	2.67
CD (p=0.05)	3.29	0.44	0.3	0.44	0.04	1.00	0.21	0.01	3.77
CD (p=0.01)	4.37	0.59	0.51	0.58	0.05	1.33	0.28	0.01	5.01

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

Table.4 Estimates of General Combining Ability (GCA) effects of lines for various traits in peas (*Pisum sativum* L.) contd....

Female Parent	Number of seed per pod	Number of primary branches per plant	Shelling percentage (%)	Ascorbic Acid content (mg/100g)	Total Sugar Content (%)	Crude Protein (%)	Total Soluble Solids (Brix=B ⁰)	Pod yield per plant (g)	Pod yield per hectare (q)
Palam Triloki	-1.36**	-0.14*	0.10	0.55**	-1.24**	0.39**	1.24**	17.82**	39.60**
Palam Priya	-0.56**	0.43**	0.67*	0.10*	-0.95**	1.17* *	-1.73**	7.81**	17.42**
Arkel	0.71**	0.09	-0.93**	0.01	0.26**	-0.84**	-0.10	1.25	2.77
Arka Karthik	0.14*	0.23**	-0.93**	-0.05	0.35**	1.16**	-1.41**	0.34	0.75
Arka Ajit	0.07	0.83**	0.17	-0.26**	-1.14**	0.09	0.59**	-0.11	-0.24
Arka Apoorva	0.54**	0.16*	1.14**	0.34**	-0.80**	1.45**	0.20* *	-5.71**	-12.69**
Arka Priya	-0.26**	-0.24**	0.67*	0.01	-0.60**	-0.23**	0.61**	-1.78*	-3.96*
Azad Pea-3	0.51**	-0.24**	0.30	-0.01	-0.58**	1.71**	0.21**	2.46**	5.56**
Vivek Matar-10	-0.23**	-0.21**	-1.10**	-0.26**	7.17**	-1.97**	0.29**	-8.64**	19.20**
Vivek Matar-11	0.14*	-0.41**	-1.464**	-0.19**	-1.19**	-1.59**	-1.25**	-5.96**	-13.26**
Matar Ageta-7	0.17**	0.93**	1.67**	-0.17**	-0.78**	-0.57**	0.92**	-1.55**	-3.45
Mithi Phali	0.14*	-0.61	-0.20	-0.09	-0.49	-0.76**	0.42**	-5.94	-13.20**
SE(gi)+	0.06	0.07	0.30	0.05	0.08	0.08	0.07	0.82	1.83
SE(gi-gj)+	0.09	0.09	0.43	0.07	0.11	0.12	0.10	1.16	2.59
CD (p=0.05)	0.13	0.13	0.60	0.10	0.16	0.17	0.14	1.64	3.66
CD (p=0.01)	0.17	0.17	0.80	0.13	0.21	0.22	0.19	2.18	4.85

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

Table.5 Estimates of Specific Combining Ability effects for various traits in peas (*Pisum sativum* L.)

Hybrids	Plant Height (cm)	Days to 50% 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
Palam Priya x P-89	-0.34	-2.25**	0.27	-0.52	-0.08*	-4.29**	-0.82**	0.19**	-2.38
Palam Priya x VL-Ageti Matar-7	-0.97	4.75**	1.51**	-0.13	0.07*	6.33**	0.73**	-0.38**	-4.57
Palam Priya x Azad Pea-1	1.31	-2.50**	-0.78**	0.65	0.01	-2.04*	0.09	0.19**	6.95*
Arka Ajit x P-89	4.30	-6.75**	-0.10	0.02	0.06	-8.12**	-0.35	0.31**	4.07
Arka Ajit x VL-Ageti Matar-7	5.91*	5.75**	0.09	0.56	0.01	6.00**	0.10	-0.39**	2.47
Arka Ajit x Azad Pea-1	-10.21**	1.00*	0.01	-0.58	-0.06	2.12*	0.25	0.07**	-6.53
Azad Pea-3 x P-89	-6.52	0.25	-0.89**	0.46	0.02	4.87**	0.12	0.17**	-10.06**
Azad Pea-3 x VL-Ageti Matar-7	-2.21	-9.25**	-0.47	-0.10	-0.03	-10.50**	-0.18	-0.27**	-16.39**
Azad Pea-3 x Azad Pea-1	8.73**	9.00**	1.36**	-0.36	0.01	5.62**	0.05	0.10**	26.45**
Arka Apoorva x P-89	-9.06**	-0.75	0.35	0.07	0.02	-0.12	0.39*	0.05**	12.31**
Arka Apoorva x VL-Ageti Matar-7	6.45*	6.75**	-0.09	0.53	-0.03	7.00**	0.42*	-0.45**	14.27**
Arka Apoorva x Azad Pea-1	2.61	-6.00**	-0.26	-0.60	0.01	-6.87**	-0.81**	0.40**	-26.59**
Arka Karthik x P-89	16.99**	-2.25**	-0.44	-0.67	-0.04	-0.96	0.61**	0.28**	-3.94
Arka Karthik x VL-Ageti Matar-7	-7.95**	6.75**	-0.86*	0.09	0.11**	5.17**	-0.31	-0.41**	9.31**
Arka Karthik x Azad Pea-1	-9.04**	-4.50**	1.29**	0.58	-0.06	-4.21**	-0.30	0.13**	-5.37
Palam Triloki x P-89	9.03**	8.75**	0.87*	-0.02	0.16**	9.87**	0.22	0.45**	9.25**
Palam Triloki x VL-Ageti Matar-7	18.03**	2.75**	-1.45**	0.16	-0.09**	3.50**	-0.58**	-0.48**	-5.99
Palam Triloki x Azad Pea-1	-27.06**	-11.50**	0.58	-0.14	-0.06	-13.37**	0.35	0.03**	-3.25
Vivek Matar-11 x P-89	-2.82	-0.42	1.70**	-0.35	0.02	-1.79*	0.82**	0.34**	-14.88**
Vivek Matar-11 x VL-Ageti Matar-7	0.71	-8.42**	-0.75*	-0.20	-0.03	-9.67**	-0.25	-0.43**	10.87**
Vivek Matar-11 x Azad Pea-1	2.11	8.83**	-0.95**	0.55	0.01	11.46**	-0.57**	0.08**	4.01
Arka Priya x P-89	0.61	-3.4**	0.42	0.50	-0.11**	-4.46**	-0.16	-2.39**	-0.55
Arka Priyax VL-Ageti Matar-7	-1.92	2.58**	-0.21	-0.34	0.04	3.17**	0.46*	4.29**	2.11
Arka Priya x Azad Pea-1	1.31	0.83*	-0.21	-0.16	0.07*	1.29	-0.29	-1.90**	-1.55
Mithi Phali x P-89	-17.98**	0.42	-0.39	-0.32	0.02	-0.46	0.89**	0.06**	1.05
Mithi Phali x VL-Ageti Matar-7	6.62*	-6.08**	0.48	0.49	-0.03	-5.33**	-0.39*	-0.19**	3.51
Mithi Phali x Azad Pea-1	11.35**	5.67**	-0.09	-0.17	0.01	5.79**	-0.45*	0.13**	-4.55
Matar Ageta- 7 x P-89	0.52	5.92**	-1.32**	1.00*	0.02	7.21**	-0.34	0.05**	34.41**
Matar Ageta- 7 x VL-Ageti Matar-7	5.57	-6.08**	2.16**	-0.67	-0.03	-6.67**	-0.43*	-0.45**	-5.43
Matar Ageta- 7 x Azad Pea-1	-6.09*	0.17	-8.4*	-0.33	0.01	-0.54	0.77**	0.40**	-28.99**
Vivek Matar-10 x P-89	7.56**	1.08**	0.71*	0.14	-0.11**	1.04	-0.78**	0.24**	-19.38**
Vivek Matar-10 x VL-Ageti Matar-7	-14.17**	7.08**	-1.10**	-0.41	0.04	8.17**	0.66**	-0.33**	-4.93
Vivek Matar-10 x Azad Pea-1	6.60*	-8.17**	0.39	0.26	0.07*	-9.21**	0.12	0.09**	24.31**
Arkel x P-89	-2.30	-0.58	-1.18**	-0.29	0.02	-2.79**	-0.54**	0.25**	-9.88**
Arkel x VL-Ageti Matar-7	-16.07**	-6.58**	0.68*	-0.02	-0.03	-7.17**	-0.24	-0.52**	-5.23
Arkel x Azad Pea-1	18.37**	7.17**	0.50	0.31	0.01	9.96**	0.78**	0.27**	15.13**
SE(Si)+	2.86	0.38	0.34	0.38	0.03	0.87	0.18	0.01	3.28
Sij-Skl+	4.04	0.54	0.47	0.54	0.05	1.23	0.26	0.01	4.63
Sij-Sik+	8.41	1.13	0.99	1.12	0.10	2.56	0.55	0.03	9.64
CD (p=0.05)	5.70	0.77	0.67	0.76	0.07	1.74	0.37	0.02	6.53
CD (p=0.01)	7.56	1.02	0.89	1.01	0.09	2.31	0.49	0.03	8.68

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

Table.5 Estimates of specific combining ability effects for various traits in peas (*Pisum sativum* L.) contd....

Hybrids	Number of seed per pod	Number of primary branches per plant	Shelling percentage (%)	Ascorbic Acid content (mg/100g)	Total Sugar Content (%)	Crude Protein (%)	Total Soluble Solids (Brix=B ⁰)	Pod yield per plant (g)	Pod yield per hectare (q)
Palam Priya x P-89	-0.87**	-0.06	-2.01**	0.17*	0.24	0.74**	0.21	-4.31**	-9.58**
Palam Priya x VL-Ageti Matar-7	0.81**	0.32**	-1.34*	0.15	0.02	-0.40**	0.10	0.53	1.17
Palam Priya x Azad Pea-1	0.06	-0.26*	3.35**	-0.32**	-0.26	-0.34*	-0.30*	3.78**	8.41**
Arka Ajit x P-89	0.03	-0.23	0.02	-0.15	-0.06	-0.83**	0.05	-3.47*	-7.77*
Arka Ajit x VL-Ageti Matar-7	-0.29*	-0.44**	0.50	-0.08	-0.24	1.02**	0.06	0.70	1.69
Arka Ajit x Azad Pea-1	0.26*	0.67**	-0.52	0.22*	0.29*	-0.19	-0.11	2.77	6.09
Azad Pea-3 x P-89	-0.04	0.01	-0.88	0.38**	-0.17	1.13**	0.49**	4.48**	9.96**
Azad Pea-3 x VL-Ageti Matar-7	-0.36**	-0.71**	0.80	-0.29**	-0.19	0.06	0.29*	2.46	5.45
Azad Pea-3 x Azad Pea-1	0.39**	0.71**	0.08	-0.09	0.36*	-1.19**	-0.77**	-6.94**	-15.42**
Arka Apoorva x P-89	0.13	-0.23	-0.18	-0.15	-0.24	-0.79**	0.94**	-1.63	-3.62
Arka Apoorva x VL-Ageti Matar-7	0.9.**	0.36**	-0.40	0.37**	0.17	0.12	-1.35**	-0.92	-2.06
Arka Apoorva x Azad Pea-1	-1.04**	-0.13	0.58	-0.23**	0.07	0.67**	0.41**	2.55	5.68
Arka Karthik x P-89	0.09	-1.13**	0.12	-0.14	0.55**	0.11	-1.09**	0.17	0.38
Arka Karthik x VL-Ageti Matar-7	-0.52	1.96**	-0.50	-0.02	-0.36*	0.15	0.53**	-1.33	-2.96
Arka Karthik x Azad Pea-1	0.43**	-0.83**	0.38	0.16	-0.19	-0.26	0.56**	1.17	2.60
Palam Triloki x P-89	-0.37**	-0.16	-0.84	0.14	-0.04	-1.33**	1.17**	0.72	1.61
Palam Triloki x VL-Ageti Matar-7	-0.39**	0.22	0.33	-0.12	-0.50**	0.81**	-0.98**	1.83	4.06
Palam Triloki x Azad Pea-1	0.76**	-0.06	0.51	-0.02	0.54**	0.52**	-0.19	-2.55	-5.66
Vivek Matar-11 x P-89	0.83**	-0.26*	-0.48	0.39**	-0.41**	-0.42**	-0.16	3.43*	7.62*
Vivek Matar-11 x VL-Ageti Matar-7	-0.19	0.42**	0.20	-0.30**	0.43**	0.39**	-0.23	-3.67*	-8.16*
Vivek Matar-11 x Azad Pea-1	-0.64**	-0.16	0.28	-0.09	-0.01	0.03	0.39**	0.24	0.53
Arka Priya x P-89	-0.14	0.71**	-1.31*	-0.20*	-0.48**	-1.52**	-0.48**	1.93	4.29
Arka Priya x VL-Ageti Matar-7	-0.16	-0.41**	0.96	0.33**	0.23	0.29*	0.85**	-4.74**	-10.55**
Arka Priya x Azad Pea-1	0.29**	-0.29*	0.35	-0.12	0.25	1.23**	-0.37**	2.81	6.26
Mithi Phali x P-89	1.19**	0.61**	1.49**	-0.16	-0.12	0.28	0.38**	-0.66	-1.46
Mithi Phali x VL-Ageti Matar-7	-1.42**	-0.11	0.16	-0.02	-0.26	-0.91**	0.82**	0.96	2.13
Mithi Phali x Azad Pea-1	0.23*	-0.49**	-1.65**	0.18*	0.38**	0.63**	-1.19**	-0.30	-0.67
Matar Ageta- 7 x P-89	-0.87**	-0.53**	-0.14	-0.10	0.18	1.74**	-1.02**	0.74	1.66
Matar Ageta- 7 x VL-Ageti Matar-7	0.31**	-0.94	0.13	-0.09	-0.09	-1.33**	0.45**	3.44*	7.64*
Matar Ageta- 7 x Azad Pea-1	0.56**	1.47	0.01	0.19*	-0.08	-0.42**	0.56**	-4.19	-9.30**
Vivek Matar-10 x P-89	-0.81**	0.61**	2.62**	-0.02	-0.16	0.78**	0.47**	-2.35	-5.21
Vivek Matar-10 x VL-Ageti Matar-7	0.68**	-0.51**	-0.20	0.05	0.63**	-0.32*	-0.60**	1.05	2.32
Vivek Matar-10 x Azad Pea-1	0.13	-0.09	-2.42**	-0.03	-0.47	-0.46	0.13	1.30	2.89
Arkel x P-89	0.83**	0.67**	-1.59**	-0.16	0.71**	0.12	-0.94**	0.95	2.13
Arkel x VL-Ageti Matar-7	0.61**	-0.14	-0.64	0.02	0.17	0.11	0.05	-0.32	-0.72
Arkel x Azad Pea-1	-1.44**	-0.53**	-0.95	0.15	-0.88**	-0.23	0.89**	-0.63	-1.41
SE(Si)+	0.11	0.11	0.53	0.08	0.14	0.14	0.12	1.43	3.17
Sij-Skl+	0.16	0.16	0.74	0.12	0.19	0.20	0.18	2.02	4.49
Sij-Sik+	0.33	0.34	1.55	0.25	0.41	0.43	0.37	4.20	9.34
CD (p=0.05)	0.22	0.23	1.05	0.17	0.27	0.29	0.25	2.85	6.33
CD (p=0.01)	0.29	0.30	1.39	0.22	0.36	0.38	0.33	3.78	8.41

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

Table.6 Estimates of General Combining Ability (GCA) effects of testers for various traits in pea (*Pisum sativum* L.)

Male Parent	Plant Height (cm)	Days to 50% 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
P-89	-8.38**	-0.75**	-0.01	-0.26*	-0.02*	-0.54*	0.72**	-0.27**	-0.05
VL Ageti Matar-7	4.59**	-5.75**	-0.19	-0.11	0.03**	-5.67**	-0.50**	0.40**	-1.51
Azad Pea-1	3.79**	6.5**	0.21*	0.37**	-0.01	6.21	-0.21**	-0.13**	1.55
SE(gi)+	0.82	0.11	0.10	0.11	0.01	0.25	0.05	0.00	0.94
SE(gi-gj)+	1.17	0.16	0.14	0.15	0.01	0.35	0.07	0.00	1.33
CD (p=0.05)	1.64	0.22	0.19	0.22	0.02	0.50	0.10	0.00	1.89
CD (p=0.01)	2.18	0.29	0.26	0.29	0.03	0.67	0.14	0.00	2.50

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

Table.6 Estimates of general combining ability effects of testers for various traits in pea (*Pisum sativum* L.) Conti.....

Male Parent	Number of seed per pod	Number of primary branches per plant	Shelling percentage (%)	Ascorbic Acid content (mg/100g)	Total Sugar Content (%)	Crude Protein (%)	Total Soluble Solids (Brix=B ⁰)	Pod yield per plant (g)	Pod yield per hectare (q)
P-89	0.57**	-0.17**	1.14**	0.08**	0.42**	2.18**	0.45**	13.11**	29.13**
VL Ageti Matar-7	-0.41**	-0.056	-1.03**	-0.04	-0.28**	-0.71**	-0.29**	-3.48**	-7.72**
Azad Pea-1	-0.16**	0.23**	-0.11	-0.04	-0.14**	-1.46**	-0.17**	-9.6**	-21.41**
SE(gi)+	0.03	0.03	0.15	0.02	0.04	0.04	0.04	0.41	0.92
SE(gi-gj)+	0.04	0.05	0.21	0.03	0.06	0.06	0.05	2.01	1.30
CD (p=0.05)	0.06	0.07	0.30	0.05	0.08	0.08	0.07	0.82	1.83
CD (p=0.01)	0.08	0.09	0.40	0.06	0.10	0.11	0.09	0.09	2.43

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

Among testers, P-89 was found to be the best general combiner for pod yield per hectare, pod yield per plant, crude protein, total sugar content, total soluble solids; days to 50% flowering, inter nodal distance, days to first picking, pod length, number of seeds per pod, shelling percentage; VL-Ageti Matar-7 for plant height, days to 50% flowering, number of pods per node, days to first picking, pod width; Azad Pea-1 for plant height, number of primary branches per plant (Table 5). The results are in agreement with earlier finding of Askander and Osman (2018), Katoch *et al.*, (2017), Kumari *et al.*, (2015), Sharma *et al.*, (2015), Al-Hamdany (2014), Mishra *et al.*, (2014), Mehmed (2013), Punia *et al.*(2011), Borah (2009), Sharma *et al.*, (2007), Narayan (2006).

It was observed that performance of parents bear direct relation for their respective *gca* effects in the parents, which showed highest *gca* effects for different traits were also observed good performance with respect to that particular traits. But this is not true always.

Estimates of Specific Combining Ability effect

Specific combining ability effects represent dominance and epistatic components of variation, which are non- fixable and can be related with heterosis (Sprague and Tatum, 1942 and Rajas and Sprague, 1952). The best hybrids possessing *sca* effects in the desired direction for fruit yield and yield components are presented in (Table 6). Negative effects are considered to be desirable for days to 50 per cent flowering (as earliness is preferred over lateness). Specific Combining Ability estimates suggests that the cross Palam Priya x VL-Ageti Matar-7 was found to be the best specific combination for number of seeds per pod, pod length, number of pods per node; Palam Priya x Azad Pea-1 for pod yield per

plant, pod yield per hectare, shelling percentage; Arka Ajit x P-89 for days to 50% flowering, days to first picking, pod width; Arka Ajit x VL-Ageti Matar-7 for crude protein; Arka Ajit x Azad Pea-1 for number of primary branches per plant, ascorbic acid content; Azad Pea-3 x P-89 for ascorbic acid content, crude protein, pod yield per plant, pod yield per hectare; Azad Pea-3 x VL-Ageti Matar-7 for days to 50% flowering, days to first picking; Azad Pea-3 x Azad Pea-1 for number of pods per plant, number of primary branches per plant; Arka Apoorva x P-89 for total soluble solids; Arka Apoorva x VL-Ageti Matar-7 for number of pods per plant, ascorbic acid content; Arka Karthik x P-89 for plant height, crude protein; Arka Karthik x VL-Ageti Matar-7 for number of pods per node, number of primary branches per plant; Palam Triloki x P-89 for plant height, number of pods per node, pod width, total soluble solids; Palam Triloki x VL-Ageti Matar-7 for plant height, node at which first flower appears, crude protein; Palam Triloki x Azad Pea-1 for days to 50% flowering, days to first picking, number of seeds per pod, total soluble solids; Vivek Matar-11 x P-89 for pod length, pod width, ascorbic acid content, pod yield per plant, pod yield per hectare; Vivek Matar-11 x VL-Ageti Matar-7 for days to 50% flowering, days to first picking; Arka Priya x P-89 for number of primary branches per plant; Arka Priya x VL-Ageti Matar-7 for pod width, ascorbic acid content, total soluble solids; Arka Priya x Azad Pea-1 for number of pods per node, crude protein, total sugar content; Mithi Phali x P-89 for pod length, number of seeds per pod, shelling percentage; Mithi Phali x VL-Ageti Matar-7 for total soluble solids; Mithi Phali x Azad Pea-1 for plant height; Matar Ageta-7 x P-89 for node at which first flower appears, number of pods per plant, crude protein; Matar Ageta-7 x VL-Ageti Matar-7 for pod yield per plant, pod yield per hectare; Matar Ageta-7 x Azad Pea-1 for pod length, pod width; Vivek Matar-10

x P-89 for shelling percentage; Vivek Matar-10 x VL-Ageti Matar-7 for node at which first flower appears, number of seeds per pod, total sugar content; Vivek Matar-10 x Azad Pea-1 for days to 50% flowering, number of pods per node, days to first picking, number of pods per plant; Arkel x P-89 for node at which first flower appears, number of seeds per pod, number of primary branches per plant, total sugar content; Arkel x VL-Ageti Matar-7 for total soluble solids; Arkel x Azad Pea-1 for plant height, pod length, number of pods per plant. The specific combining ability, which represents the predominance of non-additive gene action, is a major component that may be utilized in heterosis breeding. Similar result were observed by Shivaputra *et al.*, (2018), Singh & Dall (2018), Ram *et al.*, (2018), Katoch *et al.*, (2017), Nageshwar *et al.*, (2017), Chouhan *et al.*, (2016), Sharma *et al.* (2015), Esposito *et al.*, (2014), Singh *et al.*, (2013), Brar *et al.*, (2012) Borah (2009), Sharma *et al.*, (2007) and Narayan (2006).

Heterosis in the cross involving poor x good combiners might be due to dominant x additive type of interaction, which is partially fixable and the crosses involving both the poor combining parents showing high sca (Sivagama Sundari *et al.*, 1992). The cross Palam Triloki x P-89 show significantly high sca for number of pods per node (Table 6). But both the parents showed negative significant gca effect due to complementation of favorable genes for this trait (Rewale *et al.*, (2003). Therefore it cannot be generalized that the parents with high gca effects can only produce good hybrids. The findings of present investigation revealed that Palam Triloki, Vivek Matar-10, Palam Priya, Azad Pea-3, Arka Karthik and Arka Ajit and testers P-89 and VL-Ageti Matar-7 were best general combiners. Hence, can be used as parents in the hybridization program to get desirable recombinants in segregating generations. The

cross Palam Triloki x P-89 could be exploited for number of pods per node. The crosses Palam Priya x VL-Ageti Matar-7, Palam Priya x Azad Pea-1, Arka Ajit x P-89, Arka Ajit x VL-Ageti Matar-7, Arka Ajit x Azad Pea-1 and Azad Pea-3 x P-89 showed maximum sca effects for most of the traits studied including the yield and yield attributing traits. Thus, these crosses could be advanced to recover desirable segregate for the improvement of yield and yield contributing traits. Result showed that non additive gene action is an integral component of the genetic architecture of different characters in the material used in pea.

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