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Line x tester analysis for yield and its contributing characters in field pea (*Pisum sativum* L.)

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Abstract
Seventeen genotypes including fourteen females (lines) and three males (testers) were crosses in line x tester mating design during *Rabi* 2016-2017 and forty-two hybrids along with seventeen parents were evaluated during *Rabi* 2017-2018. The ratio of variance due to general combining ability (GCA) and specific combining ability (SCA) was shown to be less than unity for all the characters studied indicating the predominant role of non-additive gene action for all the characters. Among the tester, Makhyatmubi was recorded as the best general combiner for plant height, number of pods per plant, pod length, number of seeds per pod, seed yield per plant, 100 seed weight and harvest index. Among the lines, HFP 9426 was shown to be good general combiner for pod length, seed yield per plant and harvest index while IPF 15-21 was shown to be good general combiner for days to 50% flowering and plant height. In case of specific combining ability, IPF 15-13 x Pant P 42 was good specific combiner for seed yield per plant and harvest index while HFP 1024 x Rachna was good specific combiner for days to 50% flowering. Out of forty-two cross combination, KPMR 939 x Makhyatmubi showed high heterosis over better and standard parent for seed yield per plant and harvest index. Some of the crosses were observed superior for the specific combining ability effects as well as for the standard heterosis *viz*., RFP 11-2 x Pant P 42, KPMR 939 x Makhyatmubi, HFP 9426 x Pant P 42 and Pant P 302 x Makhyatmubi for days to maturity, number of pods per plant, pod length and 100 seed weight respectively. These findings can be further utilized to develop and enhance the yield potential of field pea.

Keywords: Field pea, line x tester, combining ability, heterosis, yield and yield components

Introduction
Pea is a leguminous vegetable crop of worldwide importance. It is an annual herbaceous and self-pollinated crop. Pea (*Pisum sativum* L.), 2n=2x=14, belongs to the family Leguminoceae. It is one of the important pulse crops of the state Manipur growing during *Rabi* season. It is generally grown for both vegetable as well as seed purposes. It provides a rich and cheap source of protein particularly to the vegetarians and the poor. The peas grown in Manipur (in field or garden) are almost all harvested as green pods for culinary/vegetable purpose. However, the productivity of pea in Manipur is still very low as compared to the other pea growing states of India. In 2016-2017, total production of pea in India was 1011.2 thousand metric tonnes while in Manipur, the total production of pea was 17.4 thousand metric tonnes during 2016-2017 (Anonymous, 2017) [1]. Even though the crop is of high demand in the state Manipur, there is not yet suitable and well adapted high yielding variety available. One of the main reasons is the lack of high yielding varieties which are suitable for growing under varied agro-climatic conditions of the state. Therefore, for the evolution of varieties which are high yielding, early maturing, nutritionally rich and well adapted to local conditions, it is imperative to exploit heterosis and study the general combining ability of the parents and specific combining ability of hybrids. The knowledge of combining ability and nature of gene action is necessary for the selection of best parents for hybridization in order to improve the existing cultivars. It is also necessary to know the performance of a cross combination in comparison to the parents involved in the hybrids.

Materials and Methods
The present investigation was carried out at the research field of Department of Genetics and Plant Breeding, College of Agriculture, Central Agricultural University, Imphal during *Rabi* 2016-1017 and 2017-1018. The experimental material consisted of seventeen genetically diverse genotypes of field pea. Fourteen genotypes *viz*., HFP 9426, RFP 11-2, IPF 15-13,

RFPG 85, VL 62, RFP 2011-3, HFP 1024, KPMR 939, Pant P 302, RFPG 78, VL 63, RFPG 95, IPF 15-21 and Pant P 286 were used as lines and three genotypes *viz*., Makhyatmubi, Pant P 42 and Rachna were used as testers in Line x Tester design to produce forty-two F_1's hybrids. Seventeen parents along with their forty-two F_1's were grown in a randomized block design with three replications. The distance between the plants was maintained at 10 cm while the rows were spaced 30 cm apart. The recommended agronomic package of practices and plant protection measures were followed to maintain optimum plant growth. Observations were recorded on five randomly selected individual plants (excluding border plants) per replication for each genotype on nine yield contributing traits *viz*., days to 50% flowering, days to maturity, plant height (cm), number of pods per plant, pod length, number of seeds per pod, seed yield per plant (g), 100 seed weight (g) and harvest index (%). The analysis of variance and combining ability analysis were computed as per the methods suggested by Kempthorne (1957) [10]. Heterosis was worked out over better parent and standard variety (Rachna) and their significance was determined by t test as suggested by Rai and Rai (2006) [6].

Result and Discussion

The analysis of variance was carried out for all the nine characters (Table 1). Analysis of variance for the mean sum of square due to parents and crosses showed significant differences for all the characters studied indicating the presence of variability among parents and crosses. The mean sum of square due to progenies was significant for all the characters studied. There were no significant different among the lines. There were significant differences among the testers for days to maturity, seed yield per plant, 100 seed weight and harvest index. The line x tester interaction gave significant differences for all the characters studied indicating the diversity among crosses and the prevalence of non-additive variance. Parents versus crosses also showed significant differences for all the characters except days to 50% flowering. The present findings were quite similar with that of Ceyhan *et al*. (2008) [5], Kumar *et al*. (2009) [9] and Kumar *et al*. (2016) [12].

It was found that the magnitude of SCA variance (σ^2_s) was higher than GCA variance (σ^2_g) for all the characters under studied (Table 2). Hence, the ratio of σ^2_g/σ^2_s was less than unity for all the characters indicating the predominant role of non-additive gene action for all the characters understudied. Similar results were also reported by Ceyhan (2006) [4], Bora *et al*. (2009) [2], Esposito *et al*. (2013) [8] and Suman *et al*. (2017) [21].

GCA effects of lines and testers are shown in Table 3. Among the testers, the parent Makhyatmubi was proved to be best general combiner for plant height, number of pods per plant, pod length, number of seeds per pod, seed yield per plant, 100 seed weight and harvest index. Pant P 42 was found to be best general combiner for days to 50% flowering and days to maturity. Among the lines, HFP 9426 exhibited the best general combiner for pod length, seed yield per plant and harvest index. IPF 15-21 was found to be best general combiner for days to 50% flowering and plant height while KPMR 939 was found to be best general combiner for number of pods per plant. VL 63 and VL 62 exhibited the best general combiner for number of seeds per pod and 100 seed weight respectively. The present findings were in general agreement with that of Ceyhan (2006) [4], Kumar *et al*. (2016) [12] and Kumar *et al*. (2017) [13].

Out of 42 cross combinations, the cross IPF 15-13 x Pant P 42 exhibited the highest SCA effect for seed yield per plant and harvest index (Table 4). The result is in agreement with that of Brar *et al*. (2012) [3], Dagla *et al*. (2013) [7] and Singh *et al*. (2014) [19]. The cross combinations with high SCA effect i.e. KPMR 939 x Makhyatmubi for number of pods per plant, HFP 9426 x Pant P 42 for pod length and Pant P 302 x Makhyatmubi for 100 seed weight were associated with high *per se* performance for the said characters. However, high mean performance of crosses did not always reflect the high SCA effects of the characters studied. Similar results were reported by Sofi *et al*. (2006).

From the Table 5, it was found that crosses which exhibited high SCA effects were found to have either or both of the parents as good or average general combiner for the characters under studied in majority of the cases. These results corroborate the results obtained by Dagla *et al*. (2013) [7], Sharma *et al*. (2015) [7] and Chauhan *et al*. (2016) [6].

The cross combination KPMR 939 x Makhyatmubi showed highest significant positive heterosis over better parent and standard variety for seed yield per plant and harvest index (Table 6). It also exhibited highest significant positive heterosis over standard variety for number of pods per plant while RFP 11-2 x Pant P 42 showed highest significant positive heterosis over better parent for number of pods per plant. Similar results were reported by Gautam *et al*. (2005) [9] and Chauhan *et al*. (2016) [6]. RFP 11-2 x Pant P 42 exhibited highest significant negative heterosis over better parent for days to maturity and standard variety for days to maturity and days to 50% flowering. Similar results were observed by Dagla *et al*. (2013) [7]. There was no positive significant heterosis over better parent for number of seeds per pod. Patel (2012) [15] also reported similar result for number of seeds per pod in field pea.

Some of the crosses were observed superior for the SCA effects as well as standard heterosis. RFP 11-2 x Pant P 42, KPMR 939 x Makhyatmubi, HFP 9426 x Pant P 42 and Pant P 302 x Makhyatmubi exhibited highest significant SCA effects as well as standard heterosis for days to maturity, number of pods per plant, pod length and 100 seed weight respectively. These results were in general agreement with that of Shrivastava *et al*. (1986) [18] and Brar *et al*. (2012) [3].

Table 1: Analysis of variance for line x tester in field pea

Source of Variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of pods per plant	Pod length (cm)	Seeds per pod	Seed yield per plant (g)	100 seed weight (g)	Harvest index (%)
Mean sum of squares										
Replication	2	9.77	3.41	14.45	1.24	0.39*	0.86*	0.50	1.17	0.21
Progenies	58	23.76*	23.18*	316.78*	6.59*	2.32*	2.58*	17.87*	35.06*	12.91*
Parents	16	33.34*	15.28*	334.52*	3.83*	0.68*	0.37*	2.76*	31.65*	6.50*
Crosses	41	20.41*	25.55*	311.83*	7.62*	2.76*	1.89*	15.59*	33.57*	11.46*
Parents Vs Crosses	1	8.12	52.39*	235.63*	8.57*	10.90*	66.56*	353.35*	150.67*	174.89*

Lines	13	26.04	14.91	387.83	6.65	2.70	2.69	6.03	15.44	9.80
Testers	2	45.39	135.39*	675.40	15.41	1.35	1.13	114.83*	384.61*	75.39*
Line x Tester	26	15.67*	22.42*	245.87*	7.51*	2.89*	1.54*	12.73*	15.63*	7.37*
Error	116	5.18	2.93	36.65	0.70	0.09	0.19	0.40	0.49	2.78

Where d.f. = degrees of freedom, * = significant at 5% level

Table 2: Estimation of components of genetic variance in intervarietal crosses in field pea

Sl. No.	Characters	σ^2_g	σ^2_s	σ^2_g/σ^2_s	σ^2_A	σ^2_D
1.	Days to 50% flowering	0.064	7.587	0.008	0.129	7.587
2.	Days to maturity	0.043	17.974	0.002	0.085	17.974
3.	Plant height	0.897	128.155	0.007	1.794	128.155
4.	Number of pods per plant	-0.004	3.073	-0.001	-0.007	3.073
5.	Pod length	-0.002	0.750	-0.002	-0.004	0.750
6.	Seeds per pod	0.005	0.508	0.009	0.009	0.508
7.	Seed yield per plant	0.039	14.491	0.003	0.078	14.491
8.	100 seed weight	0.244	44.642	0.005	0.488	44.642
9.	Harvest index	0.060	8.506	0.007	0.119	8.506

Table 3: General combining ability effects of parents for seed yield and its components in field pea

Parents	Days to 50% flowering		Days to maturity		Plant height (cm)		No. of pods per plant		Pod length (cm)	
Testers	**GCA effect**	**Mean**	**GCA effect**	**Mean**	**GCA effect**	**Mean**	**GCA effect**	**Mean**	**GCA effect**	**Mean**
Makhyatmubi	0.41	72.33	1.34*	103.33	4.55*	105.11	0.46*	8.60	0.13*	7.13
Pant P 42	-1.18*	70.33	-2.04*	105.00	-1.54	98.64	0.23	6.53	0.07	6.45
Rachna	0.77*	75.67	0.70*	107.67	3.01*	101.20	-0.69*	8.40	-0.20*	6.46
S.E.	0.35		0.26		0.93		0.13		0.05	
Lines										
HFP9426	1.09	76.00	-0.90	109.33	-7.55*	90.57	0.83*	5.20	1.07*	6.26
RFP 11-2	-2.25*	74.33	-2.79*	110.67	5.74*	90.93	0.97*	6.60	-0.40*	5.84
IPF 15-13	-0.13	74.00	-1.23*	106.33	3.11	97.26	1.12*	5.53	-0.13	6.26
RFPG 85	2.64*	73.67	2.21*	109.33	-1.59	104.07	-0.52	8.40	-0.27*	5.85
VL 62	0.53	76.00	0.21	110.33	-3.94	113.61	-0.75*	5.73	0.71*	6.11
RFP 2011-3	-0.69	76.33	-0.45	109.00	-1.79	99.99	-1.21*	5.53	-0.42*	5.92
HFP 1024	2.75*	75.67	1.44*	110.33	-10.64*	96.73	-0.90*	6.07	-0.24*	6.56
KPMR 939	-0.13	75.00	0.99	108.33	3.58	100.15	1.52*	5.87	-0.26*	6.02
Pant P 302	-0.69	77.00	-0.79	110.00	-1.12	107.97	-0.19	5.20	-0.59*	6.56
RFPG 78	0.31	76.00	0.10	109.67	7.90*	106.71	0.30	6.13	-0.47*	6.26
VL 63	-.0.80	72.33	0.99	108.33	-1.01	90.17	-0.63*	7.53	-0.27*	6.36
RFPG 95	1.64*	81.67	1.10	112.00	-9.53*	93.85	-0.83*	6.13	-0.15	5.82
IPF 15-21	-3.36*	68.00	-0.56	105.67	11.26*	66.41	0.28	5.53	0.85*	7.52
Pant P 286	-0.91	68.33	-0.34	108.00	5.58*	88.72	0.03	6.07	0.56*	6.95
S.E.	0.76		0.57		2.02		0.28		0.10	

Parents	Number of seeds per pod		Seed yield per plant (g)		100 seed weight (g)		Harvest index (%)	
Testers	**GCA effect**	**Mean**	**GCA effect**	**Mean**	**GCA effect**	**Mean**	**GCA effect**	**Mean**
Makhyatmubi	0.17*	5.47	1.78*	8.62	3.46*	28.94	1.26*	42.85
Pant P 42	-0.005	5.40	-0.29*	8.04	-1.29*	18.95	0.15	41.91
Rachna	-0.16*	5.00	-1.49*	8.34	-2.17*	17.96	-1.41*	41.36
S.E.	0.07		0.10		0.11		0.26	
Lines								
HFP9426	-0.19	4.87	1.73*	7.43	-0.57*	20.85	1.52*	40.61
RFP 11-2	-0.15	5.07	0.87*	7.74	-2.37*	16.62	0.88	40.90
IPF 15-13	-0.26	5.07	-0.31	7.00	-0.93*	20.22	-1.08	39.96
RFPG 85	-0.28	4.80	-0.76*	6.26	-0.80*	20.11	-0.47	39.11
VL 62	0.65*	5.60	-1.33*	7.24	2.19*	19.30	-1.61*	40.30
RFP 2011-3	-0.15	5.27	0.27	5.76	-0.56*	17.05	0.85	38.78
HFP 1024	-0.37*	4.93	0.31	8.46	0.14	26.43	0.22	41.24
KPMR 939	-0.33*	5.73	0.71*	7.06	1.28*	19.74	0.77	39.32
Pant P 302	-0.37*	5.07	-0.85*	5.69	1.92*	21.32	-1.39*	38.48
RFPG 78	-0.35*	5.47	0.23	6.03	0.16	18.80	1.26*	38.74
VL 63	1.54*	5.67	-0.15	5.85	1.33*	21.40	-0.47	38.27
RFPG 95	-0.19	4.87	0.49*	7.72	-1.53*	18.21	0.97	42.26
IPF 15-21	0.56*	5.13	-0.39	7.08	-0.46*	16.80	-0.79	42.39
Pant P 286	-0.10	6.00	-0.82*	6.89	0.19	21.85	-0.67	39.70
S.E.	0.14		0.21		0.23		0.56	

Table 4: Specific combining ability effects of crosses for seed yield and its component in field pea

Crosses	Days to 50% flowering		Days to maturity		Plant height (cm)		No. of pods per plant		Pod length (cm)		Seeds per pod		Seed yield per plant (g)		100 seed weight (g)		Harvest index (%)	
	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean	SCA effect	Mean
HFP 9426 x Makhyatmubi	-0.97	74.33	0.99	108.67	0.97	92.61	-1.72*	6.47	-1.51*	5.52	-0.08	3.80	-1.80*	11.96	0.11	23.01	-0.28	45.06
RFP 11-2 x Makhyatmubi	-1.63	70.33	0.88	106.67	3.57	108.49	-1.26*	7.07	-0.05	5.51	0.01	3.93	-0.76*	12.14	-0.39	24.84	-0.96	43.74
IPF 15-13 x Makhyatmubi	1.59	75.67	1.66	109.00	8.39*	110.69	-0.01	8.47	-0.02	5.81	-0.54*	3.27	-1.85*	9.87	0.01	24.63	-0.92	41.81
RFPG 85 x Makhyatmubi	3.81*	80.67	1.21	112.00	-14.44*	83.16	-0.17	6.67	-0.06	5.63	0.14	3.93	0.66	11.93	-0.34	27.25	0.45	43.80
VL 62 x Makhyatmubi	-1.41	73.33	0.55	109.33	8.72*	103.97	0.26	6.87	2.19*	8.87	1.48*	6.20	0.66	11.37	-0.71	22.70	1.22	43.43
RFP 2011-3 x Makhyatmubi	-0.19	73.33	0.55	108.67	-14.46*	82.93	-0.74	5.40	-0.05	5.49	-0.12	3.80	-0.13	12.18	-2.50*	20.70	-0.85	43.81
HFP 1024 x Makhyatmubi	5.70*	82.67	3.33*	113.33	-4.21	84.34	-1.52*	4.93	-0.21	5.50	-0.83*	2.87	0.40	12.75	-5.20*	27.34	0.17	44.21
KPMR 939 x Makhyatmubi	0.25	74.33	-0.56	109.00	3.87	106.64	2.99*	11.87	0.10	5.81	0.32	4.07	2.61*	15.35	0.30	32.38	2.26*	46.84
Pant P 302 x Makhyatmubi	-0.19	73.33	-0.79	107.00	-0.41	97.65	-1.43**	5.73	0.39*	5.77	-0.10	3.60	1.54*	12.72	4.70*	27.19	0.76	43.19
RFPG 78 x Makhyatmubi	-1.19	73.33	-0.67	108.00	1.74	108.83	1.94*	9.60	0.02	5.51	-0.32	3.40	0.67	12.93	1.27*	27.07	-0.51	44.56
VL 63 x Makhyatmubi	-1.08	72.33	-1.23	108.33	-1.91	96.27	-1.19*	5.53	0.16	5.85	0.72*	6.33	-3.02*	8.85	-0.03	25.82	-1.49	41.86
RFPG 95 x Makhyatmubi	-0.86	75.00	-0.01	109.67	8.74*	98.39	-0.39	6.13	0.11	5.92	0.06	3.93	0.01	12.53	1.59*	25.93	-0.88	43.91
IPF 15-21 x Makhyatmubi	-2.52	68.33	-1.34	106.67	6.95*	117.39	1.50*	9.13	-0.44*	6.37	-0.57*	4.07	1.16*	12.80	0.64	26.49	0.57	43.60
Pant P 286 x Makhyatmubi	-1.30	72.00	-4.56*	103.67	-7.54*	97.23	1.74*	9.13	-0.65*	5.87	-0.17	3.80	-0.16	11.06	0.54	20.22	0.46	43.61
HFP 9426 x Pant P 42	-0.71	73.00	-2.63*	101.67	0.27	85.82	1.63*	9.60	2.59*	9.55	0.16	3.87	1.30*	12.98	-0.24	20.22	-0.38	43.85
RFP 11-2 x Pant P 42	-2.04	68.33	-5.07*	97.33	1.75	100.57	2.50*	10.60	0.24	5.74	0.32	4.07	3.47*	14.29	1.32*	19.98	2.20*	45.79
IPF 15-13 x Pant P 42	-1.15	71.33	-2.96*	101.00	-0.77	95.43	0.75	9.00	-0.02	5.74	0.23	3.87	3.66*	13.31	1.13*	21.22	3.17*	44.80
RFPG 85 x Pant P 42	-1.60	73.67	-0.40	107.00	-0.15	91.36	-0.81	5.80	-0.15	5.48	-0.02	3.60	0.34	9.53	1.05*	21.27	0.41	42.65
VL 62 x Pant P 42	0.18	73.33	-2.07*	103.33	9.78*	98.94	0.15	6.53	-0.83*	5.78	-0.35	4.20	-0.38	8.25	0.91*	24.13	-0.77	40.34
RFP 2011-3 x Pant P 42	0.40	72.33	-1.74	103.00	8.55*	99.85	0.61	6.53	-0.05	5.43	0.05	3.80	-0.97*	9.25	3.99*	24.44	-0.31	43.25
HFP 1024 x Pant P 42	-1.37	74.00	-0.29	106.33	-3.03	79.42	0.37	6.60	0.05	5.70	0.54*	4.07	-2.72*	7.55	1.23*	22.39	-2.26*	40.67
KPMR 939 x Pant P 42	-0.15	72.33	1.82	108.00	0.35	97.03	-2.59*	6.07	-0.36*	5.27	-0.64*	2.93	-2.22*	8.45	-1.86*	20.44	-2.28*	41.20
Pant P 302 x Pant P 42	0.40	72.33	2.26*	106.67	3.53	95.50	-0.74	6.20	-0.39*	4.91	0.34	3.87	-0.59	8.52	-4.48*	18.46	-0.02	41.31
RFPG 78 x Pant P 42	2.07	75.00	2.71*	108.00	-3.83	97.17	-1.10*	6.33	-0.49*	4.94	0.05	3.60	-1.06*	9.12	-1.22*	19.96	0.96	44.93
VL 63 x Pant P 42	-0.15	71.67	-0.52	105.67	1.86	93.94	1.70*	8.20	-0.37*	5.25	-1.64*	3.80	3.21*	13.01	-0.96*	21.39	1.79	44.03
RFPG 95 x Pant P 42	0.74	75.00	1.71	108.00	-15.55*	68.01	-0.23	6.07	-0.32	5.42	-0.24	3.47	-1.32*	9.12	-0.62	18.87	-0.77	42.91
IPF 15-21 x Pant P 42	1.07	70.33	1.71	106.33	-3.73	100.62	-1.08*	6.33	1.09*	7.84	1.34*	5.80	-2.08*	7.49	0.00	20.55	-0.73	41.19
Pant P 286 x Pant P 42	2.29	74.00	5.48*	110.33	0.96	99.63	-1.17*	6.00	-1.01*	5.45	-0.13	3.67	-0.64	8.50	-0.25	20.96	-1.02	41.03
HFP 9426 x Rachna	1.67	77.33	1.63	108.67	-1.25	82.83	0.09	7.13	-1.08*	5.61	-0.08	3.47	0.50	10.99	0.12	19.69	0.66	43.34
RFP 11-2 x Rachna	3.67*	76.00	4.19*	109.33	-5.32	92.04	-1.25*	5.93	-0.20	5.03	-0.33	3.27	-2.71*	6.92	-0.94*	16.83	-1.24	40.79
IPF 15-13 x Rachna	-0.44	74.00	1.30	108.00	-7.62*	87.11	-0.73	6.60	0.04	5.53	0.32	3.80	-1.81*	6.64	-1.14*	18.06	-2.25*	37.82
RFPG 85 x Rachna	-2.21	75.00	-0.81	109.33	14.58*	104.62	0.98*	6.67	0.21	5.56	-0.13	3.33	-1.00*	7.00	-0.71	18.62	-0.86	39.82
VL 62 x Rachna	1.23	76.33	1.52	109.67	-18.51*	69.18	-0.40	5.07	-1.37*	4.97	-1.13*	3.27	-0.28	7.15	-0.21	22.12	-0.45	39.10
RFP 2011-3 x Rachna	-0.21	73.67	1.19	108.67	5.91	95.75	0.13	5.13	0.10	5.30	0.07	3.67	1.10*	10.13	-1.48*	18.09	1.16	43.16
HFP 1024 x Rachna	-4.33*	73.00	-3.03*	106.33	7.24*	88.23	1.15*	6.47	0.16	5.54	0.30	3.67	2.32*	11.39	3.97*	24.24	2.09*	43.46
KPMR 939 x Rachna	-0.10	74.33	-1.25	107.67	-4.23	90.98	-0.40	7.33	0.26	5.63	0.32	3.73	-0.39	9.09	1.56*	22.98	0.02	41.94
Pant P 302 x Rachna	-0.21	73.67	-1.48	105.67	-3.13	87.37	2.18*	8.20	0.00	5.03	-0.24	3.13	-0.95*	6.97	-0.22	21.84	-0.74	39.02
RFPG 78 x Rachna	-0.88	74.00	-2.03*	106.00	2.09	101.61	-0.85	5.67	0.47*	5.62	0.27	3.67	0.38	9.37	-0.05	20.24	-0.45	41.96
VL 63 x Rachna	1.23	75.00	1.75	110.67	0.04	90.65	-0.51	5.07	0.21	5.56	0.92*	6.20	-0.19	8.42	0.99*	22.45	-0.30	40.38
RFPG 95 x Rachna	0.12	76.33	-1.70	107.33	6.81	88.90	0.62	6.00	0.21	5.67	0.18	3.73	1.32*	10.57	-0.97*	17.63	1.65	43.76
IPF 15-21 x Rachna	1.45	72.67	-0.37	107.00	-3.23	99.65	-0.42	6.07	-0.65*	5.82	-0.77*	3.53	0.92*	9.29	-0.63	19.04	0.16	40.52
Pant P 286 x Rachna	-0.99	72.67	-0.92	106.67	6.59	103.79	-0.58	5.67	1.65*	7.83	0.30	3.93	0.80*	8.74	-0.29	20.03	0.56	41.04
S.E.	1.31		0.99		3.50		0.48		0.18		0.25		0.36		0.40		0.96	

Table 5: Top crosses showing significant desirable SCA effects, their GCA effects and mean *per se* performance

Characters	SCA effects	GCA effects	*Per se* performace
Days to 50% flowering	HFP 1024 x Rachna (-4.33)	L x L	HFP 1024 x Rachna (73.00)
Days to maturity	RFP 11-2 x Pant P 42 (-5.07)	H x H	HFP 1024 x Rachna (106.33)
	Pant P 286 x Makhyatmubi (-4.56)	A x L	RFPG 78 x Rachna (106.00)
	HFP 1024 x Rachna (-3.03)	L x L	Pant P 286 x Makhyatmubi (103.67)
	VL 62 x Pant P 42 (-2.07)	A x H	VL 62 x Pant P 42 (103.33)
	RFPG 78 x Rachna (-2.03)	A x L	RFP 11-2 x Pant P 42 (97.33)
Plant height	RFPG 85 x Rachna (14.58)	A x L	IPF 15-21 x Makhyatmubi (117.39)
	VL 62 x Pant P 42 (9.78)	A x A	IPF 15-13 x Makhyatmubi (110.69)
	RFPG 95 x Makhyatmubi (8.74)	L x H	RFPG 85 x Rachna (104.62)
	VL 62 x Makhyatmubi (8.72)	A x H	VL 62 x Makhyatmubi (103.97)
	RFP 2011-3 x Pant P 42 (8.55)	A x A	RFP 2011-3 x Pant P 42 (99.85)
	IPF 15-13 x Makhyatmubi (8.39)	A x H	VL 62 x Pant P 42 (98.94)
	HFP 1024 x Rachna (7.24)	L x L	RFPG 95 x Makhyatmubi (98.39)
	IPF 15-21 x Makhyatmubi (6.95)	H x H	HFP 1024 x Rachna (88.23)
Number of pods per plant	KPMR 939 x Makhyatmubi (2.99)	H x H	KPMR 939 x Makhyatmubi (11.87)
	RFP 11-2 x Pant P 42 (2.50)	H x A	RFP 11-2 x Pant P 42 (10.60)
	Pant P 302 x Rachna (2.18)	A x L	RFPG 78 x Makhyatmubi (9.60)
	RFPG 78 x Makhyatmubi (1.94)	A x H	HFP 9426 x Pant P 42 (9.60)
	Pant P 286 x Makhyatmubi (1.74)	A x H	IPF 15-21 x Makhyatmubi (9.13)
	VL 63 x Pant P 42 (1.70)	L x A	Pant P 286 x Makhyatmubi (9.13)
	HFP 9426 x Pant P 42 (1.63)	H x A	VL 63 x Pant P 42 (8.20)
	IPF 15-21 x Makhyatmubi (1.50)	A x H	Pant P 302 x Rachna (8.20)
	HFP 1024 x Rachna (1.15)	L x L	RFPG 85 x Rachna (6.67)
	RFPG 85 x Rachna (0.98)	A x L	HFP 1024 x Rachna (6.47)
Pod length	HFP 9426 x Pant P 42 (2.59)	H x A	HFP 9426 x Pant P 42 (9.55)
	VL 62 x Makhyatmubi (2.19)	H x H	VL 62 x Makhyatmubi (8.87)
	Pant P 286 x Rachna (1.65)	H x L	IPF 15-21 x Pant P 42 (7.84)
	IPF 15-21 x Pant P 42 (1.09)	H x A	Pant P 286 x Rachna (7.83)
	RFPG 78 x Rachna (0.47)	L x L	Pant P 302 x Makhyatmubi (5.77)
	Pant P 302 x Makhyatmubi (0.39)	L x H	RFPG 78 x Rachna (5.62)
Number of seeds per pod	VL 62 x Makhyatmubi (1.48)	H x H	VL 63 x Makhyatmubi (6.33)
	IPF 15-21 x Pant P 42 (1.34)	H x A	VL 62 x Makhyatmubi (6.20)
	VL 63 x Rachna (0.92)	H x L	VL 63 x Rachna (6.20)
	VL 63 x Makhyatmubi (0.72)	H x H	IPF 15-21 x Pant P 42 (5.80)
	HFP 1024 x Pant P 42 (0.54)	L x A	HFP 1024 x Pant P 42 (4.07)
Seed yield per plant	IPF 15-13 x Pant P 42 (3.66)	A x L	KPMR 939 x Makhyatmubi (15.35)
	RFP 11-2 x Pant P 42 (3.47)	H x L	RFP 11-2 x Pant P 42 (14.29)
	KPMR 939 x Makhyatmubi (2.61)	H x H	IPF 15-13 x Pant P 42 (13.31)
	Pant P 302 x Makhyatmubi (1.54)	L x H	HFP 9426 x Pant P 42 (12.98)
	RFPG 95 x Rachna (1.32)	H x L	IPF 15-21 x Makhyatmubi (12.80)
	HFP 9426 x Pant P 42 (1.30)	H x L	Pant P 302 x Makhyatmubi (12.72)
	IPF 15-21 x Makhyatmubi (1.16)	A x H	RFPG 95 x Rachna (10.57)
	RFP 2011-3 x Rachna (1.10)	A x L	RFP 2011-3 x Rachna (10.13)
	IPF 15-21 x Rachna (0.92)	A x L	IPF 15-21 x Rachna (9.29)
	Pant P 286 x Rachna (0.80)	L x L	Pant P 286 x Rachna (8.74)
100 seed weight	Pant P 302 x Makhyatmubi (4.70)	H x H	Pant P 302 x Makhyatmubi (27.19)
	RFP 2011-3 x Pant P 42 (3.99)	L x L	RFPG 78 x Makhyatmubi (27.07)
	HFP 1024 x Rachna (3.97)	A x L	RFPG 95 x Makhyatmubi (25.93)
	RFPG 95 x Makhyatmubi (1.59)	L x H	RFP 2011-3 x Pant P 42 (24.44)
	KPMR 939 x Rachna (1.56)	H x L	HFP 1024 x Rachna (24.24)
	RFP 11-2 x Pant P 42 (1.32)	L x L	VL 62 x Pant P 42 (24.13)
	RFPG 78 x Makhyatmubi (1.27)	A x H	KPMR 939 x Rachna (22.98)
	HFP 1024 x Pant P 42 (1.23)	A x L	VL 63 x Rachna (22.45)
	IPF 15-13 x Pant P 42 (1.13)	L X L	HFP 1024 x Pant P 42 (22.39)
	RFPG 85 x Pant P 42 (1.05)	L x L	RFPG 85 x Pant P 42 (21.27)
	VL 63 x Rachna (0.99)	H x L	IPF 15-13 x Pant P 42 (21.22)
	VL 62 x Pant P 42 (0.91)	H x L	RFP 11-2 x Pant P 42 (19.98)
Harvest index	IPF 15-13 x Pant P 42 (3.17)	A x A	KPMR 939 x Makhyatmubi (46.84)
	KPMR 939 x Makhyatmubi (2.26)	A X H	IPF 15-13 x Pant P 42 (44.80)
	HFP 1024 x Rachna (2.09)	A x L	HFP 1024 x Rachna (43.46)

Table 6: Cross combinations with best heterotic effects over better parent and standard variety of nine characters under studied in field pea

S. No.	Characters	Heterobeltiosis (%)	Standard heterosis (%)
1.	Days to 50% flowering	RFPG 95 x Pant P 42, RFPG 95 x Makhyatmubi (-8.16)	IPF 15-21 x Makhyatmubi, RFP 11-2 x Pant P 42 (-9.69)
2.	Days to maturity	RFP 11-2 x Pant P 42 (-12.05)	RFP 11-2 x Pant P 42 (-9.60)
3.	Plant height	IPF 15-21 x Makhyatmubi (11.69)	IPF 15-21 x Makhyatmubi (16.00)
4.	Number of pods per plant	RFP 11-2 x Pant P 42 (60.61)	KPMR 939 x Makhyatmubi (41.27)
5.	Pod length	HFP 9426 x Pant P 42 (47.93)	HFP 9426 x Pant P 42 (47.78)
6.	Number of seeds per pod	N.S.	VL 63 x Makhyatmubi (26.67)
7.	Seed yield per plant	KPMR 939 x Makhyatmubi (78.17)	KPMR 939 x Makhyatmubi (84.16)
8.	100 seed weight	RFP 2011-3 x Pant P 42 (28.97)	Pant P 302 x Makhyatmubi (80.24)
9.	Harvest index	KPMR 939 x Makhyatmubi (9.32)	KPMR 939 x Makhyatmubi (13.25)

It can be concluded that there is predominant role of non-additive gene action for seed yield and its contributing characters in field pea. Makhyatmubi and HFP 9426 were identified as most promising parents among testers and lines respectively for hybridization programme in field pea. Among the crosses, IPF 15-13 x Pant P 41was found to be the best specific combiner for seed yield per plant and harvest index. Study of heterosis revealed that 22 cross combinations exhibited significant heterosis over better parent for seed yield per plant while 23 cross combinations showed significant heterosis over standard variety for seed yield per plant. KPMR 939 x Makhyatmubi showed highest significant heterosis over better parent and standard variety for seed yield per plant and harvest index. These findings can be further utilized to design future pea breeding to develop a improved variety particular to Manipur.

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