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Genetic basis of heterosis for yield and related traits in pea (*Pisum sativum* L.)

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Heterosis over better parent was estimated for seed yield and related traits in 16 crosses of pea. To ascertain the genetic causes responsible for the observed heterosis in pea, the estimates of genetic parameters realized from first degree (generation mean analysis) and second degree statistical (modified TTC) models have been used. Only one cross (HUP 9 X Pusa 10) was considered for generation mean analysis. In case of modified triple test cross analysis, 15 pure lines of pea were crossed to three testers viz., HUP 9 (L_1), Pusa 10 (L_2) and F_1 of HUP 9 x Pusa 10 (L_3) to produce 3n families. Significant average heterosis over better parent was evidenced for plant height, pods per plant and seed yield per plant. Heterosis for seeds per pod and seed weight was negative or low. The generation mean analysis revealed that the observed heterosis for seed yield per plant and pods per plant was mainly due to over dominance. Further, overdominance and higher magnitude of epistatic components [h] and [I] as was observed in modified triple test cross analysis, could be the possible cause of heterosis for seed yield per plant and pods per plant. For days to flowering, partial dominance could be responsible for the higher heterosis for earliness.

Key words : Heterosis, Related traits, Pea, Generation mean analysis, Triple test cross

INTRODUCTION

Heterosis is a universal phenomenon in crop plants. Exploitation of heterosis in production of commercial hybrids has been successful in self pollinated crops like wheat, barley and rice. Although high heterosis for yield have been reported in pea (Sarawat *et al* 1994; Singh *et al* 1994; Tyagi *and Srivatava*, 2001) but the cleistigamous nature of flower and non availability of suitable male sterility system restricts its application in production of commercial hybrids. However, the phenomenon of heterosis is helpful in prediction of potential crosses likely to give transegressive segregates. The present investigation was undertaken to assess heterosis and examine into genetic causes of heterosis in peas employing generation mean analysis and modified triple test cross (TTC) analysis.

MATERIALS AND METHODS

Two experiments were undertaken to study the heterosis and its genetic basis. In experiment I, 16 F_1 hybrids (Table 1) along with their parents were evaluated. Only one cross i.e. HUP 9 X Pusa 10 was considered for generation mean analysis. The parents, F_1, F_2, F_3, B_1 and B_2 of this cross were raised in the same experiment. In experiment II,i.e. modified TTC analysis, 15 pure lines (Pi) of pea were crossed with three testers i.e. HUP 9 (L_1), Pusa 10 (L_2) and F_1 of HUP 9 x Pusa 10 (L3) to produce 3n families . All the set of triple test cross (TTC) progenies (15 L_1 i + 15 L_2 i +15 L_3 i) along with 15 pure lines and three testers were planted in two replications.

Each parent, F_1 and TTC progenies in above experiments were planted in a single row plot (3 m length), the F_2 and F_3 in four row plot and B_1 and B_2 in two row plot. The row to row distance was kept 45 cm apart and 15 cm distance was maintained between plants in each row. Observations were recorded on ten random plants from each of the parents and F_1, on 15 plants from each back cross (B_1 and B2) and on 40 plants from each F_2 and F_3 families.

In the generation mean analysis, epitasis was detected by the joint scaling test proposed by Cavalli (1952) and the gene effects were estimated using least square technique. The analysis of modified TTC was done as suggested by Ketata *et al* (1976*)* and described by Jinks *et al.* (1969).

RESULTS AND DISCUSSION

Significant average heterotic performance over the better parent was observed for three characters, namely, plant

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Table 1: Extent of heterosis (over superior parent) for seven characters in pea.

Cross	Days to flowering		Plant height (cm)		Pods/plant		Seeds/pod		Pod length (cm)		Seed weight(g)		Seed yield/plant(g)	
	Mean of F_1	% Het. over SP	Mean of F_1	% Het. Over SP	Mean of F_1	% Het. over SP	Mean of F_1	% Het. over SP	Mean of F_1	% Het. over SP	Mean of F_1	% Het. over SP	Mean of F_1	% Het. over SP
Trapper X VL 7	56.70	56.85	187.85	5.42	32.05	55.96	4.98	1.43	6.15	5.31	16.56	-0.84	19.04	35.21
Trapper X PM 5	53.30	25.26	187.95	5.47	20.15	-1.95	5.06	3.05	6.39	-6.72	16.24	-6.88	14.04	36.58
Trapper X PM 2	57.20	74.66	229.20	28.62	34.40	67.40	4.00	-18.53	5.68	-16.32	15.51	-0.14	16.24	57.98
Trapper X JP 829	57.20	33.49	189.05	6.09	36.20	76.16	4.29	-12.63	6.43	6.63	18.14	-0.05	20.47	99.12
Trapper X JP 4	52.25	4.40	197.15	5.46	45.05	119.22	4.92	0.20	6.20	8.58	16.72	3.47	26.26	138.72
Trapper X PI 280064	55.05	-9.68	213.80	19.98	26.20	27.46	4.89	-0.41	5.83	2.28	15.84	-4.35	15.46	50.39
Trapper X S 143	55.80	-2.19	174.90	-1.85	28.80	40.15	4.69	-4.46	6.18	7.29	17.03	4.54	16.56	61.09
Trapper X Rachana	60.45	-2.50	214.45	0.94	31.20	46.82	3.91	-20.37	6.54	13.74	16.98	-9.15	18.30	25.86
Trapper X HUP 7	61.40	-0.97	219.35	1.41	37.95	84.67	4.46	9.16	5.94	5.88	17.26	-14.60	24.52	138.52
Trapper X PG 3	52.60	-12.19	189.95	0.07	26.95	44.28	4.28	-12.83	5.99	-2.60	16.61	-23.14	17.26	53.15
Trapper X HFP 4	54.55	-12.02	177.20	-0.56	34.15	66.18	4.73	-3.67	5.87	4.63	17.57	-12.98	22.12	115.18
Trapper X KFPD 3	60.05	-3.15	192.40	7.97	34.95	70.07	4.20	-14.46	6.24	3.31	17.62	-5.57	19.76	80.62
Trapper XKFPD 66	51.60	-1.62	166.00	-6.85	31.55	53.53	5.03	-1.76	6.24	-9.70	18.28	-11.85	22.35	117.41
Trapper X KFPD 1	54.65	-6.50	184.35	3.45	24.95	21.41	5.09	3.67	6.04	7.09	20.12	-24.30	17.87	70.52
Trapper X HUDP 1	60.30	-2.74	189.25	6.20	28.35	37.96	4.73	-3.67	6.45	4.88	19.35	-7.99	15.75	46.10
HUP 9 X Pusa 10	57.70	51.05	209.8	14.06	27.90	74.92	5.96	42.92	7.66	14.89	30.52	-3.60	33.09	82.11
	141		**3.03***		**7.90***		**-1.11***		**1.24**		**4.16****		**8.84****	

Table 2: Cause of heterosis for yield components in the cross HUP 9X Pusa 10.

	Days to flowering	Plant height (cm)	Pods/plant	Seeds/pod	Pod length (cm)	Seed weight (g)	Seed yield/plan
HETEROSIS							
Generation							
HUP 9(P1)	74.60	184.0	15.95	4.17	6.40	25.56	18.17
Pusa 10(P2)	38.20	56.90	7.10	2.44	6.67	35.81	6.11
F_1	57.70	209.85	27.90	5.96	7.66	34.52	33.09
Heterobeltiosis	51.05	14.05	74.92	42.92	14.84	-3.60	82.11
GENERATION MEAN ANALYSIS							
M	62.30+0.24	68.83**+13.47	22.41**+2.08	4.85**+0.62	6.58**+0.43	31.15**+1.21	26.37**+
[d]	-18.18**+0.44	-63.55**+1.14	-4.36**+0.44	-0.86**+0.12	0.14+0.09	5.03**+0.62	-3.94**+
[h]	-19.62**+5.55	190.75**+44.19	-26.29**+6.44	-1.57+1.51	0.20+0.97	-10.91**+4.17	-38.96**+
[i]	-5.98**−2.24	51.61**+13.49	-11.00**+2.09	-1.57*+0.62	-0.04+0.43	-0.64+1.27	-16.36**+
[j]	-10.11**+2.03	54.42*+23.57	-2.77+3.05	2.32**+0.55	0.95**+0.31	0.31+2.69	12.32**+
[l]	154.04**+3.60	-49.71+32.27	32.13**+5.23	2.67**+0.99	0.88+0.62	14.37**+3.39	46.02**+
X^2	7.71**	0.18	23.38**	0.54	2.34	3.20	24.49*
Modified TTC model II							
Parameter							
D	114.31**	3915.57**	113.98**	0.89**	0.23**	14.12**	70.91*
H	79.59**	6021.98**	121.40**	0.80**	0.11	4.78**	108.27*
$(H/d)^{1/2}$	0.83	0.88	1.03	0.95	0.69	0.58	1.24

*, ** significant at P =0.05 and 0.01 respective.

height, pods per plant and seed yield per plant (Table 1). Ten out of sixteen crosses showed negative heterosis for days to flowering i.e. early flowering. All but one cross (Trapper x JP 4) showed heterosis for pods per plant and seed yield per plant. The heterosis over superior parent for seed per plant and seed weight was negative or low. Similar trend was observed by Pant and Bajpal (1991) and Sarawat *et al.* (1994) in pea. The heterosis for seed yield was high and ranged from 25.86 per cent to 138.72 per cent. Relative heterosis to extent of 55.66, 47.00, 81.81 per cent for seed yield were noted by Krarup and Davis (1970), Ram *et al.* (1986) and Pant and Bajpal (1991), respectively, in pea.

The parental mean and F_1 mean, and heterosis over superior parent for the cross HUP 9 X Pusa 10 has been presented in Table 2. The parents showed wide diversity for all the characters studied. The mean of hybrid exceeded both the parents for plant height, pods per plant, seeds per pod, pods length and seed yield per plant. The maximum heterosis over superior parent was noted for seed yield per plant, followed by pods per plant, seeds per pod, pod length and plant height.

The estimates of additive (D) and dominance components (H) of genetic variation and degree of dominance obtained from modified TTC analysis along with the genetic components of generation mean to understand the genetic causes of heterosis for seed yield and yield components have been given in Table 2. Partial dominance was noticed for days to flowering, plant height and seed weight. Nearly complete dominance was observed in case of seeds per pod. The dominance appears to be the cause of observed heterosis for seed yield and pods per plant.

In general, dominance components of mean in generation mean analysis was higher for most of the traits while additive components of genetic variance was evidenced in case of modified TTC analysis. The discrepancies in the two analyses are obvious because the generation mean analysis is based on first order statistics while the modified TTC is based on second degree statistics. The sampling variance in case of analysis based on second degree statistics are much more, affecting quadratic quantities like D and H than those in case of gene effects derived from the mean.

The over dominance evidenced in modified TTC and higher magnitude of non additive component (h) and (l) appears to be the cause of heterosis of seed yield and pods per plant. Partial dominance could be attributed for the observed heterosis for earliness to flowering which supports the finding of Sarawat *et al.*. (1994) but contradicts the report of Gritton (1975). In case of seeds per pod nearly complete dominance was observed in modified TTC analysis, whereas dominance X dominance (l) epitasis was found to be significant in generation mean analysis

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