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Heterotic potential and combining ability of yield and quality traits in garden pea (*Pisum sativum* L.)

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Abstract

Thirty-nine crosses of pea made in line x tester design were evaluated and SCA/GCA variance ratios for majority of the traits were more than unity which indicated the predominance of non-additive gene effects except for number of primary branches per plant, crude and soluble protein and total sugars. Among the females, 09/PMVAR-7 and NS-3 were considered to be best combiner for earliness whereas VRP-8, 10/PMVAR-4, PB-89, 09/PMVAR-4 were good general combiners for pods per node, 100 seed weight, green pod yield per plant, primary branches per plant on the basis of having *per se* performance and gca effect. The cross combination 09/PMVAR-7 x PM-65 was observed to have high per se performance along with high sca effects over better parent for days to 50% flowering and days to marketable maturity. Whereas, none of the cross combinations exhibited desirable significant heterosis over both the checks Arkel and MA-6 for earliness. The cross combination Arka Sampoorna x 08/PMVAR-4 and PB-89 x PM-65 were observed to have high heterosis over both better parent and two checks (Arkel and MA-6) along with high sca effects and mean performance for green pod yield per plant. Though the development of hybrid varieties does not seem to be economically feasible in garden pea but the development of pure line from the segregating material of hybrid combination can be used to develop a variety.

Key words: Garden Pea, heterosis, variance, combining ability, variety

Introduction

Garden Pea (*Pisum sativum* L.) is one of the most important winter vegetable crops grown on commercial scale the world over and is consumed either as a fresh succulent vegetable or in processed form. India is the largest producer of peas in the world and accounts for 21% of the world production. Punjab is the 5th largest producer of peas in the country and accounts for 6.7% of India's production. It is the 2nd important vegetable crop of Punjab and is grown on an area of 31.3 thousand ha with an annual production of 315.87 thousand tons (Anonymous 2016). An improvement in yield of self-pollinated crops like garden pea is effected mainly through selection of genotypes with desirable characters from the variation through recombination followed by selection. Heterosis in F_1 generation is of great importance in vegetable crops as heterotic crosses may give transgressive segregants for economic traits in advanced generations. Important steps for exploitation of heterosis in any crop are to study the general combining ability of the parents and specific combining ability of hybrids. The ability of parents to combine well depends on the complex interactions among genes and it cannot be estimated by mere yield performance of the parents. Therefore, the knowledge of combining ability and nature of gene effects is necessary for the selection of best parents for hybridization in order to improve the existing cultivars. Although, some information on additive and non-additive effects associated with yield and yield attributing traits in garden pea is available but that is relevant to the specific region, genetic material involved and particular environmental conditions. Therefore the present investigation were carried out to obtain information regarding general and specific combining ability effects and finding out heterotic combinations for yield and yield attributing characters in garden pea.

Materials and Methods

The present investigation was carried out at the Vegetable Research Farm of Department of Vegetable Science, Punjab Agricultural University, Ludhiana during 2010-2012. Thirteen genetically divergent genotypes of garden pea were selected. Thirteen diverse genotypes were taken as female parents and three as tester male parents and they were crossed in a line x tester fashion to generate

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thirty nine crosses. The F_1s along with their parents were sown in the field in a randomized block design with three replications. The distance between the plants was maintained at 10 cm while the rows were spaced 45 cm apart. The standard plant protection and other cultural practices were followed to maintain uniform experimental conditions. The observations were recorded on randomly taken five plants (excluding border plants) for days taken to 50% flowering, 100 seed weight, number of pods per plant, green pod yield per plant, primary branches per plant, days taken to marketable maturity, crude protein, soluble protein and total sugar. The analysis of variance was done for all characters as per the method given by Arunachalam (1974). Heterosis was worked out over better parent and their significance was determined by t test. Heterosis was expressed as per cent deviation of F_1 hybrid performance from the better parent. The crude protein content was estimated by Kjeldahl method of nitrogen estimation (McKenzie and Wallace 1954) and soluble protein content was estimated by Lowry's method (Lowry et al. 1951). Total sugar (%) content was estimated using the method given by Dubios et al. (1956).

Result and Discussion

Genetic variation: Analysis of variance for combining ability for different characters is presented in Table 1. The mean squares due to lines as well as testers were highly significant for most of the characters whereas mean sum of square due to lines x testers were highly significant for all traits except for number of pods per node both at 5 and 1 per cent level of significance. The above result indicates the role of both additive and non-additive gene effects in inheritance of all the traits under study. A wide range of variation was observed in estimating the components of genetic variance (Table 1). The SCA/GCA variance ratios for days taken to 50% flowering, green pod yield per plant, days taken to marketable maturity, number of pods per plant and 100 seed weight were 2.00, 9.05, 3.46, 5.40 and 1.70, respectively indicated the predominance of non-additive gene effects for majority of the traits studied whereas it was 0.85 for number of primary branches per plant, 0.33 for crude protein, 0.12 for soluble protein and 0.57 for total sugars. Similar finding have also been reported by Bhullar et al. (1975), Gupta and Dahiya (1984), Katiyar et al. (1987), Sirohi et al. (1993), Narayan et al. (1999) and Borah (2009). In this present investigation, all the traits studied are under the control of non-additive gene action except pod length. The general approach of selecting parental lines based on mean performance does not necessarily give fruitful results; therefore before drawing any conclusion, we have determined combining, gene action, heterotic potential and potence ratio for all the traits under study.

Estimation of general combining ability: GCA is the average performance of a strain in a series of cross combinations, estimated from the performance of F_1's from the crosses. Estimates of general combining ability effects of parents for various characters are presented in Table 2. Among the females, 09/PMVAR-7(-2.73), NS-3(-5.78), were considered to be best combiner for days taken to 50% flowering and days taken to marketable maturity, respectively on the basis of having low *per se* performance and significant negative gca effect. Similar finding have also been reported by Ceyhan et al. (2008) as they observed significance of gca effects for days to 50% flowering. Based on high *per se* performance and positive gca effects, VRP-8(0.02), 10/PMVAR-4(5.90), PB-89(16.57), 09/PMVAR-4(0.66) were good general combiners for number of pods per plant, 100 seed weight, green pod yield per plant, primary branches per plant. Borah (2009), Bhardwaj and Kohli (1998), Singh et al. (2005) reported general combiner for 100-seed weight, yield and yield traits and number of branches. Whereas, PB-89 (3.49), 10/PMVAR-4(0.81), PB-89 (5.07) showed highly significant and positive general combining ability effects for crude protein, soluble protein and total sugars, respectively. Borah (2009) revealed that parent HUP-2 was best general combiner for protein content. Similar results

Table 1: Analysis and component of variance for combining ability for different characters

Source of variation	d.f	Days taken to 50% flowering	100-seed weight	Pods/ plant	Green pod yield/plant	Primary branches/ plant	Days taken to marketable maturity	Crude protein (%)	Soluble protein (%)	Total sugars (%)
Line in hybrids	12	45.73	81.82**	67.28**	1235.33**	0.98*	75.61	24.60**	2.82*	55.84**
Tester in hybrids	2	215.13**	61.65**	53.11*	538.25*	2.02**	249.47*	4.52	0.76	110.16**
Lines × Testers	24	33.32**	22.36**	45.53**	712.71**	0.34**	70.85**	5.60**	1.49**	6.18**
Error	76	0.70	9.37	12.64	135.87	0.14	1.05	0.15	0.03	0.24
Components of genetic variance										
σ^2GCA		5.40	2.71	2.11	15.41	0.07	6.73	1.81	0.48	3.45
σ^2SCA		10.84	4.63	11.41	139.56	0.06	23.30	0.60	0.06	1.97
σ^2SCA/ σ^2GCA		2.00	1.70	5.40	9.05	0.85	3.46	0.33	0.12	0.57

*, ** significant at 5% and 1% level, respectively

Table 2: General combining ability (GCA) effects of parents for different characters

Parents	Days taken to 50% flowering	100-seed weight	Pods/ plant	Green pod yield/plant	Primary branches/ plant	Days taken to marketable maturity	Crude protein (%)	Soluble protein (%)	Total sugars (%)
Lines									
Arka Ajit	-1.40**	0.88	-4.41**	-11.43*	0.07	4.11**	0.98**	-0.29**	1.90**
Arka Karthik	4.71**	-2.39*	1.12	4.55	0.14	3.68**	-1.38**	-0.39**	-1.45**
Arka Sampoorna	0.37	-3.32**	-1.55	-5.96	-0.55**	-2.00**	-0.11	-0.31**	2.00**
C-308	1.82**	4.50**	-1.58	4.21	-0.30*	0.56	0.39**	0.45**	-2.24**
PB-89	-2.62**	1.48	0.37	16.57**	0.06	-2.33**	3.49**	0.53**	5.07**
VRP-8	0.15	-2.84**	3.51**	7.77**	0.21	1.44**	-1.15**	-0.12	-1.63**
Vasundhra	-0.51	-2.67**	-0.12	-11.63**	-0.08	3.00**	-0.1	-0.59**	0.14
GS-10	-0.4	-2.40*	-0.31	-19.16**	0.45**	0.33	0.24	0.73**	3.20**
Angoori	-1.62**	0.27	3.78**	1.31	-0.08	0	2.40**	-0.05	0.83**
NS-3	-1.85**	2.19*	2.50*	13.69**	-0.2	-5.78**	-1.08**	-0.18**	-0.15
09/PMVAR-4	3.49**	2.92**	2.88**	14.53**	0.66**	1.67**	-2.95**	-0.80**	-1.85**
09/PMVAR-7	-2.73**	-0.13	-1.77	-0.1	-0.39**	-3.44**	-0.67**	0.21**	-2.33**
10/PMVAR-4	0.6	5.90**	-4.42**	-14.32**	0.01	-1.22**	-0.07*	0.81**	-3.43**
CD at 5%	0.59	1.83	2.11	6.96	0.24	0.64	0.28	0.13	0.35
CD at 1%	0.79	2.43	2.8	9.3	0.32	0.86	0.37	0.17	0.47
Testers									
PM-65	-0.42**	-0.79*	0.87*	2.90*	0.24**	-2.75**	-0.35**	-0.03	1.30**
08/PMVAR-4	-2.11**	1.45**	-1.33**	1.29	-0.21**	2.22**	0.33**	0.15**	-1.89**
10/PEVAR-1	2.53**	-0.66	0.46	-4.19**	-0.02	0.53**	0.03	-0.12**	0.60**
CD at 5%	0.28	0.74	0.85	2.84	0.11	0.31	0.13	0.06	0.17
CD at 1%	0.38	0.99	1.12	3.79	0.15	0.41	0.17	0.08	0.22

*, ** significant at 5% and 1% level, respectively

were reported Borah (2009) as they revealed that parents having best general combining effect also have high *per se* performance. Among the male parents, PM-65 was good general combiner for pods per node, green pod yield per plant, primary branches per plant, days taken to marketable maturity and total sugars, whereas, 08/ PMVAR-4 for days taken to 50% flowering, 100- seed weight, crude protein and soluble protein.

Estimation of specific combining ability: SCA is the deviation in performance of a cross combination from that predicted on the basis of general combining abilities of the parents involved in the cross (Table 3). Out of 39 crosses, 12 crosses showed significant negative estimates for days taken to 50% flowering and the best crosses were 09/PMVAR-7 x PM-65 (-8.14), VRP-8 x 08/PMVAR-4 (-4.00), NS-3 x 10/PEVAR-1 (-3.31), Arka Karthik x PM-65 (-3.25), 09/PMVAR-4 x 10/PEVAR-1 (-2.97) and Arka Ajit x PM-65 (-2.80) respectively. The gca combination of good x good and good x average resulted in more sca effects. Singh et al. (1985) and Borah (2009) reported that at least one parent should be good combiner for maximum sca effect. The cross 10/ PMVAR-4 x 10/PEVAR-1 (-7.75) exhibited significant maximum negative sca effect for days taken to marketable maturity followed by Arka Sampoorna x 08/ PMVAR-4 (-7.00), Vasundhra x 08/PMVAR-4 (-5.67), 09/PMVAR-7 x PM-65 (-5.58), PB-89 x PM-65 (-5.36), Arka Ajit x 08/PMVAR-4 (-4.78) and NS-3 x 10/PEVAR-1 (-4.53) . It was also noted that good x poor gca combination resulted in more sca effect for the character. Gupta and Lodhi (1985) reported that all the best cross combination for this trait involves at least one good combining parent. Singh et al. (1985) and Hasan Mitu et al. (2004) revealed that the best crosses maintain their performance in next generation those involve one parent with good and another with poor combining ability. Out of 39 crosses, three crosses exhibited significantly positive sca effects for number of pods per node and the best crosses were 10/PMVAR-4 x PM-65, Arka Sampoorna x 08/PMVAR-4 and Arka Ajit x 10/PEVAR-1 with sca estimates of 0.04. Six crosses exhibited significantly positive estimates for 100-seed weight, which is considered desirable and the best crosses were PB-89 x 08/PMVAR-4 (4.68) followed by Arka Karthik x 10/PEVAR-1 (4.44), Arka Ajit x 08/PMVAR-4 (3.1), 09/PMVAR-4 x PM-65 (2.98), Angoori x 10/PEVAR-1 (2.77) and Vasundhra x 10/PEVAR-1 (2.65). It was also recorded that average x good and poor x poor gca combination resulted in more sca value for 100-seed weight. Venkateswarlu and Singh (1982) reported high sca effects in cross Early December x Arkel and revealed that good x poor combination results in more sca effect for seed weight. The sca effects for green pod yield per plant revealed that five crosses exhibited significantly positive and seven crosses significantly negative sca estimates. The cross combination Arka Sampoorna x 08/PMVAR-4 (32.21) was observed to be highest specific combiner for green pod yield per plant followed by Arka Ajit x 10/PEVAR-1 (18.71), VRP-8 x PM-65 (18.59), 10/PMVAR-4 x PM-65 (13.72) and Arka Ajit x 08/PMVAR-4 (11.13). It was also observed that poor x poor and poor x average gca combination resulted in more sca values for green pod yield per plant. Karmakar and Singh (1990) reported that superior crosses involve parents only in combination of good x poor general

Table 3: Specific combining ability (SCA) effects of hybrids for different characters

Hybrids	Days taken to 50% flowering	100-seed weight	Pods/ plant	Green pod yield/plant	Primary branches/plant	Days taken to marketable maturity	Crude protein	Soluble protein	Total sugars
Arka Ajit x PM-65	-2.80**	-0.90	-4.80**	-29.84**	0.07	0.86	-0.08	-0.35**	0.09
Arka Ajit x 08/PMVAR-4	1.22*	3.1**	-0.12	11.13*	-0.23	-4.78**	0.43	0.48**	0.51
Arka Ajit x 10/PEVAR-1	1.58**	-2.19	4.93**	18.71**	0.16	3.91**	-0.35	-0.14	-0.60
Arka Karthik x PM-65	-3.25**	-5.46**	2.00	-4.50	0.00	-3.03**	0.58*	-0.11	0.95**
Arka Karthik x 08/PMVAR-4	0.11	1.01	0.18	3.93	-0.01	-1.33*	-1.63**	-0.21	-1.52**
Arka Karthik x 10/PEVAR-1	3.14**	4.44**	-2.19	0.57	0.00	4.36**	1.05**	0.32**	0.57
Arka Sampoorna x PM-65	1.09*	1.55	-1.85	-13.01*	0.12	5.64**	-1.59**	-0.55**	1.09**
Arka Sampoorna x 08/PMVAR-4	-0.22	-0.68	6.24**	32.21**	-0.39	-7.00**	1.74**	0.53**	-1.02**
Arka Sampoorna x 10/PEVAR-1	-0.86	-0.87	-4.39**	-19.20**	0.27	1.36*	-0.16	0.02	-0.07
C-308 x PM-65	-0.03	2.20	0.35	1.86	-0.22	4.42**	-1.46**	-1.15**	-0.09
C-308 x 08/PMVAR-4	0.33	0.35	1.48	-0.63	0.36	-3.56**	0.78**	1.38**	0.31
C-308 x 10/PEVAR-1	-0.31	-2.56	-1.83	-1.23	-0.14	-0.86	0.68**	-0.22	-0.22
PB-89 x PM-65	1.09*	-0.90	0.98	4.65	-0.21	-5.36**	0.79**	0.31**	1.58**
PB-89 x 08/PMVAR-4	-2.56**	4.68**	2.71	7.73	0.40	2.00**	0.41	-0.35**	-1.09**
PB-89 x 10/PEVAR-1	1.47**	-3.78**	-3.69*	-12.38*	-0.19	3.36**	-1.20**	0.04	-0.49
VRP-8 x PM-65	2.97**	-0.02	-2.54	0.95	0.46*	1.53*	-0.05	0.99**	0.31
VRP-8 x 08/PMVAR-4	-4.00**	0.01	-0.69	-0.92	-0.21	0.89	-0.05	-0.70**	-0.84**
VRP-8 x 10/PEVAR-1	1.03	0.02	3.24*	-0.03	-0.25	-2.42**	0.11	-0.29*	0.53
Vasundhra x PM-65	-0.03	0.01	1.46	-2.88*	-0.34	-2.03**	1.30**	0.25*	-1.18**
Vasundhra x 08/PMVAR-4	0.33	-0.02	-3.62*	0.22	0.18	-5.67**	-2.37**	-0.58**	1.69**
Vasundhra x 10/PEVAR-1	-0.31	0.01	2.15	2.65*	0.16	7.69**	1.07**	0.33**	-0.51
GS-10 x PM-65	-1.14*	-0.01	0.32	1.22	0.61**	-0.36	0.92**	0.60**	3.07**
GS-10 x 08/PMVAR-4	2.56**	-0.01	-1.07	-0.71	-0.49*	4.33**	0.86**	0.15	-1.89**
GS-10 x 10/PEVAR-1	-1.42**	0.01	0.74	-0.51	-0.12	-3.97**	-1.78**	-0.75**	-1.18**
Angoori x PM-65	2.09**	-0.01	-1.11	0.69	0.43*	1.64*	0.80**	-0.26*	-2.59**
Angoori x 08/PMVAR-4	-1.56**	-0.01	-0.92	-3.46**	-0.25	0.33	1.20**	0.03	2.61**
Angoori x 10/PEVAR-1	-0.53	0.01	2.03	2.77*	-0.18	-1.97**	-1.99**	0.23*	-0.01
NS-3 x PM-65	-0.03	0.00	0.72	0.82	-0.43*	-0.25	-0.01	-0.03	-0.89**
NS-3 x 08/PMVAR-4	3.33**	0.01	1.58	-0.18	0.15	4.78**	-0.56*	0.08	-0.27
NS-3 x 10/PEVAR-1	-3.31**	-0.12**	-2.31	-0.63	0.28	-4.53**	0.57*	-0.05	1.16**
09/PMVAR-4 x PM-65	5.64**	0.02	4.44**	2.98*	-0.31	0.64	0.13	-0.18	-0.66*
09/PMVAR-4 x 08/PMVAR-4	-2.67**	0.01	0.80	-1.61	0.17	-1.97**	-1.04**	-0.10	0.47
09/PMVAR-4 x 10/PEVAR-1	-2.97**	-0.03*	-4.52**	-1.36	0.15	-0.64	0.91**	0.28*	0.19
09/PMVAR-7 x PM-65	-8.14**	-0.01	-5.47**	-0.63	-0.14	-5.58**	0.14	1.07**	-0.48
09/PMVAR-7 x 08/PMVAR-4	3.89**	-0.01	-0.41	0.02	0.10	4.11*	-1.31**	-1.41**	0.23
09/PMVAR-7 x 10/PEVAR-1	4.25**	0.02	5.89**	0.61	0.04	1.47*	1.18**	0.34**	0.25
10/PMVAR-4 x PM-65	2.53**	0.04*	5.48**	0.35	-0.04	1.86**	-1.46**	-0.58**	-1.21**
10/PMVAR-4 x 08/PMVAR-4	-0.78	-0.05**	-5.43**	-1.83	0.21	5.89**	1.53**	0.70**	0.81*
10/PMVAR-4 x 10/PEVAR-1	-1.75**	0.01	-0.05	1.48	-0.17	-7.75**	-0.07	-0.12	0.39
CD at 5%	1.03	0.03	2.98	2.58	0.42	1.12	0.48	0.22	0.61
CD at 1%	1.37	0.05	4.01	3.43	0.56	1.49	0.64	0.30	0.81

*, ** significant at 5% and 1% level, respectively

combiners for green pod yield per plant. The significant positive estimate for number of primary branches was obtained in GS-10 x PM-65 (0.61) followed by VRP-8 x PM-65 (0.46) and Angoori x PM-65 (0.43). The analysis of sca effects for crude protein revealed that sixteen crosses showed significant and positive sca effects ranged from 0.57 (NS-3 x 10/PEVAR-1) to 1.74 (Arka Sampoorna x 08/PMVAR-4). The present study revealed that good x poor gca combination resulted in more sca effects for crude protein. These results also have the close agreement with findings of Borah (2009). Among the fourteen cross combinations which exhibited significant positive sca for soluble protein, the highest sca effects were recorded in C-308 x 08/PMVAR-4 (1.38) followed by 09/PMVAR-7 x PM-65 (1.07), VRP-8 x PM-65 (0.99), 10/PMVAR-4 x 08/PMVAR-4 (0.70) and GS-10 x PM-65 (0.60). These results also have the close agreement with the findings of Borah (2009). Eight crosses showed significant positive sca effects for total sugar and maximum sca effect was observed in GS-10 x PM-65 (3.07), followed by Angoori x 08/PMVAR-4 (2.61), Vasundhra x 08/PMVAR-4 (1.69), PB-89 x PM-65 (1.58), NS-3 x 10/PEVAR-1 (1.16), Arka Sampoorna x PM-65 (1.09), Arka Karthik x PM-65 (0.95) and 10/PMVAR-4 x 08/PMVAR-4 (0.81). The present study revealed that good x good and good x poor gca combination resulted in more sca effects for total sugar.

Estimation of heterosis: Majority of crosses showed significant positive or negative heterosis for all the traits under study. The heterosis effect for 39 crosses determined as per cent increase over better parent and two checks i.e. Arkel and MA-6 have been presented in Table 4. For days to 50% flowering, cross PB-89 x 08/PMVAR-4 had exhibited highest negative better parent heterosis (-10.44%). Present findings are in tune with those of Srivastava et al. (1986) who reported significant

Table 4: Summary depicting best heterotic combinations over better parent (BP) and checks

Character	Best heterotic hybrids over better parent	Best heterotic hybrids over check (Arkel)	Best heterotic hybrids over check (MA-6)
Days taken to 50% flowering	PB. 89 x 08/PMVAR-4, VRP-8 x 08/PMVAR-4, Angoori x 08/PMVAR-4	_____	_______
100 seed weight	10/PMVAR-4 x 08/PMVAR-4, 10/PMVAR-4 x 10/PEVAR-1, 10/PMVAR-4 x PM-65, 09/PMVAR-4 x PM-65, Arka Ajit x 08/PMVAR-4	PB-89 x 08/PMVAR-4, 10/PMVAR-4 x 10/PEVAR-1, C-308 x 08/PMVAR-4, C-308 x PM-65, 10/PMVAR-4 x 08/PMVAR-4	PB-89 x 08/PMVAR-4, 10/PMVAR-4 x 10/PEVAR-1, C-308 x 08/PMVAR-4, C-308 x PM-65, 10/PMVAR-4 x 08/PMVAR-4
Number of pods/plant	09/PMVAR-4 x PM-65, VRP-8 x 10/PEVAR-1, NS-3 x PM-65, Arka Karthik x PM-65, C-308 x PM-65	09/PMVAR-4 x PM-65, VRP-8 x 10/PEVAR-1, Angoori x 10/PEVAR-1, Arka Karthik x PM-65, NS-3 x PM-65	09/PMVAR-4 x PM-65, VRP-8 x 10/PEVAR-1, Angoori x 10/PEVAR-1, Arka Karthik x PM-65, NS-3 x PM-65
Green pod yield/plant	Arka Sampoorna x 08/PMVAR-4, NS-3 x PM-65, Arka Karthik x PM-65, C-308 x PM-65, Arka Karthik x PM-65	09/PMVAR-4 x PM-65, VRP-8 x PM-65, Arka Sampoorna x 08/PMVAR-4, NS-3 x PM-65, NS-3 x 08/PMVAR-4, PB-89 x PM-65	09/PMVAR-4 x PM-65, VRP-8 x PM-65, Arka Sampoorna x 08/PMVAR-4, NS-3 x PM-65, NS-3 x 08/PMVAR-4, PB-89 x PM-65
Number of primary branches/plant	GS-10 x PM-65, Angoori x PM-65, 09/PMVAR-4 x 10/PEVAR-1, 09/PMVAR-4 x PM-65, Arka Ajit x PM-65	GS-10 x PM-65, VRP-8 x PM-65, 09/PMVAR-4 x 10/PEVAR-1, Angoori x PM-65, Arka Karthik x PM-65	GS-10 x PM-65, VRP-8 x PM-65, 09/PMVAR-4 x 10/PEVAR-1, Angoori x PM-65, Arka Karthik x PM-65
Days taken to marketable maturity	Arka Karthik x PM-65, 09/PMVAR-7 x PM-65, PB-89 x PM-65, NS-3 x PM-65, Arka Sampoorna x 08/PMVAR-4	______	_______
Crude protein	09/PMVAR-7 x PM-65, PB-89 x PM-65, PB-89 x 08/PMVAR-4, Angoori x 08/PMVAR-4	PB-89 x PM-65, PB-89 x 08/PMVAR-4, Angoori x 08/PMVAR-4, Angoori x PM-65	PB-89 x PM-65, PB-89 x 08/PMVAR-4, Angoori x 08/PMVAR-4
Soluble protein	09/PMVAR-7 x PM-65, VRP-8 x PM-65, 09/PMVAR-7 x 10/PEVAR-1, Arka Karthik x PM-65, Vasundhra x PM-65	C-308 x 08/PMVAR-4, 10/PMVAR-4 x 08/PMVAR-4, GS-10 x PM-65, 09/PMVAR-7 x PM-65, PB-89 x PM-65	C-308 x 08/PMVAR-4, 10/PMVAR-4 x 08/PMVAR-4
Total sugars	Arka Karthik x PM-65, GS-10 x PM-65, VRP-8 x PM-65, PB-89 x PM-65, Arka Sampoorna x PM-65	PB-89 x PM-65, GS-10 x PM-65, PB-89 x 10/PEVAR-1, Arka Sampoorna x PM-65	PB-89 x PM-65, GS-10 x PM-65, PB-89 x 10/PEVAR-1, Arka Sampoorna x PM-65

heterosis over better parent for days to flowering. Katiyar (1994) and Khalche and Narsinghani (1994) also revealed significant heterobeltiosis for days to 50 per cent flowering. For early maturity, 24 cross combinations (out of 39 crosses), exhibited significant negative heterosis over better parent. The range of useful heterosis for early maturity varied from -1.53% (10/PMVAR-4 x PM-65) to -12.53 % (Arka Karthik x PM-65). Whereas, none of the cross combinations exhibited desirable significant heterosis over both the checks viz. Arkel and MA-6 for early maturity. Khalche and Narsinghani (1994) also reported maximum significant heterosis in Arkel x JP-9 and JP-4 x JP-9 over the better parent. Bora et al. (2009) reported heterosis upto 7.64% for days taken to marketable maturity. The cross combination(s) for number of pods per plant, 100-seed weight, primary branches per plant, crude protein, soluble protein and total sugars exhibited maximum significant positive heterosis over better parent. Number of pods per node is the important primary component of total yield and cross combination 09/PMVAR-7 x 10/PEVAR-1 (14.05%) and Arka Kartkik x 10/PEVAR-1 (8.98%) exhibited maximum significant positive heterosis over better parent for the trait. The heterobeltiosis for number of pods per node ranged from 10.49 to 20.41 per cent over check 'Arkel' and 17.04 to 27.55 per cent over check 'MA-6'. Significant heterosis for 100-seed weight over respective better parent was 16.75 per cent (PB-89 x 08/PMVAR-4) to 26.93 per cent (10/PMVAR-4 x 08/PMVAR-4) whereas, heterosis over check Arkel and MA-6 ranged from 15.30% to 33.29 % and 14.38% to 26.84%, respectively. For primary branches per plant, range of heterosis over better parent varied from 27.96% (Arka Karthik x PM-

65) to 66.90% (GS-10×PM-65). However, significant positive heterosis over check Arkel and MA-6 ranged from 35.40 to 133.08 and 32.76 to 107.76 per cent, respectively for primary branches per plant. Significant desirable heterosis over the better parent for number of primary branches per plant was observed by Ceyhan and Avci (2005) and Bora et al. (2009). For green pod yield per plant, 31 crosses expressed the positive and significant heterosis over better parent and range of useful heterosis over better parent varied from 18.88% (09/PMVAR-7 x 08/PMVAR-4) to 41.48% (Arka Sampoorna x 08/PMVAR-4). All the cross combinations exhibit significant positive heterosis over both the checks viz. Arkel and MA-6 for green pod yield per plant and range varied from 89.67 to 192.60 and 80.54 to 178.53 per cent, respectively. For crude protein, range of heterosis over better parent varied from 3.67 (NS-3 X PM-65) to 12.02 per cent (09/PMVAR-7 X PM-65) whereas, positive heterosis over check Arkel and MA-6 ranged from 3.84 to 25.94 and 4.99 to 6.25 per cent, respectively. Bora et al. (2009) reported maximum positive heterosis over better parent (11.23%) in cross HUP-2 x DMR-7. For soluble protein, range of heterosis varied from 6.20% (10/PMVAR-4 x 08/PMVAR-4) to 44.85 % (09/PMVAR-7 x PM-65) and positive heterosis over check Arkel and MA-6 ranged from 10.51 to 37.53 and 9.64 to 15.91 per cent, respectively. For total sugars, the range of useful heterosis varied from 5.08 (Arka Sampoorna x PM-65) to 20.53 per cent (Arka Karthik x PM-65) and range of heterosis was 4.86-36.59 and 8.55-24.91 percent over checks Arkel and MA-6, respectively. Similar results were corroborated by Sarawat et al. (1994), Tyagi and Srivastava (1999) and Bora et al. (2009).

Lkkjka'k

मटर में लाइन x टेस्टर प्रजनन विधि से 39 संकरों का मूल्यांकन किया गया। विशिष्ट संयोजन क्षमता/सामान्य संयोजन विभिन्नता अनुपात अधिकांश गुणों हेतु एकता से अधिक पाया गया जिससे अयोज्य की प्रभाव के प्रबलता का संकेत मिला लेकिन यह प्रबलता प्रति पौध प्राथमिक शाखाओं की संख्या, अशोधित एवं विलेय प्रोटीन तथा कुल शर्करा के लिये नही पाया। मादा पित्रों में, 09/पी एम वार–7 व एन एस–3 को अगेतीपन के लिए अच्छा सामान्य संयोजक पाया गया जबकि वी आर पी8, 10/पी एम वार–4, पी बी–89, 09/पी एम वार–4 फलियाँ प्रति गांठ, 100 बीज भार, प्रति पौध हरी फली उपज व प्रति प्राथमिक शाखाओं की संख्या के लिए प्रति प्रदर्शन व सामान्य संयोजन क्षमता के आधार पर उत्तम संयोजक पाये गये। इसके साथ ही विशिष्ट संयोजन क्षमता का बेहतर पितृ के उपर 50 प्रतिशत पुष्पन व बाजार योग्य फल पकने के दिन पर प्रभाव पाया गया। जबकि वांछित व सार्थक ओज का प्रदर्शन प्रभाव किसी भी संकरण संयोजन का दानों नियंत्रक अर्केल एवं एम ए: 6 पर अगेतीपन की तुलना में नही पाया गया। संकरण संयोजन अर्का सम्पूर्णा x 08/पी एम वार–4 तथा पी बी–89 x पी एम–65 में उच्च ओज दोनों पितृ तथा दो नियंत्रक (अर्केल व एम ए–6) की तुलना में पाया गया जिसमें विशिष्ट संयोजन क्षमता एवं प्रति पौध हरी फली उपज और औसत निष्पादन सम्मिलित है। यद्यपि सब्जी मटर की फसल में संकर प्रजाति प्रजनन आर्थिक रूप से उपयोगी नहीं है लेकिन विसंयोजी सामाग्री जो संकर संयोजन से विकसित शुद्ध विकसित वंशक्रम का उपयोग एक उत्तम प्रजाति के विकास में किया जा सकता है।

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