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Combining ability for yield and yield contributing characters in pea (*Pisum sativum* L.)

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Abstract The findings of present investigation revealed that PMR-53, PSM-3, E-6, VL-7, PSM-4, Arkel and VP-266 were best general combiners. The lines PMR-53, PSM-3, E-6, VL-7, PSM-4, Arkel and VP-266 can be used as parents in the hybridization programme to get desirable recombinants in segregating generations. The cross Arka Ajit × Arkel could be exploited for early maturity. The crosses VRP-16 × VL-7, PMR-19 × PSM-3, Arka Ajit × PSM-3 and PSM-4 × Arkel showed maximum sca effects for most of the traits studied including the yield and yield attributing characters. Thus, these crosses could be advanced to recover desirable segregants for the improvement of yield and yield contributing characters.

Keywords: Pea, combining ability, yield, *Pisum sativum*

Introduction

Pea (*Pisum sativum* L.) is an important vegetable crop due to its high nutritive value, particularly proteins, 7.2g/ 100g (Singh, 2007) and other health building substances like carbohydrates, calcium and phosphorous. Because of self pollination nature of pea, it offers a good scope to develop high yielding pure line varieties through hybridization followed by selection. The success of hybridization programme is generally depends upon the breeder to choose suitable parents, to obtain high proportion of desirable recombinants. Knowledge of various genetic parameter and gene action is essential in selecting the parents and breeding methods to be followed for the improvement of important traits. However, gene action varies with degree of diversity among parents and their genetic architecture. Hence, it is necessary to evaluate the combining ability of genotypes for their utilization in hybridization. Combining ability analysis is one of the powerful tools in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate favorable genes and also helps the breeders to choose the suitable parents for formulating a breeding programme and provide valuable information regarding cross combinations to be exploited commercially. Thus, the technique provides the space to classify the parental lines in term of superiority in hybrid combination and to determine gene action involved in the inheritance of different characters.

Materials and Methods

Seventeen diverse genotypes including 14 lines viz. VRP-32, VRP-16, PMR-53, PMR-19, Arka Ajit, PSM-4, Nepal Pea, VP-266, E-6, PMR-62, PMR-31, PMR-60, PMR-32, AP-3 and 3 testers viz. Arkel, PSM-3 and VL-7 were used for developing 42 F_1s in rabi season of 2005-2006. Resulted 42 F_1s and 17 parents were evaluated in 2006-07 at Vegetable Research Centre, GBPUA&T, Pantnagar in RBD in three replications. Observation were recorded on fifteen quantitative characters viz. days to first flowering, number of first flowering node, days to first green pod picking, pod length (cm), 100 green pod weight (g), number of seeds per pod, 100 green seed wt. (g), shelling (%), T.S.S. (%), number of green pods per plant, number of primary branches per plant, number of nodes per main stem, plant height (cm), green pod yield per plant, dry seed yield per plant (g). The data were subjected to appropriate statistical analysis.

Results and Discussion

A general analysis of variance for combining ability was carried out for all the characters to test the significance of differences among different genotypes, parents, crosses, lines and testers. The results of analysis of

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Table 1: Analysis of variance (mean squares) for combining ability in Vegetable pea

Source of Variation	df	Days to first flowering	No. of first flowering node	Days to first green pod picking	Pod length (cm)	100-green pod weight (g)	No. of seeds per pod	100-green seed weight (g)	Shelling %	TSS (%)	No. of green pods per plant	No. of primary branches per plant	No. of nodes per main stem	Plant height (cm)	Green pod yield per plant (g)	Dry seed yield per plant (g)
Replications	2	8.79	0.23	26.16	1.11	848950.3	1.59	4.78	507.76	0.23	109.39	8.23	28.85	3706.79	848.48	41.71
Treatments	58	125.59**	8.44**	12.59	0.72**	152377.7**	1.41**	79.39**	33.90	1.44**	43.00**	4.62**	12.80**	326.19**	407.09**	44.07**
Parents	16	113.70**	14.61**	9.82	1.10**	89751.59	1.01	54.34	34.55	1.35**	19.27*	3.09**	16.35**	210.01	633.50**	30.62**
Parent Vs. Crosses	1	100.43**	0.20	2.25	1.13*	167956.0	1.34	5.37	26.12	1.88*	1280.03**	37.71**	11.15*	1254.53**	1253.60**	238.32**
Crosses	41	130.85**	6.23**	13.92*	0.56**	176437.5**	1.57**	90.97**	33.83	1.47**	22.09**	4.41**	11.46**	348.88**	298.09**	44.58**
Lines	13	380.27**	18.20**	21.67*	1.09**	280979.2*	2.21*	164.83**	38.20	3.01**	26.19	11.27**	30.26**	732.21**	415.78	83.91**
Testers	2	15.80	0.09	15.69	1.53**	97297.52	1.97	26.05	0.83	0.25	5.99	0.41	1.25	122.44	179.29	4.50
L x T	26	14.98**	0.72	9.90	0.22	130254.3**	1.22*	59.03	34.19	0.81**	21.28**	1.28	2.85	174.64	248.38**	28.00**
Error	116	6.68	0.49	9.18	0.22	65004.42	0.64	38.53	37.62	0.30	10.72	0.89	2.45	152.88	61.21	13.15

variance are presented in table 1. The 'F' test revealed that the differences among genotypes were highly significant for all the characters except two characters viz. days to first green pod picking and shelling percentage, indicating inherent genetic differences among the genotypes for the character studied. Partitioning of variance due to treatments into parents, crosses and parents vs. crosses indicated that variance due to parents were significant for all the characters under study except for days to first green pod picking, 100-green pod weight (g), number of seeds per pod, 100-green seed weight (g), shelling percentage and plant height (cm). The crosses also showed highly significant variances for all the traits except shelling percentage.

However, the mean squares for parent vs. crosses appeared significant for days to first flowering, number of green pods per plant, number of primary branches per plant, plant height (cm), green pod yield per plant (g) and dry seed yield per plant (g) at 1 per cent level and pod length (cm), total soluble solid (%) and number of nodes per main stem at 5 per cent level of significance, for rest of the characters there were non significant results. The variance due to lines was significant at 1 per cent for days to first flowering, number of first flowering node , pod length (cm), 100-green seed weight (g), total soluble solid (%), number of primary branches per plant, number of nodes per main stem, plant height (cm) and dry seed yield per plant (g). However, it was significant at 5 per cent for days to first green pod picking, 100-green pod weight (g) and number of seeds per pod. Others lines gave non significant response to the traits under study. The testers showed non significant variances for all the characters except pod length (cm) (significant at 1 per cent). For line × tester interaction, number of seeds per pod showed significant variances at 5 per cent, days to first flowering, 100-green pod weight (g), total soluble solid (%), number of green pods per plant, green pod yield per plant (g) and dry seed yield per plant (g) were highly significant. Variances due to female (lines) were greater than variances due to males (testers) for all the characters except for pod length (cm) and 100-green pod weight (g). It indicates the presence of greater variability among the female parents for these characters. Variances due to males were greater than females for rest of the traits indicating greater variability among male parents.

Ranking of desirable parents based on *per se* performance, gca and sca effects for 15 economic traits (Table 2) revealed that it was difficult to pick-up a single good combiner for all the characters. It was observed that in general, the majority of the crosses, which showed significant sca effects for increased yield, also

Table 2: Ranking of parents and crosses based on *per se* performance, gca and sca effects

S. No.	Character	Mean basis		Estimates basis	
		Best parent	Best F_1	Best general combiner	Best specific combiner
1.	Days to first flowering	E-6 (37.40) PMR-62 (37.67) PMR-31 (37.80)	E-6 × Arkel (37.23) E-6 × VL-7 (37.70) E-6 × PSM-3 (38.50)	E-6 (-8.26) PMR-31 (-5.59) VP-266 (-5.40)	Arka Ajit × Arkel (-3.74) PSM-4 × Arkel (-2.92) VRP-32 × PSM-3 (-2.88)
2.	No. of first flowering node	PMR-31 (7.73) E-6 (8.27) PMR-62 (8.53)	E-6 × PSM-3 (8.10) E-6 × VL-7 (8.30) PMR-31 × Arkel (8.50)	E-6 (-1.95) PMR-31 (-1.75) VP-266 (-1.49)	PSM-4 × Arkel (-0.82) Arka Ajit × VL-7 (-0.73) PMR-19 × VL-7 (-0.65)
3.	Days to first green pod picking	VP-266 (80.67) Nepal Pea (82.67) Arkel (82.67)	PMR-53 × PSM-3 (79.33) PSM-4 × PSM-3 (79.33) PMR-19 × PSM-3 (81.00)	PMR-53 (-3.65) PSM-4 (-2.54) PMR-60 (-1.43)	E-6 × Arkel (-2.74) PMR-19 × PSM-3 (-2.66) VRP-16 × VL-7 (-2.38)
4.	Pod length (cm)	Arka Ajit (9.47) PSM-3 (9.20) PMR-53 (9.07)	Arka Ajit × PSM-3 (9.50) Arka Ajit × Arkel (9.07) PMR-53 × PSM-3 (8.97)	Arka Ajit (0.77) PMR-53 (0.35) VRP-32 (0.34)	Arka Ajit × PSM-3 (0.44) AP-3 × VL-7 (0.43) PSM-4 × Arkel (0.40)
5.	100-green pod weight (g)	AP-3 (1125.20) PMR-62 (935.07) E-6 (933.60)	PSM-4 × Arkel (1303.20) PMR-53 × VL-7 (1154.20) PMR-31 × Arkel (1088.90)	PSM-4 (344.99) PMR-53 (263.46) PMR-31 (149.38)	E-6 × PSM-3 (414.07) PSM-4 × Arkel (320.16) PMR-31 × Arkel (301.47)
6.	No. of seeds per pod	PSM-3 (7.47) PMR-19 (6.87) PSM-4 (6.77)	PMR-62 × Arkel (7.67) PMR-60 × Arkel (7.50) PMR-32 × Arkel (7.50)	PMR-62 (0.84) PMR-60 (0.81) Arkel (0.27)	Arka Ajit × PSM-3 (0.95) PMR-19 × PSM-3 (0.76) PMR-31 × PSM-3 (0.70)
7.	100-green seed weight (g)	PMR-53 (52.67) Arka Ajit (46.67) Arkel (44.67)	AP-3 × VL-7 (56.00) VP-266 × PSM-3 (54.00) PMR-53 × PSM-3 (52.00)	PMR-53 (5.33) PMR-32 (4.88) AP-3 (4.33)	AP-3 × VL-7 (9.32) VP-266 × PSM-3 (9.21) Arka Ajit × VL-7 (4.76)
8.	Shelling %	Nepal Pea (46.00) VRP-32 (44.61) VRP-16(44.27)	VRP-16 × VL-7 (49.23) PMR-19 × PSM-3 (48.30) Arka Ajit × PSM-3 (47.15)	-	VRP-16 × VL-7 (5.18) Arka Ajit × PSM-3 (4.27) PMR-53 × VL-7 (4.07)
9.	T.S.S. (%)	Nepal Pea (4.53) E-6 (4.07) PMR-31 (4.00)	Nepal Pea × VL-7 (4.53) VP-266 × Arkel (4.53) PMR-62 × Arkel (4.07)	VP-266 (0.86) Nepal Pea (0.66) AP-3 (0.24)	PMR-62 × Arkel (1.02) Nepal Pea × VL-7 (0.85) PMR-32 × VL-7 (0.78)
10.	No. of green pods/plant	Arkel (13.60) Nepal Pea (11.00) VP-266 (9.67)	PMR-31 × VL-7 (19.00) Nepal Pea × Arkel (18.65) PSM-4 × PSM-3 (17.73)	PSM-4 (3.83) Arkel (0.41) PMR-53 (2.21)	PMR-31 × VL-7 (4.55) Nepal Pea × Arkel (3.95) PMR-60 × VL-7 (3.81)
11.	No. of primary branches per plant	PMR-53 (5.93) Arka Ajit (5.20) VRP-32 (4.00)	PMR-53 × PSM-3 (7.80) PMR-53 × VL-7 (7.67) Arka Ajit × PSM-3 (6.30)	PMR-53 (2.75) Arka Ajit (1.06) PSM-4 (0.84)	VRP-16 × VL-7 (1.03) PSM-4 × VL-7 (0.81) Arka Ajit × PSM-3 (0.78)
12.	No. of nodes per main stem	Arka Ajit (19.20) PMR-62 (18.13) PMR-53 (18.00)	Arka Ajit × VL-7 (22.45) PSM-4 × Arkel (21.30) PSM-4 × PSM-3 (20.47)	Arka Ajit (3.74) PSM-4 (3.68) PMR-53 (1.05)	Arka Ajit × VL-7 (1.93) VRP-16 × VL-7 (1.73) PMR-19 × PSM-3 (1.10)
13.	Plant height (cm)	E-6 (51.60) PMR-31 (53.07) PMR-60 (56.73)	VRP-32 × PSM-3 (54.13) PMR-60 × VL-7 (61.50) VRP-16 × PSM-3 (62.33)	VRP-32 (-12.54) VRP-16 (-7.79) PMR-60 (-6.57)	PMR-19 × Arkel (-11.07) Nepal Pea × VL-7 (-9.20) Nepal Pea × PSM-3 (-8.47)
14.	Green pod yield per plant (g)	VP-266 (90.33) PSM-3 (51.33) VL-7 (45.73)	PSM-4 × PSM-3 (76.97) PMR-53 × PSM-3 (71.17) PMR-31 × VL-7 (58.20)	PMR-53 (11.72) Nepal Pea (7.50) PMR-31 (6.39)	PSM-4 × PSM-3 (22.99) PMR-19 × PSM-3 (11.52) PMR-53 × PSM-3 (10.92)
15.	Dry seed yield per plant (g)	Arkel (15.42) PMR-19 (11.42) AP-3 (11.39)	PMR-53 × Arkel (19.50) PMR-53 ×PSM-3 (19.42) Arka Ajit × VL-7 (15.93)	PMR-53 (6.68) Arka Ajit (3.66) PSM-3 (0.38)	Nepal Pea × Arkel (5.15) VRP-16 × VL-7 (4.33) PMR-31 × VL-7 (3.43)

involved at least one parent having high and significant gca estimates. The best cross combinations is not always found between parents with high × high gca effects but may also occur in other types of parental combinations. E-6, PMR-31 and VP-266 appeared as best general combiners for earliness (days to first flowering). The best specific cross was Arka Ajit × Arkel. The early maturity was found to be controlled by both additive and non additive gene effects. E-6, PMR-31 and VP-266 were good combiners for numbers of flowers per inflorescence. But none of the crosses appeared best for this character. Gupta and Singh (2004) have reported high general combining ability effects for number of first flowering node in pea.

The top ranking general combiners for days to first green pod picking and pod length were PMR-53, PSM-4 and Arka Ajit, PMR-53, respectively. But none of the crosses appeared best for these two characters. Pod length is an important character that contributes towards green pod yield. The top ranking general combiner for pod length was Arka Ajit. PMR-53 also had high *per se* performance. These findings indicated that for improvement in length, the long pod parents should be involved in crossing programme. Similar results have been reported by Saxena *et al.* (1987) and Singh et al. (1994).

Among the parents PSM-4, PMR-53 and PMR-31 were best combiners for 100-green pod weight based on high gca effects and high *per se* performance. Among the crosses, E-6 × PSM-3, PSM-4 × Arkel and PMR-31 × Arkel were best for 100-green pod weight. PMR-62, PMR-60 and Arkel were the best combiners for number of seeds per pod. The cross found best for seeds per pod was Arka Ajit × PSM-3 which involved parents with poor × good gca effects. Hence non additive types of gene actions are involved for expression of number of seeds per pod. The parents PMR-53 and PMR-32 were identified best general combiner for 100-green seed weight. However, AP-3 × VL-7 and VP-266 × PSM-3 crosses emerged as best specific combinations for this trait. None of the parents and crosses showed good combining ability for shelling percentage. Parents VP-266 and Nepal Pea were identified as the best combiner where as crosses PMR-62 × Arkel, Nepal Pea × VL-7 and PMR-32 × VL-7 showed the best combination for total soluble solids (%).

PSM-4 and Arkel were the best combiners for number of green pods per plant. The crosses found best for this character were PMR-31 × VL-7 and Nepal Pea × Arkel. These cross involved parents with poor x average, poor × good gca effects. Hence non additive types of gene actions are involved for expression of number of green pods per plant. The parent PMR-53, Arka Ajit and PSM-4 were identified as best general combiner for number of primary branches per plant and number of nodes per main stem. However, none of the crosses emerged as good specific combinations for these two traits. None of the crosses showed good combining ability for plant height. However, VRP-32 was identified as the best combiner for plant height.

Five crosses showed significant positive sca effects, for green pod yield and involved the parents with poor × poor, average × poor and good × poor, indicating the involvement of dominance and epistatic effects. The parents PMR-53, Nepal Pea and PMR-31 were best combiner for green pod yield. Thus, to improve green pod yield these crosses can be exploited following recurrent selection. PMR-19 × PSM-3 was the best combination for days to first green pod picking, number of seeds per pod, number of nodes per main stem and green pod yield per plant. Similar results were reported by, Moitra et al. (1988), Sharma (1999), Gupta and Singh (2004), Zaman and Hazarika (2005) and Singh et al. (2005). The top ranking general combiners for dry seed yield per plant was PMR-53 followed by Arka Ajit and PSM-3. The crosses appeared best for this character were Nepal Pea × Arkel and VRP-16 × VL-7.

On the basis of findings of present investigation, it can be concluded that PMR-53 for days to first green pod picking, pod length, 100-green pod weight, 100-green seed weight, number of primary branches per plant, number of nodes per main stem, green pod yield per plant (g) and dry seed yield per plant (g), PSM-3 for number of seeds per pod and dry seed yield per plant, E-6 for days to first flowering and number of first flowering node, VL-7 for number of seeds per pod, PSM-4 for days to first green pod picking, 100-green pod weight, number of green pods per plant, number of primary branches per plant and number of nodes per main stem, and Arkel for number of seeds per pod and number of green pod per plant and VP-266 for days to first flowering, number of first flowering node and T.T.S. (%) were best general combiners. PMR-53, PSM-3, E-6, VL-7, PSM-4, Arkel and VP-266 can be used in the hybridization programme to get desirable recombinants in segregating generations. The cross Arka Ajit × Arkel could be exploited for early maturity. The crosses VRP-16 × VL-7, PMR-19 × PSM-3, Arka Ajit × PSM-3 and PSM-4 × Arkel can be advanced to recover desirable segregants for the improvement of yield and yield contributing characters.

सारांश

सब्जी मटर की 59 प्रजातियाँ, (14 लाइन, 3 टेस्टर और 42 एफ़्र–1 संकर) का मूल्याँकन लाइन टेस्टर संकरण पद्धति द्वारा 15 गुणों पर किया गया। पी. एम.आर.–53 ने पहली तुड़ाई फली की लम्बाई, 100–हरी फली का वजन, 100–हरे बीज का वजन, प्राथमिक शाखा प्रति पौध, मुख्य शाखा पर गांठो की सख्या, हरी फली की उपज प्रति पौध और बीज उपज प्रति पौध, पी. एस. एम.–3 ने प्रति फली बीज सख्या और बीज उपज प्रति पौध, ई–6 ने अगेती फसल, वी. एल. –7 ने प्रति फली बीज सख्या, पी. एस. एम.–4 ने हरी फली की प्रथम तुड़ाई, 100–हरी फली का वजन, हरी फली की सख्या प्रति पौध,

प्राथमिक शाखा प्रति पौध और मुख्य शाखा पर गांठो की सख्या, अर्किल ने प्रति फली बीज सख्या और हरी फली की सख्या प्रति पौध तथा वी. पी.–266 ने अगेती फसल और टी. एस. एस. (प्रतिशत), के लिये सर्वोत्तम सामान्य संयेाजन क्षमता प्रदर्शित की। लाइन पी. एम. आर.–53, पी. एस. एम.–3, ई.–6, वी. एल.–7, पी. एस. एम.–4, अर्किल तथा वी. पी.–266 को संकरण योजना में पितॉ समतुल्य प्रयोग कर सकते है, ताकि वियोजक पॉथक पीढी में वांछनीय पुनर संयेाजक प्राप्त हो सके। संकर वी. आर. पी.–16 x वी. एल.–7, पी. एम. आर.–19 पी. x एस. एम.–3, अर्का अर्जित x पी. एस. एम.–3, तथा पी. एस. एम.–4 x अर्किल उपज तथा उपज गुण के लिये सर्वोत्तम संयेाजन क्षमता वाले पाये गये।

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