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Combining ability and heterosis for pod yield and its related horticultural traits in garden pea (*Pisum sativum* L.) under mid-hill sub-temperate and high-hill dry-temperate conditions of Himachal Pradesh

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Abstract

A line × tester analysis involving 10 promising lines and 2 testers having wider genetic base were carried out for pod yield and related horticultural traits in garden pea (*Pisum sativum* L.) in diverse environments at Kukumseri (dry-temperate) and Palampur (sub-temperate) during summer 2004 and winter 2004-05, respectively. Among the parents, Green Pearl, Azad P 1, DPP 9418-06 and DPP 9411 were observed as good general combiners for pod yield/plant and majority of the component traits. The cross combinations Green Pearl × DPP 9411 and Azad P 1 × Sugar Giant showed high heterosis and *sca* effects for pod yield and related horticultural traits. The cross Green Pearl × Sugar Giant was the most promising for early flowering and green pod picking. For powdery mildew incidence, the cross VRPMR 10 × Sugar Giant where both parents revealed high negative *gca* effects also showed significant negative *sca* effect and heterosis. For most of the traits including pod yield/plant, both additive and non-additive gene actions were of prime importance.

Key words: Garden pea, combining ability, heterosis, pod yield, environments

Introduction

Garden pea (*Pisum sativum* L.) is one of the most important off-season vegetable crops grown during summer season in high-hills of Himachal Pradesh. It is recognized as a major cash crop for the growers as it fetches premium prices in the market of plains where it is grown as winter crop. A number of high yielding pea varieties have been developed but these are prone to various diseases especially powdery mildew (*Erysiphe polygoni*). Under such situations, farmers sometime incur huge losses in yield leading ultimately to low returns. Hence, there is need to develop varieties with lush green pods having high yield and resistance to powdery mildew disease. The success of a plant breeding programme largely depends upon the choice of parents for hybridization and identification of superior recombinants in the segregating generations on the basis of their heterotic performance and combining ability. The combining ability analysis developed by Kempthorne [1] provides useful information on different parents which in turn helps the plant breeders to identify promising crosses for further use in breeding programmes. The present investigation has, therefore, been intended to select parents for effective hybridization programme as well as to identify superior cross combinations on the basis of heterosis and combining ability.

Materials and methods

Ten lines *viz.*, NDVP 24, Azad P1, Palam Priya, NDVP 9, Green Pearl, Matar Ageta and Lincoln (susceptible to powdery mildew), VRPMR 10, DPP 26G and DPP 9418-06 (resistant to powdery mildew) were crossed with two broad based testers DPP 9411 (moderately resistant with green pods and dwarf growth habit) and Sugar Giant (resistant to powdery mildew with yellowish green pods and semi-tall growth habit) to generate 20 cross combinations during winter 2003-04. The material comprising 2 testers, 10 lines and their 20 hybrid combinations were evaluated in randomized block design with three replications in two locations at Kukumseri (high-hill dry-temperate zone) and Palampur (mid-hill sub-temperate zone) during summer, 2004 and winter 2004-05, respectively. Each cross/parent was raised in two rows of 2.7 m length with inter and intra row spacing of 45 cm and 10 cm, respectively. Data were recorded individually on five random plants on days to flowering, days to first picking, pod length (cm), seeds/pod, shelling percentage, plant height (cm), pods/plant, pod yield/plant (g) and powdery mildew disease incidence (%). The mean values of each genotype were subjected to combining ability analysis by following line × tester method of Kempthorne [1].

Results and discussion

Analysis of variance for combining ability in pooled over environment indicated significant differences among lines and testers for all the characters except shelling percentage which indicated the existence of genetic diversity in the parental material. The mean squares due to males were found to be smaller than those due to females. Variations among line × tester interactions were significant for all the traits except shelling percentage. This indicated the manifestation of parental genetic variability in their crosses and presence of uniformity among the hybrids [2]. The significance of mean squares due to females × environment, males × environment and (male × female) × environment interactions for majority of the traits suggested that both parents as well as their interaction variances were influenced by the environment. The results are in the close proximity with those of Narayan and Narayan [3] and Sharma and Kalia [4] in pea and Dubey *et al.*, [5] in maize.

The estimates of general combining ability effects (Table 1) for parental lines revealed that none of the 12 parents showed desirable significant *gca* effects for all the traits. However, the lines Matar Ageta and NDVP 24 (days to flowering and days to first picking), Green Pearl and NDVP 9 (pod length), Green Pearl, Palam Priya and NDVP 9 (seeds/pod), Lincoln (shelling percentage), DPP 9418-06, Palam Priya and VRPMR 10 (plant height), Azad P 1, Matar Ageta and DPP 9418-06 (pods/plant), Azad P 1, Green Pearl and Palam Priya (pod yield/plant) and VRPMR 10 and DPP 9418-06 (powdery mildew incidence) exhibited desirable *gca* effects with respects to traits mentioned in parenthesis. Among the testers, DPP 9411 was good general combiner for days to flowering, days to first picking, pod length, seeds/pod, plant height, pods/plant and pod yield/plant whereas Sugar Giant for powdery mildew incidence. However, in general, it was observed that the parents Green Pearl, Azad P 1, DPP 9418-06 and DPP 9411 were found to be significantly superior general combiners for pod yield and other important traits.

Specific combining ability effects (Table 2) revealed a very wide range of variation for all characters. Cross combinations Green Pearl × DPP 9411, DPP 9418-06 × Sugar Giant, DPP 26 G × DPP 9411, VRPMR 10 × Sugar Giant and Azad P 1 × Sugar Giant were the superior specific combiners for high pod yield. Of these crosses, DPP 9418-06 × Sugar Giant also exhibited significant sea effects for pod length, plant height and pods/plant. The other cross combinations exhibited similar desirable effects were DPP 26G × DPP 9411 and Azad P 1 × Sugar Giant for pods/plant, Green Pearl × DPP 9411 for plant height and VRPMR 10 × Sugar Giant for powdery mildew incidence alongwith high yield. For earliness, cross combination Green Pearl × Sugar Giant was the most promising for flowering and picking. Similar results regarding *gca* and *sca* effects for different parents and crosses were reported by Kumar and Jain [6], Singh and Mishra [7], Kumar and Tewatia [8] and Singh and Dhillon [9]. The crosses involving one good and other poor or average combiner may give desirable transgressive segregants if the additive effect of one parent and complementary epistatic effects (if present in the cross) act in the same direction

Table 1. Estimates of *gca* effects of lines and testers for different traits in garden pea in pooled over environment

Trait	Days to flowering	Days to first picking	Pod length (cm)	Seeds/ pod	Shelling percentage	Plant height (cm)	Pods/ plant	Pod yield/ plant (g)	Powdery mildew incidence (%)
Line									
NDVP 24	–3.69*	–2.93*	0.04	–0.18*	–1.55	4.15*	–1.11*	–6.46*	8.29*
Azad P 1	–3.72*	–0.57	0.05	0.15	–0.61	–1.23	1.94*	15.32*	6.00*
Palam Priya	1.48*	–0.06	0.15	0.35*	–0.56	–3.68*	0.32	9.22*	4.15*
NDVP 9	–0.28	–0.51	0.20*	0.31*	0.58	–0.51	–2.60*	–10.14*	9.43*
VRPMR 10	3.17*	1.75*	–0.07	0.13	0.99	–3.43*	–2.25*	–10.52*	–20.79*
Green Pearl	–1.15*	0.55	0.55*	0.54*	0.40	9.42*	0.60	12.25*	17.92*
Matar Ageta	–3.75*	–0.68	–0.24*	–0.71*	–1.01	–1.57	1.50*	–1.49	7.44*
Lincoln	1.17*	1.32*	–0.04	0.06	1.96*	1.80*	0.19	–5.93*	6.96*
DPP 26G	3.05*	2.92*	–0.28*	–0.46*	0.25	8.60*	0.37	–4.84*	–12.49*
DPP 9418-06	1.58*	–1.45*	–0.35*	–0.19*	–0.44	–13.55*	1.04*	2.59	–16.92*
SE (gi)t	0.34	0.39	0.09	0.08	0.79	0.84	0.39	1.10	0.84
SE (gi-gj) ±	0.48	0.55	0.12	0.11	1.12	1.18	0.56	1.45	1.18
Tester									
DPP 9411	–0.96*	–1.56*	0.19*	0.17*	–0.32	–19.07*	0.62*	4.27*	3.81*
Sugar giant	0.96*	1.56*	–0.19*	–0.17*	0.32	19.07*	–0.62*	–4.27*	–3.81*
SE (gj) ±	0.15	0.17	0.04	0.03	0.35	0.37	0.18	0.49	0.37
SE (gj-gk) ±	0.22	0.25	0.05	0.05	0.50	0.53	0.25	0.65	0.53

*Significant at P ≤ 0.05

and maximize the desirable plant character [10]. But in the present study, high *sca* effects were also shown by some cross combinations with poor × poor and average × poor *gca* values. This might be due to parental lines used in the present study had origin from the diverse genetic background and hence exhibited high sea effects. It was also observed that the ranking based on *sca* effects of crosses was not reflected by heterosis and *per se* performance. Though, selection of crosses based on *sca* effects would be more reliable than heterosis.

On the basis of economic heterosis calculated over Azad P 1, a good number of crosses showed the presence of desirable heterotic response for different characters (Table 2). For pod yield, Green Pearl × DPP 9411, Azad P 1 × DPP 9411, Palam Priya × DPP 9411, Azad P 1 × Sugar Giant and Matar Ageta × DPP 9411 were the top five. The top cross combinations Green Pearl × DPP 9411 and Azad P 1 × Sugar Giant had also high significant *sca* effects coupled with high *gca* of female parent for pod yielo and major yield components. Therefore, additive component seemed to influence pod yield in these crosses. On the other hand, the crosses Azad P 1 × DPP 9411, Palam Priya × DPP 9411 and Matar Ageta × DPP 9411 had low *sca* effects but one of the parents had high *gca*. Hence, in these crosses heterosis for yield may be due to predominance of additive gene action and better selection advance can be expected in subsequent generations. Therefore, it may be possible to take advantage of such heterotic effects in subsequent generations [2]. These results for heterosis for various traits are in close proximity with those of Kumar and Tewatia [8], Mishra [11], Tyagi and Srivastava [12]. Powdery mildew incidence is an important component influencing yield. Six crosses showed significant negative heterosis. Among these, only one cross VRPMR 10 × Sugar Giant had significant negative *sca* and both parents of this cross had high negative *gca* effects suggesting thereby operation of additive gene effects. On the other hand, two of these crosses DPP 26 G × Sugar Giant and DPP 9418-06 × Sugar Giant had non-significant *sca* effects but both of their parents had significant *gca* effects suggesting operation of additive gene effects on heterosis. Therefore, it may be possible to get desirable recombinants in early generations. Pod yield and major yield components showed the

Table 2. Estimates of *sca* effects and economic heterosis (EC) over Azad P1 for different traits in garden pea in pooled over environment

Trait	Days to flowering		Days to first picking		Pod length (cm)		Seeds/pod		Shelling percentage		Plant height (cm)		Pods/plant		Pod yield/plant (g)		Powdery mildew incidence (%)	
Cross	*sca*	EC	*sca*	EC	*sca*	EC	*sca*	EC	*sca*	EC	*sca*	EC	*sca*	EC	*sca*	EC	*sca*	EC
NDVP 24 × DPP 9411	0.20	–5.02*	–0.01	–3.69*	0.11	4.61	–0.08	–7.30	1.36	–0.07	0.14	4.78	–0.21	20.67	–2.82	–3.01	2.96*	32.75*
Azad P 1 × DPP 9411	–0.82	–9.19*	–0.49	–3.66*	0.05	4.19	0.21	5.27	0.57	0.28	–0.91	–5.89	–1.49*	41.82*	–3.31*	44.46*	–2.12	14.77*
Palam Priya × DPP 9411	0.21	–1.07	–0.08	–1.43	–0.21	1.82	–0.01	4.87	0.12	–0.61	2.23	–4.73	0.26	43.37*	2.06	42.83*	–1.99	11.25*
NDVP 9 × DPP 9411	–0.95*	–4.89*	1.17*	–0.65	–0.02	5.17	0.09	5.88	–0.71	0.07	0.17	–2.90	0.01	5.50	–2.64	–10.84	2.04	33.40*
VRPMR 10 × DPP 9411	0.23	1.15	–1.16*	–0.72	0.03	1.96	–0.11	–1.62	–0.55	1.30	0.85	–6.61	–0.37	5.14	–4.09*	–14.89*	3.17*	–39.53*
Green Pearl × DPP 9411	1.71*	–2.54	1.17*	0.39	0.06	11.03*	0.08	10.75*	–0.23	0.72	–10.53*	–4.18	0.04	44.21*	7.87*	62.54*	–1.14	43.42*
Matar Ageta × DPP 9411	–0.95*	–9.41*	0.77	–1.21	0.05	0.00	0.05	–15.20*	0.57	–0.61	–2.51*	–9.10*	0.71	62.84*	2.56	20.07*	–0.05	23.60*
Lincoln × DPP 9411	–0.30	–2.15	0.01	0.00	0.27*	5.87	0.15	2.03	0.12	4.87	1.08	2.46	1.06	51.37*	2.20	9.36	1.05	25.64*
DPP 26 G × DPP 9411	0.91	1.89	–0.09	1.47	0.00	–1.26	–0.26*	–16.60*	–1.19	–1.72	1.09	13.74*	1.64*	60.45	4.46*	16.83*	–1.88	–57.21*
DPP 941 8-06 × DPP 9411	–0.25	–1.55	–1.29*	–3.49*	–0.34*	–6.98	–0.13	–8.52	–0.06	0.74	8.40*	–10.9*	–1.66*	29.03*	–6.30*	9.41	–2.05	–40.40*
NDVP 24 × Sugar Giant	–0.20	–3.02*	0.01	–0.62	–0.11	–3.77	0.08	–11.00*	–1.36	–4.57	–0.14	67.63*	0.21	10.75	2.82	–9.48	–2.96*	–0.29
Azad P 1 × Sugar Giant	0.82	–4.55*	0.49	0.36	–0.05	–2.79	–0.21	–10.10*	–0.57	–0.83	0.91	60.45*	1.49*	62.49*	3.31*	40.18*	2.12	6.72
Palam Priya × Sugar Giant	–0.21	0.89	0.08	1.76	0.21	2.23	0.01	–1.42	–0.12	0.26	–2.23	51.15*	–0.26	22.22	–2.06	14.60*	1.99	4.92
NDVP 9 × Sugar Giant	0.95*	0.10	–1.17*	0.10	0.02	0.28	–0.09	–4.26	0.71	4.54	–0.17	59.83*	–0.01	–9.56	2.64	–18.10*	–2.04	5.12
VRPMR 10 × Sugar Giant	–0.23	3.06*	1.16*	4.61*	–0.03	–4.19	0.11	–3.85	0.55	5.09	–0.85	53.86*	0.37	–0.84	4.09*	–15.72*	–3.17*	–73.60*
Green Pearl × Sugar Giant	–1.71*	–4.50*	–1.17*	1.15	–0.06	4.05	–0.08	0.61	0.23	3.11	10.53*	94.07*	–0.04	28.20*	–7.87*	8.41	1.14	31.56
Matar Ageta × Sugar Giant	0.95*	–4.42*	–0.77	0.33	–0.05	–6.84	–0.05	–24.1*	–0.57	–1.67	2.51*	62.54*	–0.71	31.06*	–2.56	–10.39	0.05	5.39
Lincoln × Sugar Giant	0.30	1.15	–0.01	3.04*	–0.27*	–7.12	–0.15	–10.6*	–0.12	5.74	–1.08	62.16*	–1.06	11.11	–2.20	–19.49*	–1.05	1.19
DPP 26 G × Sugar Giant	–0.91	2.02	0.09	4.70*	0.00	–6.56	0.26*	–13.00*	1.19	4.87	–1.09	73.44*	–1.64*	6.33	–4.46*	–22.10*	1.88	–63.82*
DPP 941 8-06 × Sugar Giant	0.25	1.63	1.29*	2.10	0.34*	–3.07	0.13	–9.94*	0.06	0.91	–8.40*	24.53*	1.66*	53.76*	6.30*	18.44*	2.05	–46.91*
SE (Sij) ±	0.48	1.14	0.55	1.19	0.12	0.27	0.11	0.22	1.12	2.28	1.18	2.29	0.56	1.02	1.45	2.80	1.18	3.05
SE (Sij-Skl) ±	0.69		0.78		0.17		0.15		1.58		1.68		0.79		2.05		1.67	

*Significant at $P \leq 0.05$

significance of both additive and non-additive type of gene action in different cross combinations for different characters, thereby, revealing the importance of breeding methods like reciprocal recurrent selection and diallel selective mating system in the improvement of pod yield in garden pea. The presence of additive gene action suggested that a part of the heterosis is likely to be fixed in subsequent generations to facilitate further selection.

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