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Research Article

Diallel analysis in fieldpea [*Pisum sativum* (L.) *var arvense*.]

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Abstract

Heterosis and combining ability study for yield and yield related attributes in Fieldpea [*Pisum sativum* (L.) var arvense.] was carried out through a 10 x 10 half diallel analysis at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Experimental materials comprising 10 parents, their 45 crosses and a standard check DF-1. The material was planted in a randomized block design with three replications during rabi 2012-13. The analysis of variance indicated significant differences among genotypes, parents and crosses for all the characters. The mean squares due to parents vs. hybrids were significant for all the characters except days to maturity, number of seeds per pod, number of primary branches and test weight under study. Exploitable heterosis over mid parent, better parent and standard heterosis, out of 45 hybrids, few hybrids exhibited significant heterosis in desired direction for days to flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, number of primary branches per plant, grain yield per plant, test weight, protein content and harvest index . The highest heterosis over standard check variety (DF-1) for Grain yield per plant was registered by the cross IPFD-1-10 x LFP 477 followed by HUDP 954 x Pant P 167, HFP-4 x Pant P 167, HFP-4 x IPFD-1-10 *and* HUDP 954 x IPFD 10-13. Heterosis for grain yield per plant was reflected through number of seeds per pod, number of pods per plant and harvest index. The crosses DF-1 x HFP-4, HUDP 954 x LFP 477 and LFP 477 x IPFD 10-13 were found to be most promising for grain yield with respect to high and significant *sca* effects. The ratio of gca : sca variance ($\sigma^2_{gca}/\sigma^2_{sca}$) was less than unity for all the characters under study. This indicated that non-additive types of gene action were primarily involved in the expression of these characters. Among the parents, DF-1, IPFD 10-13 and GCO-703 were good general combiners for grain yield. They were also good general combiners for important traits like days to flowering, days to maturity, number of seeds per pod and test weight. DF-1 was also good general combiner for grain yield per plant, days to maturity, protein content and harvest index. High general combining ability effects are related to additive gene action and additive x additive interaction effects which represent the fixable genetic component of variation. In view of this, IPFD 10-13, DF-1 and HFP-4 appeared to be worth for commercial exploiting in the fieldpea, breeding programme aimed at yield improvement. Among the crosses, positive significant *sca* effects for grain yield were exhibited by 17 crosses. These crosses also exhibited significant *sca* effects in desirable direction for one or more important yield components and other quantitative traits. The crosses DF-1 x HFP-4, HUDP 954 x LFP 477 and LFP 477 x IPFD 10-13 were found to be most promising for grain yield with respect to high and significant *sca* effects.

Key words
Heterosis, Combining ability, Diallel analysis, *gca*, *sca*

Introduction

Pulses occupy pivotal position particular in developing countries like India, where most of the population is vegetarian. Pulses belong to the family *Leguminosae* and subfamily *Papilionoidaceae*. Pulses being rich in protein and essential amino acids, particularly lysine, they are highly nutritive and chief source of protein in vegetarian diet. They provide 22-24 per cent protein and the seeds are considered easily digestible. Among all the pulses, pea (*Pisum sativum* L.) is a leguminous plant of the subfamily *Papilionoidaceae* and belongs to the general class of dicotyledons. Pea consists of chromosome number 2n=14. It is the popular pulse crop and the second important food legume of the world. Pulses occupy second place next to cereals and they are main source of protein. It is native of South Western Asia and widely grown in temperate countries. It is essentially a cold weather crop and can withstand light frost. Two types of peas are generally cultivated, i.e., one is the fieldpea (*Pisum sativum* (L.) *var arvense)* and other is gardenpea (*Pisum sativum* (L.) *var hortens).* Fieldpea is generally used as a pulse crop and gardenpea as vegetable. The species is used as a vegetable, fresh, frozen or canned and is also grown to produce dry peas like the split pea. These varieties are typically called fieldpeas. It is winter crop and grown as a mixed inter crop with wheat and barley. Dry peas are used as split pea *dal* and *besan* for various preparations. Both pods and seeds are rich in protein content ranging from 21 to 33% (Anonymous, 1987). The per capita availability of pulses is only 37 g/person/day against as for World Health Organization (WHO) recommendation of 78 g/person/day (Anonymous, 1999). In India the cultivation of pea is about 7.93 lakh hectares with a total production of 7.10 lakh metric tones and productivity of 895 kg ha^{-1} (Anonymous, 2010).

Heterosis expresses the superiority of F_1 hybrid over its mid parental value in terms of yield and other characters. Exploitation of hybrid vigour has been recognized as an important tool for genetic improvement of yield and may serve as a major fruitful technique to break existing yield barriers. Study of heterosis in self pollinated crops offers an opportunity to breeders for identifying promising crosses in early generation that can give transgressive segregants in later segregating generations. Now days, the utilization of hybrid vigour and selection of parents on the basis of combining ability has opened new vistas in plant breeding. Combining ability analysis on the basis of diallel mating system is one of the most appropriate methods to recognize the best combiners, which can be utilized for hybridization program. It gives information about the nature of gene action and the relative magnitudes of fixable (additive) and non-fixable (non-additive/dominance) genetic variations. The most widespread and tested method for combining ability estimation is the diallel analysis mostly applied in pea breeding (Sharma *et al*.,1999, Srivastava *et al*., 2000, Bourion *et al*., 2002). During the last three decades, diallel-crossing technique has attracted the attention of several workers. A diallel is a mating system that involves all possible crosses among a group of parents. This genetic design is used to study polygenic systems that determine quantitative traits. The analysis of diallel cross data may be interpreted into different ways viz., heterosis, combining ability analysis (Griffing, 1956b) and components of genetic variation (Hayman, 1954a). Diallel analysis provides a systematic approach for identification of superior parents and crosses which are the basic material on which success of breeding programme rests. Moreover the breeding procedure to be adopted depends upon the type and magnitude of genetic variances and hence an added advantage of the diallel analysis is that it gives overall genetic picture of the material under investigation in a single generation. It provides an idea of parental performance both for general and specific combining ability with respect to target trait. The knowledge about nature of gene action governing the expressions of various traits could help in predicting the effectiveness of selection. In fieldpea, both diallel and line x tester analysis are used to evaluate the genetic recombination behavior and genetics of the trait. (Singh *et al*., 2010).

Materials and method

Heterosis and combining ability study in fieldpea (*Pisum sativum* (L.) *var arvense*) was carried out at Centre of Excellence for Research on Pulses, S. D. Agricultural University, Sardarkrushinagar, District: Banaskantha, during *Rabi* 2012. A set of 55 genotypes comprising 10 parents and their 45 F_1 hybrids were sown in a Randomized Block Design (RBD) with three replications during *rabi* 2012-13 at Centre of Excellence for Research on Pulses, S. D. Agricultural University, Sardarkrushinagar. The parent DF-1 was used as a standard check. Each genotype was sown in one row of three meter length. The distance between rows and within rows was 45 cm and 10 cm, respectively. Five competitive plants were randomly selected to record the observations on ten qualitative and quantitative characters and mean values were subjected to statistical analysis. The analysis of variance was carried out as suggested by Panse and Sukhatme (1978). The analysis of experimental material was done according to Griffing (1956a and b).

Results and discussion

The analysis of variance (Table 1) for various characters revealed that considerable genetic variation existed among the parents and hybrids for all the traits under study. Comparison of mean squares due to parent vs. hybrids indicated presence of overall heterosis for all the characters except length of main spike, spikelets per spike, 100-grain weight and protein content indicating that the performance of hybrids was different than that of the parents for most of the characters. The parent DF-1 had maximum values for grain yield per plant and harvest index while, hybrids DF-1 x HFP-4, HFP-4 x IPFD 10-13, LFP 477 x IPFD 10-13 and HFP-4 x IPFD 10-13, LFP 477 x IPFD 10-13, DF-1 x HFP-4 exhibited higher grain yield per plant and harvest index, respectively. The parent GCO-703 was earliest in flowering and days to maturity whereas, the hybrids DF-1 x Pant P 167 and HUDP 954 x IPFD 10-13 were early in flowering and days to maturity, respectively. The parent KPMR 400 was dwarfest parent followed by LFP 477 and HFP-4 and hybrids HFP-4 x HUDP 954, HUDP 954 x HFP 715 and HFP 715 x IPFD-1-10 were dwarfest among the hybrids.

The parent GCO-703 had more number of seeds per pod and registered maximum number of primary branches per plant, while, hybrids HFP 715 x IPFD-1-10, IPFD-1-10 x GCO-703, DF-1 x GCO-703 and DF-1 x Pant P 167, KPMR 400 x LFP 477, HFP 715 x IPFD-1-10 exhibited largest number of seeds per pod and number of primary branches, respectively.

The parent KPMR 400 had highest number of pods per plant, followed by HUDP 954 and DF-1. The hybrids HFP-4 x HFP 715, HFP-4 x IPFD 10-13 and HFP-4 x LFP 477 recorded maximum number of pods per plants. The parent HUDP 954 had highest protein content followed by KPMR 400 and GCO-703.The hybrids DF-1 x HUDP 954, followed by KPMR 400 x IPFD 10-13 and DF-1x KPMR 400 manifested high protein content.

The parent Pant P 167 had wide range of test weight, followed by HFP 715 and IPFD 10-13, while, the hybrid HUDP 954 x KPMR 400, HFP 715 x GCO-703 and Pant P 167 x IPFD-1-10 revealed highest test weight in plants. With regard to heterosis (Table 2) over mid parent, better parent, and standard heterosis, out of 45 hybrids, few hybrids exhibited significant heterosis in desired direction for number of pods per plant (24, 3, 1), number of seeds per pod (6, 1, 0), number of primary branches(5, 4, 4), grain yield per plant (29,19, 7), protein content(17, 14, 9), and harvest index (24, 13, 5). The profit-making utilization of heterosis in fieldpea has limited application because of low natural out crossing and non-availability of sterility system. However, the nature and magnitude of heterosis would help in the identification of superior cross combinations and their exploitation to get better transgressive segregants. In the utilization of hybrid vigour, only the vigour in excess of the better parent (heterobeltiosis) of significant.

Heterosis is a function of number of loci at which the parent carry different alleles and the magnitude and direction of the non-additive effects within or between those loci in hybrid combinations (Jinks, 1983). With respect to number of seeds per pod, it recorded relative heterosis (41.18 %), heterobeltiosis (35.29 %) and standard heterosis (18.52 %) over standard check (DF-1). The similar results for number of seeds per pod were obtained by Singh *et al.* (1994), Sarawat *et al.* (1994), Sharma *et al*. (1998). For grain yield per plant, with regards to standard heterosis, seven hybrids depicted significant heterosis over standard check variety DF-1 in desired direction. The best hybrids with positive value were IPFD-1-10 x LFP 477 (39.24 %), HUDP 954 x Pant P 167 (37.67 %) and HFP-4 x Pant P 167 (36.29 %). These findings are in agreement with the report of Sarawat *et al.* (1994), Lila Bora *et al* (2009 a&b), Borah (2009), Sarode *et al.* (2009), Punia *et al.* (2011).

The analysis of variance for combining ability for various characters is presented in (Table 3). The analysis of variance for combining ability exhibited that mean squares due to general combining ability and specific combining ability were found significant for all the traits except *gca* for days to maturity and number of primary branches. This indicated that both additive and non-additive gene effects involved in the inheritance of the characters under study.

The ratio of GCA & SCA genetic variance indicated predominance of non-additive gene action in the expression of all the traits. The ratio of *gca* : sca variance ($\sigma^2_{gca}/\sigma^2_{sca}$) was less than unity for all the characters under study. This indicated that non-additive type of gene actions were primarily involved in the expression of these characters. This is in accordance with the finding of Pandey (1995), Zaman and Hazarika (2005), Ranjan *et al.* (2005), Ercan *et al.* (2008), Borah (2009), Singh *et al*. (2010), Punia *et al*. (2011) and Abbas (2012).

The estimates of general combining ability (*gca*) effects of ten parents and sca effects of 45 crosses are presented in (Table 4) and (Table 5) respectively. This indicated that general combining ability variances were highly significant for all the characters, except for days to maturity and number of primary branches while specific combining ability variances were highly significant for all the characters. This suggested that both additive and non-additive gene actions were involved in the expression of grain yield and its component traits. The parent IPFD 10-13 ranked first as it was good general combiner for most of the characters viz., days to maturity, number of seeds per pod, grain yield per plant, test weight, protein content and harvest index. The HFP 715 was good combiner for plant height, number of primary branches, test weight, protein content and harvest index. GCO-703 had good combiner for days to flowering, days to maturity, number of seeds per pod, grain yield per plant (g) and test weight (g). The parent DF-1 was found to be good general combiner for days to maturity, grain yield per plant, protein content and harvest index. HFP-4 had good general combining effects for plant height, number of pods per plant and grain yield per plant. The parent HUDP 954 was good general combining ability effects for days to maturity, plant height, number of pods per plant, protein content and harvest index. The KPMR 400 had good general combining ability effect for number of pods per plant, number of primary branches and protein content. The parent IPFD-1-10 had good general combining ability effects for number of seeds per pod and protein content. The parents Pant P 167 and LFP 477 had good general combining ability effect for test weight and plant height, respectively. Thus, it was poor and average combiner for all other characters. An overall consideration of *gca* effects indicated that the parents DF-1, HFP-4 and HUDP 954 appeared to be good general combiners for grain yield per plant and harvest index. They also registered good general combining ability effects for other yield contributing characters in which number of seeds per pod, harvest index and number of pods per plant, were common indicating the importance of these characters toward yield attributes. High general combining ability effects are related to additive gene action and additive x additive interaction effects (Griffing, 1956a), which represent the fixable genetic component of variation. In view of this, DF-1, HFP-4 and HUDP 954 appeared to be worth for commercial exploitation in the fieldpea breeding programme aimed at yield improvement. The parent with high *gca* effect for a particular component breeding programme, thereby, seeking improvement in yield through that particular component (Patil and Shete, 1986).

Specific combining ability effects of hybrid revealed that none of the hybrids was consistently good for all the characters under study (Table 5). Out of 45 crosses, 17 crosses exhibited positive and significant *sca* effects for grain yield per plant. The cross DF-1 x HFP-4 was good for grain yield per plant and harvest index in desired direction. The cross DF-1 x Pant P 167 recorded significant and negative *sca* effect for days to flowering while significant and positive *sca* effect for number of primary branches. The cross HUDP 954 x IPFD 10-13 exhibited significant and negative *sca* effect for days to maturity and cross HFP-4 x HUDP 954 recorded significant and negative *sca* effect in desired direction for plant height.

Out of 45 crosses studied, 20 exhibited significant and positive specific combining ability effects for number of pods per plant in desired direction. The cross HFP-4 x HFP715 exhibited significant and highest positive *sca* effects for pods per plant. The cross HFP 715 x IPFD-1-10 for number of seeds per pod and KPMR 400 x LFP 477 for test weight. The cross DF-1 x HUDP 954 exhibited significant and positive *sca* effect for protein content and LFP 477 x IPFD 10-13 for harvest Index. On the basis of SCA effects the crosses viz., DF-1 x HFP4, HFP 4 x IPFD 10-13 and LFP 477 x IPFD 10-13 which exhibited high significant SCA effect in desired direction for grain yield per plant, number of pods per plant and harvest index (%) resulting from good x good, good x poor and good x good parents, respectively.

The best parent, general combiners, *per se* performance of F_1's and specific combinations revealed that the most promising parents were not always good general combiners. These findings are in accordance with the result of Patil and Bhapkar (1986) and Thiyagarajan et al. (1993). The best general combiner could not always produce best specific combination for all the characters. The crosses exhibiting high positive or negative specific combining ability effects involved either good x good, good x average, good x poor, average x average, average x poor and poor x poor combining parents. The good general combiners when crossed did not always produce the best hybrid. Marked negative effects were observed in crosses between good x good and good x average which could be attributed to the lack of complementation between favourable alleles of the parents involved. Marked positive *sca* effects observed in crosses between poor x poor, average x poor, average x average could be ascribed to better complementation between favourable alleles of parents involved.

Conclusion

From the ongoing discussion, it can be concluded that the crosses viz., DF-1 x HFP-4, HFP-4 x IPFD 10-13, IPFD-1-10 x LFP477, HUDP 954 x Pant P 167 and HFP-4 × Pant P 167 exhibited significant and desirable economic heterosis for all the remaining characters. Heterosis for grain yield per plant was reflected through number of seeds per pod, number of pods per plant and harvest index. Analysis of variances for combining ability revealed that mean squares due to *gca* and *sca* were significant for all the characters indicating that additive as well as non-additive gene actions were important in the expression of these characters. However, the predictability ratio as well as magnitude of *gca* and *sca* variance indicated the preponderance of non-additive gene actions for all of the characters. The results of present investigation revealed the involvement of both types of gene action with preponderance of non-additive gene action suggesting that superior genotypes could be isolated in the segregating generations. Biparental mating may be employed in segregating generation to break undesirable linkage. Among the parents, DF-1, IPFD 10-13 and GCO-703 were good general combiners for grain yield. They were also good general combiners for important traits like days to flowering, days to maturity, number of seeds per pod and test weight. DF-1 was also good general combiner for grain y ield per plant, days to maturity, protein content and harvest index. The crosses DF-1 x HFP-4, HUDP 954 x LFP 477 and LFP 477 x IPFD 10-13 were [illegible] be most promising for grain yield with re[illegible] 102 [illegible]igh and significant *sca* effects.

References

Abbas, H.S. 2012. Inheritance of earliness, dry matter and shelling percentage in fieldpea. *Research J. Agric. Bio. Sci.,* **8(1)**: 1-5.

Anonymous. 1987. National Bureau of plant Genetic Resources Research Achievements Adecade (eds. K.P.S. Chandel and B.M. Singh) New Delhi, Sci., Monogr.; **11**: 170.

Anonymous. 1999. The World Health Organization (WHO) recommendation.

Anonymous. 2010. Gujarat agri statistics at a glance 2009-10, Directorate of agriculture, Gujarat state, Gandhinagar.

Borah, H.K. 2009. Studies on combining ability and heterosis in fieldpea (*Pisum sativum L.*). *Legume Res*., **32(4)**: 255-259.

Bourion, V.G., Fouilloux, C., Le Signor and Lejeune-Henaut. 2002. Genetic studies of selection for productive and stable peas. *Euphytica*., **127** : 261-273.

Ercan Ceyhan., Mehmet Ali, Avci and Serdar Karada. 2008. Line x tester analysis in pea (*Pisum sativum L.*). Identification of superior parents for seed yield and its components. *African. J. Bio*., **7**(16): 2810-2817.

Griffing, B. 1956a. A generalized treatment of the use of diallel crosses in quantitative inheritance. *Heredity*, **10**: 31-50.

Griffing, B. 1956b. Concept of general and specific combining ability in relation to diallel crossing systems. *Aus. J. Biol. Sci.,* **9**: 463-493.

Hayman, B.I. 1954a. The theory and analysis of diallel crosses. *Genet*., **39**: 789-809.

Lila, Bora., Sharma, V.K., Raturi, H.C. and Maurya, S.K. 2009a. Studies on hybrid breeding and genetic variability in vegetable pea under high hilly condition of Uttarakhand. *Annl. Hortic.,* **2**(2) :171-176.

Lila Bora., Sharma, V.K., Raturi, H.C. and Maurya, S.K. 2009b. Hybrid breeding for green pod quality, yield and its components in gardenpea (*Pisum sativum L*.). *Annl. Hortic*., **2**(2)**:**161-165.

Pandey, N. 1995. Combining ability for quality traits in fieldpea (*Pisum sativum*.). *Madras Agric. J.,* **82**(3):171-173.

Panse, V.G. and Sukhatme, P.V. 1978. Statistical Methods for Agricultural Workers. ICAR, New Delhi.

Patil, R.B. and Bhapkar, D.G. 1986. Combining ability in cowpea. *J. Maharashtra. Agric. Univ.,* **11** (3): 303-306.

Patil, R.B. and Shete, M.M. 1986. Combining ability analysis in cowpea [*Vigna unguiculata* (L.) Walp.]. *J. Maharashtra Agric., Univ.,* **11**(3): 293-295.

Punia, S.S., Baldev Ram, Verma, P., Koli, N.R. and Rokaria, P. 2011. Combining ability studies in fieldpea (*Pisum sativum* L.). *J. Food Legumes*, **24**(3): 120-124.

Ranjan.S., Manoj Kumar and Pandey, S.S. 2005. Genetic studies in pea involving tall and dwarf genotypes. *Legume Res*., **28**(3): 202-205.

Sarawat, P., Stoddard, F.L., Marshall, D.R. and Ali, S.M. 1994. Heterosis for yield and related characters in pea. *Euphytica,* **80**(1-2): 39-48.

Sarode, S.B., Gupta, Kamal and Srivastava, C.P. 2009. Line x tester analysis in pea (*Pisum sativum* L.). *Intl. J. Plant Sci.*, **4**(1): 233-236.

Sharma, D.K., Adarsh, B. and Chaudhary, D.R. 1999. Studies on combining ability and gene action in pea (*Pisum sativum* L.). *Indian J. Hill Far.*, **12** : 32-36.

Sharma, R.N., Mishra, R.K., Pandey, R.L. ad Rastogi, N.K. 1998. Study of heterosis in fieldpea (*Pisum sativum* L.). *Annl. of Agric. Res.,* **19**(1): 58-60.

Singh, I., Sandhu, J.S. and Singh, J. 2010. Combining ability for yield and it's components in fieldpea. *Journal of Food Legumes,* **23**:143-145.

Singh, K.P., Singh, H.C. and Verma, M.C. 2010. Genetic analysis for yield and yield traits in pea. *Journal of Food Legumes*, **23**(2): 113-116.

Singh, M. N., Rai, B. and Singh, R.M. 1994. Potentialities of heterosis breeding in *Pisum*. *Indian J. Genet.,* **54**(4): 398-401.

Sofi, Parvez., Rather, A.G. and Warn, Shafiq A. 2006. Combining ability and gene action studies over environments in field pea (*Pisum sativum* L.). *Pakistan J. Bio. Sci.,* **4**: 2689-2692.

Srivastava, C., Tyagi, M., Agrawal, R. and Rai, B. 2000. Combining ability analysis for seed yield a related traits in peas of Indian and exotic origin. *Madras Agric. J.,* **86**(7-9): 366-370.

Thiyagarajan, K., Natrajan, C., Rathnaswamy, R. and Rejasekaran, S. 1993. Combining ability for yield and its components in cowpea. *Madras Agric. J.,* **80**(3): 124-129.

Zaman, S. and Hazarika, G.N. 2005. Combining ability in pea (*Pisum sativum* L.). *Legume Res.,* **28**(4): 300- 302.

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Table 1. Analysis of variance (mean squares) for parents and hybrids for different characters in fieldpea

Source of variation	d. f.	Days to flowering	Days to maturity	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Number of primary branches	Grain yield per plant (g)	Test weight (g)	Protein content (%)	Harvest index (%)
Replications	2	0.709	1.32	0.05	0.49	0.01	0.09	0.01	0.03	0.03	20.98
Genotypes	54	38.89**	38.07**	59.85**	173.89**	2.16**	0.34 **	31.67**	11.69**	4.05**	427.55 **
Parents	9	20.28	26.3	43.59**	223.32**	1.74 **	0.47 *	42.30**	10.77**	0.86**	273.93**
Hybrids	44	41.08**	41.09**	61.38**	161.57**	2.26**	0.31 *	27.38**	12.14**	4.75**	433.08 **
Parents vs. Hybrids	1	110.16**	11.27	139.23**	271.27**	1.60	0.26	124.96**	0.08	1.77**	1567.18 **
Error	108	15.33	19.85	1.49	2.31	0.61	0.19	0.827	1.48	0.12	27.84

*and ** are significant at P = 0.05 and P = 0.01 levels, respectively

Table 2. Number of crosses showing significant and desirable heterosis over mid-parent, better parent and standard Parent for different traits in fieldpea

Sr.No.	Characters	Number of crosses showing significant and desirable heterosis		
		MP	BP	SC
1.	Days to Flowering	6	7	15
2.	Days to Maturity	4	3	6
3.	Plant Height (cm)	23	30	41
4.	Number of Pods Per Plant	24	13	1
5.	Number of seeds Per Pod	6	1	0
6.	Number of Primary Branches	5	4	4
7.	Grain Yield Per Plant (g)	29	19	7
8.	Test Weight (g)	6	2	2
9.	Protein Content (%)	17	14	9
10.	Harvest Index (%)	24	13	5

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Table 3. Analysis of variance for combining ability for different characters in fieldpea

Source of variation	d. f.	Days to flowering	Days to maturity	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Number of primary branches	Grain yield per plant (g)	Test weight (g)	Protein content (%)	Harvest index (%)
GCA	9	14.24 **	11.92	5.32 **	83.42**	1.10**	0.07	10.89**	9.00**	1.97**	342.79 **
SCA	45	12.70 **	12.84**	22.87**	52.87**	0.64**	0.12**	10.49**	2.87**	1.22**	102.46 **
Error	108	5.11	6.61	0.49	0.77	0.20	0.06	0.27	0.49	0.04	9.28
σ^2gca		0.76	0.44	0.40	6.88	0.07	0.001	0.88	0.70	0.16	27.79
σ^2sca		7.59	6.22	22.38	52.10	0.44	0.057	10.21	2.38	1.18	93.18
σ^2gca/ σ^2sca		0.16	0.12	0.03	0.20	0.25	0.02	0.14	0.37	0.21	0.37

* and ** are significant at P = 0.05 and P = 0.01 levels, respectively

Table 4. Estimation of general combining ability (*gca*) effects of parents for various characters in fieldpea

Sr. No.	Parents	Days to flowering	Days to maturity	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Number of primary branches	Grain yield per plant (g)	Test weight (g)	Protein content (%)	Harvest index (%)
1.	DF-1	-0.60	-1.10*	-0.04	-1.67**	-0.33**	-0.02	0.96**	-1.82**	0.39**	11.19 **
2.	HFP-4	0.81	1.90 **	-1.03**	3.77**	-0.48**	0.01	0.31*	-0.73**	-0.74**	1.58
3.	HUDP 954	-0.62	-1.07*	-0.46*	2.72**	-0.06	-0.05	-0.17	-0.30	0.16**	2.07*
4.	KPMR 400	1.73**	0.56	1.13**	4.35**	-0.10	0.10*	-1.80**	0.02	0.60**	-9.64**
5.	HFP 715	0.06	-0.01	-0.63**	-1.36**	0.21	0.11*	0.09	0.72**	0.15**	0.89
6.	Pant P 167	1.09	0.73	0.61**	-1.66**	-0.21	0.00	0.20	1.10**	-0.39**	-4.53**
7.	IPFD-1-10	0.03	0.65	0.50**	-0.61*	0.33**	-0.07	-0.79 **	0.28	0.11*	0.48
8.	LFP 477	0.31	0.12	-0.50*	-1.59**	-0.05	0.05	-0.80 **	-0.48*	0.00	-3.11**
9.	IPFD 10-13	-0.73	-0.68*	0.32	-0.57*	0.26*	-0.13	1.49 **	0.59**	0.13*	0.59
10.	GCO-703	-2.10 **	-1.10*	0.09	-3.36**	0.43**	-0.018	0.51 **	0.61**	-0.41**	0.46
$S.E._{(gi)}$ ±		1.40	1.59	0.43	0.54	0.28	0.15	0.32	0.43	0.12	1.88

* and ** are significant at P = 0.05 and P = 0.01 levels, respectively.

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Table 5. Estimation of specific combining ability (*sca*) effects of hybrids for various characters in fieldpea

Sr. No.	Hybrids	Days to flowering	Days to maturity	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Number of primary branches	Grain yield per plant (g)	Test weight (g)	Protein content (%)	Harvest index (%)
1	DF-1 x HFP-4	0.58	-1.45	0.93	-9.30**	0.32	-0.08	6.21 **	1.03	2.18**	8.69**
2	DF-1 x HUDP 954	3.02	0.51	4.79 **	-6.45**	-0.29	-0.08	-1.93 **	0.67	2.31**	-3.31
3	DF-1 x KPMR 400	-0.33	-4.12	-2.87**	-7.88**	0.14	-0.31	-2.46**	-0.99	0.97**	-1.26
4	DF-1 x HFP715	0.33	-0.53	2.43 **	0.02	-1.37**	0.13	-2.36**	-2.69**	0.002	2.63
5	DF-1 x Pant P 167	-10.69**	-2.28	-6.22 **	8.32 **	-0.74	0.76**	-3.31 **	-3.12**	-0.05	4.19
6	DF-1 x IPFD-1-10	-8.63 **	-0.20	-0.81	1.07	-0.49	0.33	-2.64**	1.14	-0.005	17.31**
7	DF-1 x LFP 477	1.08	1.32	1.93 **	-1.54	-0.70	-0.16	3.03**	2.66 **	-1.34 **	0.93
8	DF-1 x IPFD 10-13	4.13	3.12	-4.49 **	-2.35**	-0.22	0.02	-4.93**	-1.13	-0.17	7.88 **
9	DF-1 x GCO-703	4.50*	6.54**	-0.26	-1.77*	1.40 **	0.17	-1.11 *	0.81	-1.52 **	-12.94 **
10	HFP-4 x HUDP 954	3.61	-1.48	-9.64 **	-8.50**	-0.74	-0.02	1.56 **	0.52	-0.70**	-2.40
11	HFP-4 x KPMR400	2.25	-2.12	-0.97	1.86 *	-0.30	-0.38	2.19 **	-0.80	-1.95 **	5.66 *
12	HFP-4 x HFP715	-2.08	-2.53	5.46**	21.57**	-0.02	0.24	0.79	-0.83	-0.21	-6.47 *
13	HFP-4 x Pant P 167	-1.11	0.71	-2.09**	6.87 **	-0.39	0.48 *	0.007	-0.57	0.16	-2.64
14	HFP-4 x IPFD-1-10	-1.05	1.79	-5.41**	-5.57**	-0.54	-0.20	1.18 *	-0.66	-0.31	-4.64
15	HFP-4 x LFP 477	0.66	1.32	7.39**	7.80**	1.04 *	-0.16	-3.30 **	-0.73	-0.32	9.11**
16	HFP-4 x IPFD 10-13	0.72	4.12	7.27 **	9.39 **	-0.27	0.35	4.88 **	1.42*	-0.237	1.06
17	HFP-4 x GCO-703	-1.91	-1.45	-4.20 **	-1.42	0.35	0.21	-6.29 **	-1.19	0.27	5.07
18	HUDP 954 x KPMR 400	-3.30	-1.81	3.71 **	-5.08**	0.67	-0.31	-1.32**	5.36**	-0.43*	-5.84 *
19	HUDP 954 x HFP 715	-2.63	4.43	-6.18**	-7.57**	-0.64	-0.16	0.27	-0.66	-3.02 **	-9.35 **
20	HUDP 954 x Pant P 167	3.33	4.68	-0.83	7.52**	0.59	-0.24	0.25	-1.32*	-1.02**	-1.51
21	HUDP 954 x IPFD-1-10	-2.94	-1.23	3.64**	2.07*	-0.75	0.29	2.17**	0.57	1.00**	9.80**
22	HUDP 954 x LFP 477	-2.88	1.29	-4.38**	5.85 **	-0.57	-0.22	5.68**	0.10	0.36	12.18 **
23	HUDP 954 x IPFD 10-13	-2.83	-8.89**	3.46 **	2.64 **	0.30	0.09	0.70	-0.40	0.25	-6.61 *
24	HUDP 954 x GCO-703	0.52	-0.48	3.42**	5.22**	-0.25	0.04	-0.48	-2.18**	0.32	18.19**
25	KPMR 400 x HFP 715	-2.00	3.79	-1.18	-3.40 **	-0.80	0.04	2.57 **	1.33 *	0.87 **	0.30
26	KPMR 400 x Pant P 167	0.97	2.04	6.93 **	5.29**	-0.77	-0.01	3.79**	-0.04	-1.58**	9.18**

Contd.,

Table 5. Contd.,

Sr. No.	Hybrids	Days to flowering	Days to maturity	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Number of primary branches	Grain yield per plant (g)	Test weight (g)	Protein content (%)	Harvest index (%)
27	KPMR 400 x IPFD-1-10	3.02	3.12	1.24	2.24 **	-0.32	0.06	-1.53**	-1.53 *	0.78**	-7.72 **
28	KPMR 400 x LFP 477	1.75	1.32	8.22**	5.82**	0.45	0.49 *	-3.03 **	-4.13**	1.07**	-0.19
29	KPMR 400 x IPFD 10-13	-4.19	0.46	0.66	-3.18**	0.74	-0.07	0.17	0.74	1.92 **	4.72
30	KPMR 400 x GCO-703	5.16 *	4.87 *	-4.74 **	-5.40 **	0.37	-0.41	2.99**	0.41	-0.31	-1.70
31	HFP 715 x Pant P 167	0.63	3.62	-4.02 **	-2.78 **	-1.09 *	0.21	0.05	-0.54	1.69**	12.46 **
32	HFP 715 x IPFD-1-10	0.69	-8.28**	-5.75**	0.16	1.75**	0.47*	-0.10	-0.96	0.42 *	17.16 **
33	HFP 715 x LFP 477	-4.58 *	-0.76	4.19**	-3.26 **	0.94 *	-0.16	-3.76**	0.07	1.22**	-20.52**
34	HFP 715 x IPFD 10-13	0.47	-4.95 *	-4.66**	7.12**	0.22	0.25	2.26**	-0.23	0.48 *	7.465 *
35	HFP 715 x GCO-703	3.83	4.46	-0.87	-4.88**	-0.74	-0.09	0.25	3.26**	0.20	4.27
36	Pant P 167 x IPFD-1-10	2.66	-1.03	-4.93 **	-8.33**	-0.008	-0.22	0.94	2.16**	-0.54 **	-8.86 **
37	Pant P 167 x LFP 477	2.38	-5.51 *	-5.15**	-3.56 **	1.17 **	0.11	1.80**	0.85	1.28**	1.54
38	Pant P 167 x IPFD 10-13	0.44	3.29	3.18**	-4.17**	1.05*	-0.46*	-2.67 **	-1.53*	-0.74 **	-11.41**
39	Pant P 167 x GCO-703	-3.19	0.71	-2.09 **	2.61 **	-1.30 **	-0.35	4.97 **	1.44 *	0.49*	1.62
40	IPFD-1-10 x LFP 477	-0.55	0.57	0.74	9.78 **	-0.37	-0.60 *	1.63 **	-0.55	-0.04	-9.02 **
41	IPFD-1-10 x IPFD 10-13	-1.5	2.37	-1.30 *	10.37**	-0.49	0.17	0.65	1.03	-0.33	1.96
42	IPFD-1-10 x GCO-703	0.86	0.79	4.04 **	4.96**	0.74	-0.40	0.48	0.82	0.44*	-6.16*
43	LFP 477 x IPFD 10-13	1.22	1.90	-5.49 **	-8.64**	0.49	-0.08	5.34 **	0.68	0.02	26.02**
44	LFP 477 x GCO-703	-7.41 **	-1.67	-5.17 **	-1.66 *	-0.87 *	0.003	3.32 **	0.55	-1.36**	10.84 **
45	IPFD 10-13 x GCO-703	-2.36	-6.87**	0.63	5.32 **	0.20	-0.57*	-0.47	-1.32*	-0.34	-12.30 **
	Range of *sca*	-10.69 to 5.16	-8.89 to 6.54	-9.64 to 8.22	-9.30 to 21.57	-1.37 to 1.75	-0.60 to 0.76	-6.29 to 6.21	-4.13 to 5.36	-3.02 to 2.31	-20.52 to 26.02
	No. of crosses showing significant desirable *sca* effects	4	5	19	20	6	4	17	7	15	14
	S.Em.(±)	4.19	4.77	1.30	1.63	0.83	0.46	0.97	1.30	0.38	5.65

* and ** are significant at P = 0.05 and P = 0.01 levels, respectively.