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Study of Heterosis and *per se* Performance in Fieldpea (*Pisum sativum* L.)

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ABSTRACT: A study carried out to identify superior hybrids by utilizing a half diallel set involving six fieldpea genotypes. This investigation was conducted at Castor and Pulses Research Station, Navsari agricultural university, Navsari and in subsequent season F_1's were evaluated in 2019-20, *Rabi* season. The magnitude of heterosis varied from the cross to cross for all the characters studied. The top five cross combinations for yield per plant were GDF-1 × NIFPVg-17-12, NIFPVg-1712 × NIFPGr-17-63, GDF-1 × NIFPVg-17-10, NF-18-52(Local) × NIFPGr17-12, and NIFPGr-17-64 × NIFPVg-17-12 respectively. None of the crosses were found significantly superior to the standard check but gave a superior yield than the standard check (GDF-1). The highest heterosis over standard check found was 12.12 for GDF-1 × NIFPVg-17-12. Presence of many challenges, in utilizing pea as a study material like low yielding nature, lower harvest index, difficulty in crossing, lower success rate in crossing. This study was done to overcome the yield barriers and finding best heterotic combination.

Keywords: Heterosis, relative heterosis, heterobeltiosis and standard heterosis.

INTRODUCTION

Fieldpea (*Pisum sativum* L. var. arvense) is an important commercial *Rabi* pulse crop in India. Two types of peas are generally cultivated i.e. one is fieldpea (*Pisum sativum* L. var. arvense) and another one is garden pea (*Pisum sativum* L.var. hortense). Among them, fieldpea is generally used for its dry, mature pods while garden pea is for vegetable purpose. The chromosome number of pea is 2n = 14. It is a self-pollinated crop which belongs to the family *Papilionaceae*. Fieldpea has high levels of the amino acids, lysine, and tryptophan, which are relatively low in cereal grains. Fieldpea contains approximately 21 to 25 per cent protein. Even though being rich in nutrition, it is mainly taken as minor crop in India. Heterosis or hybrid vigor may be defined as the superiority of a F_1 hybrid over both the parents in terms of yield and some other character (Shull, 1914). It is firstly reported in plants by Koelreuter (1766) in *Nicotiana* spp. The magnitude of heterosis helps in the identification of potential crosses to be used in conventional breeding programmes to enable and create a wide array of variability in segregating generations.

The exploitation of heterosis in crop plants is regarded as one of the breakthroughs in the field of plant breeding. The application of heterosis is considered to be an outstanding application of principles of genetics in agriculture. The scopes of exploitation of heterosis depend on the directions and magnitude of heterosis and the type of gene action involved. The economically important character for fieldpea is the yield per plant but other component characters also contribute towards yield. The measure of heterosis over better parent and standard check is of great practical importance in plant breeding. In the present investigation, therefore, the heterosis has been measured over the mid parent, better parent, and standard check. Thus, heterosis analysis aimed to search out the best combination of parents for their prospects for future use in the breeding programme to be utilized for developing high yielding varieties.

MATERIALS AND METHODS

This experimental study carried out in two seasons in which during *Rabi*-2018 for crossing and *Rabi*-2019 for evaluation at Castor and Pulses Research Station, Navsari agricultural university, Navsari. Six different elite genotypes (NIFPGr-17-64, GDF-1, NF-18-52 (Local), NIFPVg-17-10, NIFPVg-17-12, and NIFPGr-17-64) were used to carry out heterosis analysis for yield and yield attributing traits in fieldpea. All the six genotypes were crossed in half diallel fashion (Griffing, 1956a and 1956b) to generate 15 hybrids. The experiment design used was a randomized block design (Nandarajan and Gunasekaran 2005) with three replications. Here one outstanding parent used in the experiment was used as a check *i.e.* GDF-1. The per se performance of F_1's and Parents along with estimates of heterosis are mentioned in Table 1 to 5. Heterosis was estimated using the following formulas.

$$\text{Heterosis (\%)} = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard check (\%)} = \frac{\overline{F}_1 - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{F}_1$ = Mean performance of the F_1 hybrid

$\overline{MP}$ = Mean value of the parents (P_1 and P_2) of a hybrid

$\overline{BP}$ = Mean value of better parent

$\overline{SC}$ = Mean value of Standard check (GDF-1)

Table 1: Comparative *per se* performance of different fieldpea genotypes for different characters.

Characters Genotypes	Days to 50% flowering	Duration of reproductive phase	Days to maturity	Plant height	Branches per plant	pods per plant	seeds per pod	Pod length	100-seed weight	yield per plant
NIFPGr-17-64	52.33	60.67	101.67	57.57	2.93	20.33	5.33	5.17	11.50	4.22
GDF-1	51.00	59.00	99.33	***33.6***	***2.27***	27.33	4.07	5.90	16.10	5.61
NF-18-52 (Local)	53.33	60.67	102	**80.9**	4.40	***19.33***	3.93	5.47	17.17	***4.05***
NIFPVg-17-10	***49.33***	***55.67***	98.33	68.57	3.93	31.00	4.87	5.53	18.47	**6.30**
NIFPVg-17-12	55.67	64.33	104.33	72.28	4.00	29.67	4.60	3.87	12.17	6.05
NIFPGr-17-63	52.33	60.00	104.00	48.1	3.40	23.00	3.60	3.83	***10.00***	4.56
NIFPGr-17-64 × GDF-1	52.00	61.67	102.33	59.03	2.83	25.00	4.00	4.57	10.43	4.91
NIFPGr-17-64 × NF-18-52 (Local)	55.33	64.33	**105.67**	61.00	4.53	29.00	5.07	5.63	12.37	5.51
NIFPGr-17-64 × NIFPVg-17-10	***49.33***	56.67	***98.00***	62.03	3.73	23.67	5.27	5.13	12.30	4.78
NIFPGr-17-64 × NIFPVg-17-12	49.67	56.67	98.33	76.50	3.47	28.33	**6.13**	4.90	11.10	5.62
NIFPGr-17-64 × NIFPGr-17-63	**57.33**	66.00	106.33	50.97	2.83	27.67	3.60	4.27	11.67	5.41
GDF-1 × NF-18-52 (Local)	50.67	58.00	101.33	63.83	3.00	22.33	4.53	5.90	17.47	4.67
GDF-1 × NIFPVg-17-10	***49.33***	57.33	101.67	68.77	2.87	27.33	5.20	**6.17**	18.17	5.99
GDF-1 × NIFPVg-17-12	57.67	**67.33**	101.67	74.93	3.30	**34.67**	4.73	5.20	13.37	6.29
GDF-1 × NIFPGr-17-63	50.67	58.67	101.00	61.20	3.57	22.33	3.63	4.63	11.40	5.12
NF-18-52 (Local) × NIFPVg-17-10	56.00	65.67	103.67	68.10	2.85	22.67	3.60	5.67	**19.40**	4.47
NF-18-52 (Local) × NIFPVg-17-12	53.00	61.67	101.67	72.00	**7.20**	27.33	5.77	5.23	13.30	5.79
NF-18-52 (Local) × NIFPGr-17-63	53.00	60.67	101.00	76.20	5.17	23.00	4.13	4.80	14.13	5.42
NIFPVg-17-10 × NIFPVg-17-12	50.00	58.00	99.67	72.00	6.24	26.67	5.73	4.90	12.40	5.61
NIFPVg-17-10 × NIFPGr-17-63	52.67	61.33	103.00	65.80	4.67	26.67	4.07	4.87	14.10	5.34
NIFPVg-17-12 × NIFPGr-17-63	57.33	65.67	103.33	58.64	3.78	30.00	***3.40***	***3.73***	12.37	6.11
Mean	52.76	60.95	102.11	64.38	3.86	26.06	4.54	5.02	13.78	5.33
CV%	4.68	5.55	11.44	10.25	23.07	12.98	10.71	6.91	2.91	15.81
CD 5%	4.08	5.59	19.01	10.89	1.47	5.58	0.80	0.57	0.66	1.39

Bold figure indicate maximum and italic bold shows the minimum value

Table 2: Estimates of heterosis percentage over mid parent, better parent, and standard check for days to 50 per cent flowering, duration of reproductive phase and days to maturity for fieldpea.

Sr. No.	Characters	Days to 50 per cent flowering			Duration of reproductive phase			Days to maturity		
	Hybrids	MP	BP	SC	MP	BP	SC	MP	BP	SC
1.	NIFPGr-17-64 × GDF-1	0.65	1.96	1.96	3.06	1.65	4.53	1.82	3.02	3.02
2.	NIFPGr-17-64 × NF-18-52 (Local)	4.73	5.73	8.49*	6.04	6.04	9.03	3.76	3.93	6.38**
3.	NIFPGr-17-64 × NIFPVg-17-10	-2.95	0.00	-3.27	-2.58	-6.59	-3.95	-2.00	-0.34	-1.34
4.	NIFPGr-17-64 × NIFPVg-17-12	-8.02*	-5.10	-2.61	-9.33*	-11.92**	-3.95	-4.53*	-3.28	-1.01
5.	NIFPGr-17-64 × NIFPGr-17-63	9.55**	9.55*	12.41**	9.39*	8.79	11.86*	3.40	4.59*	7.05**
6.	GDF-1 × NF-18-52 (Local)	-2.88	-0.65	-0.65	-3.06	-4.40	-1.69	0.66	2.01	2.01
7.	GDF-1 × NIFPVg-17-10	-1.66	0.00	-3.27	0.00	-2.82	-2.83	2.87	3.39	2.36
8.	GDF-1 × NIFPVg-17-12	8.12*	13.07**	13.08**	9.19*	4.66	14.19**	5.73**	8.39**	8.40**
9.	GDF-1 × NIFPGr-17-63	-1.94	-0.65	-0.65	-1.40	-2.22	-0.56	-0.66	1.68	1.68
10.	NF-18-52 (Local) × NIFPVg-17-10	9.09*	13.51**	9.80*	12.89**	8.24	11.31*	3.49	5.42*	4.37
11.	NF-18-52 (Local) × NIFPVg-17-12	-2.75	-0.62	3.92	-1.33	-4.15	4.53	-1.45	-0.33	2.36
12.	NF-18-52 (Local) × NIFPGr-17-63	0.32	1.27	3.92	0.55	0.00	2.83	-1.94	-0.98	1.68
13.	NIFPVg-17-10 × NIFPVg-17-12	-4.76	1.35	-1.96	-3.33	-9.84*	-1.69	-1.64	1.36	-29.86**
14.	NIFPVg-17-10 × NIFPGr-17-63	3.61	6.76	3.27	6.05	2.22	3.95	1.81	4.75*	3.69
15.	NIFPVg-17-12 × NIFPGr-17-63	6.17	9.55*	12.41**	5.63	2.07	11.31*	-0.80	-0.64	4.03
16.	SEd	1.74	2.02	2.02	2.39	2.76	2.76	1.80	2.08	2.08
17.	CD 5%	3.75	4.33	4.33	5.14	5.93	5.93	3.87	4.47	4.47
18.	CD 1%	4.72	5.46	5.46	6.47	7.48	7.48	4.88	5.64	5.64

*,** Significant at 5%, and 1% respectively

Table 3: Estimates of heterosis per cent over mid parent, better parent, and standard check for plant height and branches per plant.

Sr. No.	Characters	Plant height			Branches per plant		
	Hybrids	MP	BP	SC	MP	BP	SC
1.	NIFPGr-17-64 × GDF-1	29.51**	75.69**	75.68**	8.97	-3.41	24.67
2.	NIFPGr-17-64 × NF-18-52 (Local)	-11.89	5.96	81.55**	23.64	3.03	99.56**
3.	NIFPGr-17-64 × NIFPVg-17-10	-1.64	7.76	84.61**	8.74	-5.08	64.32
4.	NIFPGr-17-64 × NIFPVg-17-12	17.89*	32.95**	127.68**	0.00	-13.33	52.86
5.	NIFPGr-17-64 × NIFPGr-17-63	-3.53	5.96	51.70**	-10.53	-16.67	24.67
6.	GDF-1 × NF-18-52 (Local)	11.50	89.98**	89.97**	-10.00	-31.82	32.16
7.	GDF-1 × NIFPVg-17-10	34.62**	104.66**	104.67**	-7.53	-27.12	26.43
8.	GDF-1 × NIFPVg-17-12	41.56**	123.02**	123.01**	5.32	-17.50	45.37
9.	GDF-1 × NIFPGr-17-63	49.82**	82.14**	82.14**	25.88	4.90	57.27
10.	NF-18-52 (Local) × NIFPVg-17-10	-8.88	-0.68	102.68**	-31.60	-35.23	25.55
11.	NF-18-52 (Local) × NIFPVg-17-12	-5.98	-0.37	114.29**	71.43**	63.64**	217.18**
12.	NF-18-52 (Local) × NIFPGr-17-63	18.14*	58.42**	126.79**	32.48	17.42	127.75**
13.	NIFPVg-17-10 × NIFPVg-17-12	2.25	5.01	114.29**	57.39**	56.08**	174.89**
14.	NIFPVg-17-10 × NIFPGr-17-63	12.80	36.80**	95.83**	27.27	18.64	105.73**
15.	NIFPVg-17-12 × NIFPGr-17-63	-2.52	21.97	74.52**	2.07	-5.58	66.52
16.	SEd	4.67	5.39	5.39	0.63	0.73	0.73
17.	CD 5%	10.01	11.56	11.56	1.35	1.56	1.56
18.	CD 1%	12.62	14.57	14.57	1.70	1.96	1.96

*,** Significant at 5%, and 1% respectively.

Table 4: Estimates of heterosis percentage over mid parent, better parent, and standard check for pods per plant, seeds per pod and pod length.

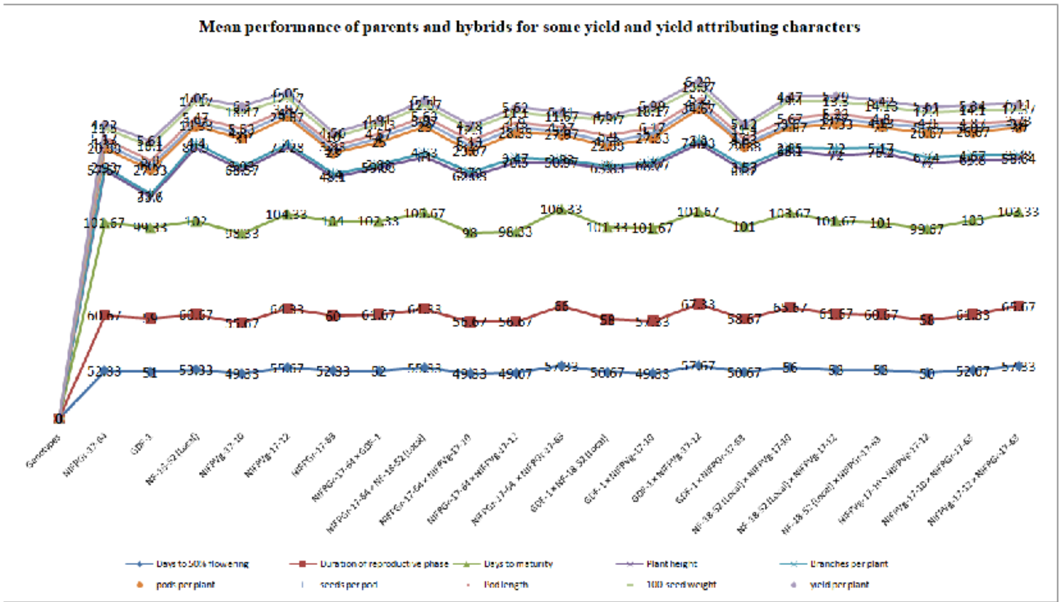
Sr. No.	Characters	Pods per plant			Seeds per pod			Pod length (cm)		
	Hybrids	MP	BP	SC	MP	BP	SC	MP	BP	SC
1.	NIFPGr-17-64 × GDF-1	4.90	-8.54	-8.53	-14.89	-25.0**	-1.72	-17.5**	-22.6**	-22.6**
2.	NIFPGr-17-64 × NF-18-52 (Local)	46**	43**	6.11	9.35	-5	24.57*	5.96	3.05	-4.52
3.	NIFPGr-17-64 × NIFPVg-17-10	-7.79	-24*	-13.39	3.27	-1.25	29.48**	-4.05	-7.23	-12.99**
4.	NIFPGr-17-64 × NIFPVg-17-12	13.33	-4.49	3.66	23.5**	15	50.61**	8.49	-5.16	-16.95**
5.	NIFPGr-17-64 × NIFPGr-17-63	27.69*	20.29	1.24	-19.40*	-32.5**	-11.55	-5.19	-17.4**	-27.67**
6.	GDF-1 × NF-18-52 (Local)	-4.29	-18.29	-18.29	13.33	11.48	11.30	3.81	0	0
7.	GDF-1 × NIFPVg-17-10	-6.29	-11.8	0.00	16.42	6.85	27.76**	7.87	4.52	4.52
8.	GDF-1 × NIFPVg-17-12	21.64*	16.85	26.86*	9.23	2.9	16.22	6.48	-11.86*	-11.86*
9.	GDF-1 × NIFPGr-17-63	-11.26	-18.3	-18.29	-5.22	-10.66	-10.81	-4.79	-21.5**	-21.47**
10.	NF-18-52 (Local) × NIFPVg-17-10	-9.93	-27**	-17.05	-18.2*	-26**	-11.55	3.03	2.41	-3.95
11.	NF-18-52 (Local) × NIFPVg-17-12	11.56	-7.87	0.00	35.2**	25.4**	41.77**	12.14*	-4.27	-11.30*
12.	NF-18-52 (Local) × NIFPGr-17-63	8.66	0	-15.84	9.73	5.08	1.47	3.23	-12.20*	-18.60**
13.	NIFPVg-17-10 × NIFPVg-17-12	-12.09	-13.98	-2.41	21.13**	17.81*	40.79**	4.26	-11.45*	-16.95**
14.	NIFPVg-17-10 × NIFPGr-17-63	-1.23	-13.98	-2.41	-3.94	-16.44	0.00	3.91	-12.05*	-17.51**
15.	NIFPVg-17-12 × NIFPGr-17-63	13.92	1.12	9.77	-17.07	-26.1**	-16.46	-3.03	-3.45	-36.72**
16.	SEd	2.39	2.76	2.76	0.34	0.40	0.40	0.25	0.28	0.28
17.	CD 5%	5.13	5.92	5.92	0.74	0.85	0.85	0.53	0.61	0.61
18.	CD 1%	6.47	7.47	7.47	0.93	1.07	1.07	0.66	0.77	0.77

*,** Significant at 5%, and 1% respectively

Table 5: Estimates of heterosis percentage over mid parent, better parent, and standard check for 100-seed weight and yield per plant.

Sr. No.	Characters	100- seed weight (gm)			Yield per plant (gm)		
	Hybrids	MP	BP	SC	MP	BP	SC
1.	NIFPGr-17-64 × GDF-1	-24.40**	-35.20**	-35.22**	-0.1	-12.53	-12.48
2.	NIFPGr-17-64 × NF-18-52 (Local)	-13.72**	-27.96**	-23.17**	33.4*	30.75	-1.78
3.	NIFPGr-17-64 × NIFPVg-17-10	-17.91**	-33.39**	-23.60**	-9.07	-24.09*	-14.80
4.	NIFPGr-17-64 × NIFPVg-17-12	-6.20**	-8.77**	-31.06**	9.42	-7.16	0.18
5.	NIFPGr-17-64 × NIFPGr-17-63	8.53**	1.45	-27.52**	23.23	18.55	-3.57
6.	GDF-1 × NF-18-52 (Local)	5.01**	1.75*	8.51**	-3.28	-16.75	-16.76
7.	GDF-1 × NIFPVg-17-10	5.11**	-1.62*	12.86**	0.64	-4.82	6.77
8.	GDF-1 × NIFPVg-17-12	-5.42**	-16.98**	-16.96**	7.86	3.97	12.12
9.	GDF-1 × NIFPGr-17-63	-12.64**	-29.19**	-29.20**	0.56	-8.85	-8.73
10.	NF-18-52 (Local) × NIFPVg-17-10	3.27**	-0.36	20.50**	-13.6	-29.0*	-20.32
11.	NF-18-52 (Local) × NIFPVg-17-12	-9.32**	-22.52**	-17.39**	14.72	-4.24	3.21
12.	NF-18-52 (Local) × NIFPGr-17-63	4.05**	-17.67**	-12.24**	25.93	18.85	-3.39
13.	NIFPVg-17-10 × NIFPVg-17-12	-19.04**	-32.85**	-22.99**	-9.18	-10.96	0.00
14.	NIFPVg-17-10 × NIFPGr-17-63	-0.94	-23.65**	-12.42**	-1.63	-15.17	-4.81
15.	NIFPVg-17-12 × NIFPGr-17-63	11.58**	1.64	-23.17**	15.2	1.05	8.91
16.	SEd	0.10	0.11	0.11	0.60	0.69	0.69
17.	CD 5%	0.21	0.24	0.24	1.28	1.47	1.47
18.	CD 1%	0.26	0.30	0.30	1.61	1.86	1.86

*,** Significant at 5%, and 1% respectively.



RESULT AND DISCUSSION

A large number of hybrids had significantly desired heterosis over the mid parent, better parent, and standard check for various characters under study. Negative heterosis is considered desirable for 50 per cent flowering, days to maturity, and plant height, while for the rest of the characters significant positive heterosis was considered desirable. The present study is an attempt to access the possibilities of commercial exploitation of heterosis and to develop better varieties and elite lines for further breeding programmes. The results in this direction are being discussed in the following ways. As regards heterosis over the mid parent, better parent and standard check a large number of crosses recorded significant in the desired direction for days to 50 per cent flowering (7, 4, and 6), duration to reproductive phase (9, 8, and 9), days to maturity (7, 5 and 3), plant height (6, 2 and 0), branches per plant (11, 6 and 15), pods per plant (8, 5 and 7), seeds per pod (9, 7 and 10), pod length (10, 4 and 2), 100-seed weight (6, 3 and 3) and yield per plant (9, 5 and 6).

For yield per plant (9, 5, and 6) crosses showed significant positive relative heterosis, heterobeltiosis, and standard heterosis respectively. The cross combination NIFPGr-17-64 × NF-18-52 (Local) exhibited the highest heterosis, heterobeltiosis, and cross GDF-1 × NIFVg-17-12 exhibited the highest heterosis over the standard check. The results are in agreement with the findings of Punia *et al.* (2011); Dagla *et al.* (2013); Sharma and Bora (2013); Yadav *et al.* (2015); Joshi *et al.* (2015); Brar *et al.* (2016); Dhyani (2016); Kumar *et al.* (2017); Hariom *et al.* (2017); Askander and Osman (2018); Tampha *et al.* (2018); Nagheswar *et al.* (2020); Zyada and Samar (2021).

With regards to days to 50 per cent flowering cross, NIFPGr-17-64 × NIFVg17-12 manifested numerically higher negative heterosis over the mid parent, better parent, and standard check for days to 50 per cent flowering. The results are akin to the findings of Dagla *et al.* (2013); Sharma and Bora (2013); Yadav *et al.* (2015); Joshi *et al.* (2015); Brar *et al.* (2016); Hariom *et al.* (2017); Tampha *et al.* (2018); Askander and Osman (2018); Galal *et al.* (2019); Kumar *et al.* (2019); Katoch *et al.* (2019); Nagheswar *et al.* (2020); and Kumar *et al.* (2021). The results for the duration to reproductive phase revealed that cross NF-18-52 (Local) × NIFVg17-10 had significant heterosis over the mid parent, cross NIFPGr-17-64 × NIFPGr-17-63 over the better parent and cross GDF-1 × NIFVg-17-12 over the standard check.

The results for days to maturity (7, 5, and 3) crosses expressed significant negative heterosis, heterobeltiosis, and standard check in the direction of early maturity. The cross NIFPGr-17-64 × NIFVg-17-12 had significant negative heterosis over mid-parent and better parent. The cross NIFVg-17-10 × NIFVg-17-12 was recorded with the highest negative heterosis over the standard check. The results are as per the findings of Dagla *et al.* (2013); Yadav *et al.* (2015); Kumar *et al.* (2017); Hariom *et al.* (2017); Tampha *et al.* (2018); Nagheswar *et al.* (2020).

With regards to plant height cross, NIFPGr-17-64 × NF-18-52 (Local) manifested numerically higher negative heterosis over mid parent and cross NF-18-52 (Local) × NIFVg-17-10 over better parent for plant height. The results are akin to the findings of Dagla *et al.* (2013); Kosev (2014); Yadav *et al.* (2015); Brar *et al.* (2016); Hariom *et al.* (2017); Tampha *et al.* (2018); Askander and Osman (2018); Galal *et al.* (2019); Kumar *et al.* (2019); Katoch *et al.* (2019); Nagheswar *et al.* (2020); Zyada and Samar (2021); Kumar *et al.* (2021).

Cross NF-18-52 (Local) × NIFVg-17-12 depicted the highest heterosis, heterobeltiosis, and standard heterosis, respectively for branches per plant. The results are in agreement with the findings of Ceyhan *et al.* (2008); Yadav *et al.* (2015); Hariom *et al.* (2017); Kumar *et al.* (2019); Nagheswar *et al.* (2020); Zyada and Samar (2021); Kumar *et al.* (2021).

The best performing cross for pods per plant was NIFPGr-17-64 × NF-18-52 (Local) over mid parent and better parent and cross GDF-1 × NIFVg-17-12 over the standard check. Significant positive pods per plant were also reported by Ceyhan *et al.* (2008); Dagla *et al.* (2013); Sharma and Bora (2013); Yadav *et al.* (2015); Joshi *et al.* (2015); Hariom *et al.* (2017); Kosev (2015); Brar *et al.* (2016); Tampha *et al.* (2018); Galal *et al.* (2019); Kumar *et al.* (2019); Katoch *et al.* (2019); Nagheswar *et al.* (2020); Zyada and Samar (2021); Kumar *et al.* (2021).

Concerning seeds per pod cross NF-18-52 (Local) × NIFVg-17-12 depicted the highest heterosis, heterobeltiosis, and cross NIFPGr-17-64 × NIFVg-17-12 showed the highest standard heterosis, respectively. The results are in agreement with the findings of Ceyhan *et al.* (2008); Dagla *et al.* (2013); Yadav *et al.* (2015); Joshi *et al.* (2015); Hariom *et al.* (2017); Kumar *et al.* (2017); Askander and Osman (2018); Tampha *et al.* (2018); Galal *et al.* (2019); Kumar *et al.* (2019); Katoch *et al.* (2019); Nagheswar *et al.* (2020); Zyada and Samar (2021); Kumar *et al.* (2021).

The best performing cross for pod length was NF-18-52 (Local) × NIFVg-1712 over mid parent and cross GDF-1 × NIFVg-17-10 over better parent and standard check. Significant positive pod length was also reported by Dagla *et al.* (2013); Kosev (2014); Yadav *et al.* (2015); Brar *et al.* (2016); Hariom *et al.* (2017); Kumar *et al.* (2017); Galal *et al.* (2019); Kumar *et al.* (2019); Katoch *et al.* (2019); Nagheswar *et al.* (2020); Zyada and Samar (2021); Kumar *et al.* (2021).

For 100-seed weight, the cross combination NIFVg-17-12 × NIFPGr-17-64 exhibited the highest heterosis over the mid parent, and cross GDF-1 × NF-18-52 (Local) exhibited the highest heterosis over better parent and standard check. The results are in agreement with the findings of Ceyhan *et al.* (2008); Dagla *et al.* (2013); Brar *et al.* (2016); Kumar *et al.* (2017); Hariom *et al.* (2017); Tampha *et al.* (2018); Galal *et al.* (2019); Nagheswar *et al.* (2020); Zyada and Samar (2021).

The top five cross combinations for yield per plant were GDF-1 × NIFPVg-17-12, NIFPVg-1712 × NIFPGr-17-63, GDF-1 × NIFPVg-17-10, NF-18-52(Local) × NIFPGr17-12, and NIFPGr-17-64 × NIFPVg-17-12 respectively. None of the crosses were found significantly superior to the standard check but gave a superior yield than the standard check. The crosses between average × good parent and average × average parent gave superior combinations may be due to the combining of superior genes. But the cross between poor × good parents gave a superior combination maybe because of the dominance effect of the good parent genes. The cross GDF-1 × NIFPVg-17-12 was also found significant for days to 50 per cent flowering, duration of reproductive phase, days to maturity, pods per plant over the mid parent, and standard check. Cross NIFPVg-17-12 × NIFPGr-17-63 was also found significant for days to 50 per cent flowering, duration of reproductive phase, and plant height over mid parent and standard check. Cross GDF-1 × NIFPVg-17-10 was found significant for plant height and 100-seed weight over mid parent and standard check.

CONCLUSION

In the case of heterosis over the mid-parent, significant positive heterosis was observed for all the characters under observation. Over better parents, the cross NF-18-52 (Local) × NIFPVg-17-12 and NIFPVg-1710× NIFPVg-17-12 showed significant desirable heterotic cross combination for branches per plant and seeds per pod, and cross NIFPGr-17-64 × NF-18-52 (Local) for pods per plant. In the case of standard heterosis, the cross NF-18-52 (Local) × NIFPVg-17-12 showed a significantly desirable heterotic combination for seeds per pod and branches per plant. Cross NIFPVg-17-10 × NIFPVg-17-12 found significant heterotic for days to maturity and branches per plant. Cross NIFPGr-17-64 × NIFPVg-17-12 found significant heterotic over the standard check for plant height and seeds per pod and GDF-1×NIFPVg-17-10 for 100-seed weight. These crosses can be utilized for higher biomass and yield. For further improvement going for population improvement methods, such as biparental and diallel selective mating would be the most desirable breeding approach.

Conflict of interest. None.

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