Forage Res., **41** (3) : pp. 152-159 (2015) **http://forageresearch.in**

HETEROTIC RESPONSES IN YIELD COMPONENT TRAITS IN FABABEAN (*VICIA FABA* L.)

S. K. BISHNOI[1,]*, J. S. HOODA AND PREETI SHARMA

Department of Genetics & Plant Breeding
CCS Haryana Agricultural University,
Hisar-125 004 (Haryana), India
**(e-mail : skbishnoi.ars@gmail.com)*

(Received : 10 October 2015; Accepted : 30 November 2015)

SUMMARY

The present investigation was carried out during the year 2013-14 at CCS Haryana Agricultural University, Hisar with the objective to estimate heterotic responses in yield component traits in 48 hybrid combinations constituted by 16 fababean genotypes of diverse origins across the world. The experiment was laid out in randomized complete block design with three replications and observations were made on 10 randomly selected plants for 10 yield component traits. Significant positive as well as negative heterosis was observed for plant height, number of branches per plant, number of pods per plant, number of pod clusters per plant, pod length, seeds per pod, 100-seed weight and seed yield per plant. However, only negative significant heterosis was observed for number of days to 50 per cent flowering and number of days to maturity. The mean performance of the parents and their respective crosses has also been presented in the paper along with per cent heterosis for individual cross. Character-wise better performing and poor performing crosses have also been given. The present study is supposed to help select parents to produce overall better performing and thus better yielding hybrid combinations. Moreover, further evaluation of the better performing crosses in the present study may help improve yield in fababean along with an insight to help understand the way heterotic combinations behave in this crop.

Key words : *Vicia faba*, fababean, heterosis, yield component traits

Fababean (Fabaceae) is one of the oldest crops grown by man and used as a source of protein in human diets, as fodder and forage crop for animals and for available nitrogen in the soil (Maalouf, 2011). It is one of the most efficient atmospheric nitrogen fixers contributing to soil nitrogen content improvement and an alternative good source of protein for humans in developing countries and for animals in industrialized countries (Zeinab and Helal, 2014). The protein content in fababean depends upon the genotype and ranges from 27 to 34 per cent (Alghamdi, 2009) making it the second most important crop next only to soybean in terms of protein content. Because of this, fababean is gaining importance as a grain legume for protein security of demographically expanding and climatically changing world (Bishnoi *et al.*, 2012).

Despite the huge importance of fababean as a protein source for humans and animals in ensuring food and nutritional security in context of global population increase and global climate change, its full potential through hybrid breeding remains unexploited largely due to its unique pollination biology and yield instability.

Fababean is a partially allogamous crop. The per cent mean cross pollination in this crop has been reported to range from 32 and 40 per cent. The rate of outcrossing depends on the genotype, environmental factors, row space and the number of pollinating insects, especially honeybees (Berthelem *et al.*, 1991; Rashid and Bernier, 1994; Bishnoi *et al.*, 2012). The increased yield caused by heterozygosity due to outcrossing has been well documented in fababean. Cross pollination in faba bean has been associated with increased seed yields and accelerated growth. The honey bee mediated cross pollination accelerates the rate of set of faba bean pods and has been reported to result in significantly greater seed yields than self-fertilization (Musallam *et al.*, 2004). A yield increase of 49 and 19-52 per cent under cross pollinated conditions over self-pollinated conditions has

[1]The present study is the part of the Ph. D. work of the first author.

been reported by Musallam *et al.* (2004) and Somerville (2002), respectively.

Thus, heterosis, resulting from the combined action and interaction of allelic and interallelic genes is effective in fababean and improved yield can be obtained by hybrid combinations. The heterotic effects in *Vicia faba* may range from significantly positive to significantly negative for different traits depending on the genetic makeup of the parents. Superiority of hybrids over the better parent for seed yield and its attributes are associated with the magnitude of heterotic effects in important yield component traits viz., number of branches per plant, pod setting percentage, number of pods per plant, 100-seed weight, shellout percentage and pod filling percentage (Bishnoi *et al.*, 2012, Zeinab and Helal, 2014; Abdalla *et al.*, 2015; Saad *et al.*, 2015).

Hence, estimate of heterosis, which is expressed as increase in vigour of the F_1 hybrids over the mid-parents or the better parents in various yield component traits, provides important information for improving seed yield and other economic traits in fababean. The present study was carried out with the objective to estimate heterosis in 10 seed yield component traits in 48 F_1 hybrid crosses involving 16 genotypes originating from diverse geographic locations across the world.

MATERIALS AND METHODS

This trial was carried out at the research farm of the CCS Haryana Agricultural University, Hisar. A total of 16 genotypes were used in the study in which four genotypes used as female were crossed to 12 pollinator genotypes used as male parents to produce a total of 48 hybrid crosses in a randomized complete block design with three replications. Out of the total 16 genotypes, 10 genotypes were indigenous, five genotypes were exotic and were procured from the National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi and one genotype was the variety Vikrant released by CCS Haryana Agricultural University, Hisar. The genotypes HB 85, HB 86, HB (M)-1 and Vikrant were used as female parents and were crossed to HB-8, HB 14, HB 23, HB 36, HB 43, HB 46, HB 49, EC 117705, EC 247640, EC 321682, EC 591864 and EC 628938. The recommended package of practices for fababean cultivation in the area of study was followed. For estimation of heterosis over better parent, observations were recorded on 10 randomly selected plants for 10 characters viz., days to 50 per cent flowering, days to maturity, plant height (cm), number of branches per plant, number of pods per plant, number of pod clusters per plant, pod length (cm), seeds per pod, 100-seed weight (g) and seed yield per plant (g). The mean values of parents and F_1 were used to calculate per cent heterosis over better parent and the least significant difference was estimated for heterosis over better parent and also for mean performance of the hybrid combinations and parental genotypes as well was calculated based on the standard error for difference between F_1 and better parent. Based on the statistical analysis of the data, conclusions and inferences were drawn about the heterotic responses in yield component traits.

RESULTS AND DISCUSSION

The mean performance of the 16 parental genotypes along with their F_1 hybrids is presented in Table 1. Among the parental genotypes the genotype HB 85 (mean number of days=55.00) was earliest to flower, while the genotype EC 628938 (mean number of days=73.42) was the latest to flower. Among hybrids, the cross HB 86 x HB 49 (mean number of days=48.33) was earliest to flower, while HB-(M)-1 x EC 628938 (mean number of days=71.00) was the latest one. Similarly, among parents, HB 14 (143.92) and Vikrant (178.64) were earliest and latest to mature, while the crosses HB 86 x EC 591864 (140.33) and Vikrant x HB 23 (181.33) were earliest and latest to mature with the mean number of days in parenthesis. The genotype HB-(M)-1 (106.81 cm) had maximum average plant height and EC 591864 (43.00 cm) had the minimum. Among the crosses, HB-(M)-1 x HB 49 (152.78 cm) and HB-(M)-1 x HB 49 (152.78 cm) had tallest and shortest plants, respectively. The genotypes HB 43 (5.05) and EC 628938 (2.71) ranked first and last respectively, in number of branches per plant and the first and last ranking respective crosses were HB 85 x HB 43 (9.26) and Vikrant x HB 46 (2.52). The trait number of pod clusters per plant showed a wide range among parents and crosses with HB 43 (22.86) and EC 247640 (10.09) at maximum and minimum limits among parental genotypes and HB 85 x HB 43 (41.01) and Vikrant x HB 46 (12.76) among the crosses. The character pod length displayed a narrow range of variability with EC 628938 (6.68 cm) and EC 247640 (4.86 cm) at maximum and minimum limits among the parents, respectively, and

TABLE 1
Mean performance of parents and their hybrids for all studied characters

Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pod clusters/ plant	Pod length (cm)	No. of pods/ plant	No. of seeds/ pod	100-seed weight (g)	Seed yield/ plant (g)
HB 85	55.00	159.19	100.51	4.09	18.07	5.08	41.55	3.16	30.24	43.93
HB 86	59.39	165.32	91.81	3.87	16.26	5.68	38.08	3.81	27.05	39.79
HB (M)-1	71.33	177.97	106.81	3.97	16.75	5.92	37.88	3.87	29.48	42.60
Vikrant	65.69	178.64	94.20	3.36	14.84	5.12	33.78	3.00	27.34	28.42
HB 8	63.75	163.92	101.68	3.49	16.31	5.41	38.65	3.04	26.36	32.60
HB 14	58.58	143.92	87.89	3.27	14.06	5.89	30.70	3.13	30.87	30.05
HB 23	64.00	153.08	92.86	3.19	13.88	5.37	30.09	3.07	27.87	26.32
HB 36	60.92	157.08	83.44	3.83	16.76	6.02	36.75	3.00	26.66	29.56
HB 43	65.17	164.58	84.91	5.05	22.86	4.91	48.43	3.00	28.15	43.17
HB 46	65.50	157.83	78.15	3.41	14.80	5.51	34.47	3.00	26.88	28.97
HB 49	55.83	145.75	63.82	4.45	20.70	5.28	46.18	3.00	27.25	37.98
EC 117705	65.75	155.83	83.42	4.62	20.01	4.94	42.84	3.02	28.96	42.07
EC 321682	70.50	158.25	68.04	3.63	14.58	5.02	32.78	3.00	24.68	23.86
EC 247640	71.50	159.33	57.92	3.07	10.09	4.86	22.92	3.01	31.59	21.47
EC 628938	73.42	162.08	54.92	2.71	11.79	6.68	26.36	3.02	25.90	21.83
EC 591864	59.83	151.25	43.00	4.04	15.94	5.88	33.84	3.00	31.00	31.26
F_1 (HB 85 x HB8)	62.00	160.33	122.19	5.90	27.87	5.49	60.34	3.31	30.42	61.74
F_1 (HB 85 x HB14)	57.00	152.00	107.07	5.80	25.42	5.52	54.35	3.04	31.36	53.17
F_1 (HB 85 x HB23)	53.33	150.33	106.33	4.67	23.26	5.70	48.41	3.10	29.12	44.66
F_1 (HB 85 x HB36)	57.67	150.33	103.83	5.41	23.43	5.74	49.46	3.07	30.61	48.12
F_1 (HB 85 x HB43)	51.33	155.00	108.79	9.26	41.01	5.65	86.63	3.24	30.61	89.27
F_1 (HB 85 x HB46)	56.00	148.67	93.96	4.04	17.23	5.55	36.56	3.12	30.66	34.77
F_1 (HB 85 x HB49)	51.67	146.67	110.79	5.29	22.66	5.60	48.51	3.20	30.12	46.25
F_1 (HB 85 x EC117705)	52.00	149.00	113.65	7.59	33.02	5.75	70.91	3.24	30.67	72.79
F_1 (HB 85 x EC 321682)	61.33	149.33	93.48	5.08	21.07	5.21	45.51	3.17	33.81	51.21
F_1 (HB 85 x EC 247640)	65.00	163.00	110.43	5.95	24.74	5.57	51.03	3.29	32.43	53.91
F_1 (HB 85 x EC 628938)	62.33	158.67	123.73	5.39	22.75	6.49	48.61	3.11	29.75	45.72
F_1 (HB 85 x EC591864)	51.33	146.00	97.77	6.08	26.22	5.62	56.12	3.30	30.77	57.52
F_1 (HB 86 x HB 8)	51.67	151.00	122.46	6.84	29.10	6.24	60.83	3.42	30.07	64.87
F_1 (HB 86 x HB 14)	58.00	150.33	96.90	4.86	17.96	5.61	39.62	3.66	30.15	43.36
F_1 (HB 86 x HB 23)	66.33	164.33	104.01	3.89	15.64	5.43	33.55	3.81	32.45	40.27
F_1 (HB 86 x HB 36)	54.00	144.67	95.18	4.24	15.78	6.19	33.36	3.70	29.18	35.13
F_1 (HB 86 x HB 43)	60.33	154.33	108.21	4.50	15.03	5.62	32.56	3.82	30.09	37.21
F_1 (HB 86 x HB 46)	60.67	160.33	93.24	4.69	18.48	6.03	38.39	3.71	32.54	46.14
F_1 (HB 86 x HB 49)	48.33	145.33	118.12	4.47	17.75	5.84	39.91	3.70	27.47	40.11
F_1 (HB 86 x EC 117705)	51.33	150.00	115.33	6.65	29.36	5.72	60.68	3.56	31.53	70.30
F_1 (HB 86 x EC 321682)	62.67	155.67	132.77	4.05	16.88	5.59	37.60	3.67	30.12	39.11
F_1 (HB 86 x EC 247640)	63.33	153.33	93.90	4.64	17.81	5.42	38.28	3.38	32.44	40.34
F_1 (HB 86 x EC 628938)	65.33	159.33	107.89	4.28	17.42	6.79	36.79	3.55	25.88	33.01
F_1 (HB 86 x EC 591864)	50.33	140.33	83.79	3.95	16.25	6.19	35.20	3.75	33.01	42.42
F_1 (HB (M)-1 x HB 8)	61.33	151.67	123.72	4.86	19.82	6.36	42.93	4.00	30.94	52.04
F_1 (HB (M)-1 x HB 14)	53.67	141.33	110.76	3.74	13.59	6.53	29.15	3.97	33.00	37.54
F_1 (HB (M)-1 x HB 23)	69.00	162.00	121.19	4.19	17.22	6.04	36.81	3.74	33.16	45.45
F_1 (HB (M)-1 x HB 36)	68.67	178.67	139.87	6.41	28.40	6.61	61.94	3.83	27.22	65.15
F_1 (HB (M)-1 x HB 43)	59.00	153.67	115.47	6.42	29.41	6.01	60.15	3.59	30.38	68.06

Contd.

Table 1 contd.

F_1 (HB (M)-1 x HB 46)	60.00	160.00	91.57	5.74	25.69	5.68	54.65	3.81	31.71	64.36
F_1 (HB (M)-1 x HB 49)	55.67	143.67	152.78	6.85	30.20	5.83	65.59	4.00	32.28	83.14
F_1 (HB (M)-1 x EC 117705)	62.33	149.33	133.39	8.54	40.07	6.66	82.74	3.29	32.33	92.25
F_1 (HB (M)-1 x EC 321682)	71.00	160.00	97.43	4.73	18.25	5.99	39.66	3.80	29.33	43.66
F_1 (HB (M)-1 x EC 247640)	66.33	160.67	87.69	4.20	15.15	5.79	33.82	3.70	32.03	35.54
F_1 (HB (M)-1 x EC 628938)	54.33	151.33	97.62	4.28	16.40	6.40	36.06	3.68	27.20	35.79
F_1 (HB (M)-1 x EC 591864)	60.33	149.33	108.68	5.70	23.68	6.25	50.45	3.36	32.20	53.63
F_1 (Vikrant x HB 8)	67.67	166.33	104.13	4.03	15.57	5.38	31.91	3.00	28.86	27.89
F_1 (Vikrant x HB 14)	61.67	150.00	105.98	4.85	17.95	5.98	37.91	3.14	31.00	37.30
F_1 (Vikrant x HB 23)	62.00	181.33	94.76	3.62	13.85	5.95	30.14	3.29	30.47	30.03
F_1 (Vikrant x HB 36)	57.00	144.33	123.60	4.93	20.03	6.52	41.67	3.29	30.56	41.07
F_1 (Vikrant x HB 43)	53.67	144.00	123.68	7.26	29.60	5.77	64.03	3.37	30.90	69.06
F_1 (Vikrant x HB 46)	60.00	157.67	103.76	2.52	12.76	5.76	26.99	3.00	29.52	23.70
F_1 (Vikrant x HB 49)	65.67	169.33	113.81	7.37	31.32	5.53	68.94	3.25	30.84	64.89
F_1 (Vikrant x EC 117705)	60.67	143.67	146.93	7.54	33.77	5.55	73.52	3.09	32.88	80.06
F_1 (Vikrant x EC 321682)	67.67	170.00	98.63	4.25	17.82	5.65	40.00	3.00	27.03	32.52
F_1 (Vikrant x EC 247640)	66.33	158.33	113.02	3.48	16.12	5.25	36.37	3.00	32.44	35.26
F_1 (Vikrant x EC 628938)	60.33	148.33	114.56	7.48	32.51	6.26	68.92	3.30	33.44	80.52
F_1 (Vikrant x EC 591864)	58.33	154.00	95.91	5.15	20.00	5.88	44.02	3.29	30.24	44.04
Mean	60.66	155.65	102.75	4.93	20.83	5.78	44.95	3.36	30.09	46.22
Range	48.33-73.42	140.33-181.33	43.00-152.78	2.5-9.26	10.09-41.01	4.86-6.79	22.92-86.63	3.00-4.00	24.68-33.81	21.47-92.25
LSD	2.89	4.79	10.25	0.71	3.67	0.35	7.58	0.23	1.48	7.57
CV (%)	2.95	1.90	6.17	8.89	10.88	3.72	10.42	4.28	3.05	10.13

HB 86 x EC 628938 (6.79 cm) and HB 85 x EC 321682 (5.21 cm) among the crosses. The parental genotype HB 43 (48.43) had maximum number of pods per plant, while EC 247640 (22.92) had the minimum average for the same trait. Among the crosses for the same character HB 85 x HB 43 (86.63) and Vikrant x HB 46 (26.99) exhibited maximum and minimum average number of pods per plant, respectively. The number of seeds per pod remained the least variable trait in the present study with HB-(M)-1 (3.87) at its maximum limit and four genotypes Vikrant, HB-36, HB 46 and HB 49 each with an average of three seeds per pod at its minimum limit. The crosses HB-(M)-1 x HB 8 and HB-(M)-1 x HB 49 with an average of four seeds per pod and four crosses Vikrant x HB 8, Vikrant x HB 46, Vikrant x EC 247640 and Vikrant x EC-321682 with an average of three seeds per pod, respectively, constituted the maximum and minimum average number of seeds per pod. On the contrary, the trait 100-seed weight ranged widely among the parental genotypes with the parents EC 247640 (31.59 g) and EC 321682 (24.68 g) displaying maximum and minimum of the range. The crosses HB 85 x EC 321682 (33.81 g) and HB-86 x EC-628938 (25.88 g) exhibited maximum and minimum heterosis for the trait 100-seed weight. The maximum yield per plant or best yielder parental genotype was HB 85 (43.93 g), while the least yielder parental genotype was EC 247640 (21.47 g). The maximum heterotic response for the trait seed yield per plant was exhibited by the cross combination HB (M)-1 x EC 117705 (92.25 g), while the minimum heterosis was reflected by the cross combination Vikrant x HB 46 (23.70 g) with the average seed yield in grams in the parentheses.

The percentage of heterosis relative to the better parent for yield and its component traits is presented in Table 2. The per cent heterosis over better parent for days to 50 per cent flowering ranged from -25.99 to 3.65 per cent with an average of -11.37 and critical difference of 2.89 and 3.83 at 5 and 1 per cent significance levels, respectively. Out of the total 48 crosses, 37 crosses exhibited significant negative heterosis over better parent which is desirable heterosis in fababean and none of the crosses exhibited significant positive heterosis for days to 50 per cent flowering. The crosses HB-(M)-1 x EC 628938 (-25.99), HB-(M)-1 x HB 14 (-24.77), HB-(M)-1 x HB 49 (-21.96), HB-86 x EC 117705 (-21.93) and HB 85 x HB 43 (-21.23) exhibited maximum desirable heterosis with per cent significant negative heterosis in parentheses. The cross HB 86 x HB23 (3.65) was the latest to flower.

The negative heterosis is also desirable in the trait days to maturity and 42 crosses out of the total 48 exhibited significant negative heterosis which ranged from -20.59 to 2.30 per cent with an average of -8.60 and critical difference of 4.9 and 6.49 at 5 and 1 per cent significance levels respectively. The crosses HB-(M)-1 x HB 14 (-20.59), Vikrant x EC 117705 (-19.58), Vikrant x HB 43 (-19.39), HB-(M)-1 x HB 49 (-19.28) and Vikrant x HB 36 (-19.20) were the earliest to mature and the cross HB 85 x EC 247640 matured most late among all.

Plant height is an important yield component trait as with plant height increases the number of poded nodes and therefore increases the number of pods which contributes positively towards yield enhancement in faba- bean. The per cent heterosis over better parent for plant height ranged from -17.91 to 55.97 with an average of 9.86 and critical difference of 10.70 and 14.18 at 5 and 1 per cent significance levels, respectively. Twenty-two of the crosses exhibited significant positive heterosis over the taller parent and two of the crosses viz., HB-(M)-1 x HB 46 and HB-(M)-1 x EC 247640 exhibited significant negative heterosis for plant height. The F_1 hybrids produced from the cross combinations Vikrant x EC 117705 (55.97), HB 86 x EC 321682 (44.61), HB-(M)-1 x HB 49 (43.04), Vikrant x HB 43 (31.29) and Vikrant x HB 36 (31.20) were tallest and those produced from the cross HB-(M)-1 x HB 46 (-14.27) were found to be the shortest ones.

Positive heterosis over better parent is highly desirable in the trait number of branches per plant and in the present study it ranged from -10.95 to 122.40 with an average of 36.14 and critical difference of 0.76 and 1.01 at 5 and 1 per cent significance levels, respectively. Thirty cross combinations expressed significant positive heterosis over better parent and one cross combination viz., Vikrant x HB 46 (-26.20) exhibited significant negative heterosis for plant height. The following crosses viz., Vikrant x EC 628938 (122.40), HB-(M)-1 x EC 117705 (85.05), HB 85 x HB 43 (83.18), HB 86 x HB 8 (76.81) and Vikrant x HB 49 (65.82) with the per cent heterosis in parentheses in decreasing order showed maximum positive heterosis over better parent for the trait number of branches per plant. The per cent heterosis over better parent for the trait number of pod clusters per plant ranged from -34.27 to 119.00 with an average of 31.88 and critical difference of 4.02 and 5.33 at 5 and 1 per cent significance levels, respectively. Out of the total 48 crosses, 22 crosses exhibited significant positive heterosis over better parent and one of the crosses viz., HB 86 x HB 43 (-34.27%) exhibited significant negative heterosis for number of pod clusters per plant. In the cross combinations, Vikrant x EC 628938 (119.00%), HB-(M)-1 x EC-117705 (100.20%), HB 85 x HB 43 (79.38%), HB 86 x HB 8 (78.42%) and HB-(M)-1 x HB 36 (69.45%) maximum pods were born in the form of clusters containing more than one pod.

In the present study, the trait pod length was included and observed as a yield component trait, positive heterosis in which might positively affect the overall seed yield. Eleven crosses out of the total 48 showed significant positive heterosis over better parent and one of the crosses HB 85 x HB 14 (-6.23%) exhibited significant negative heterosis for this trait. The per cent heterosis over better parent ranged from -6.29 to 13.33 with an average of 3.36 and critical difference of 0.35 and 0.46 at 5 and 1 per cent significance levels, respectively. The crosses HB 85 x EC 117705 (13.33%), Vikrant x HB 43 (12.62%), HB-(M)-1 x EC 117705 (12.56%) and HB 85 x HB 43 (11.29%) and Vikrant x HB 23 (10.93%) yielded F_1 hybrids bearing longest pods. Overall seed yield in fababean is directly dependent on the number of pods per plant for which heterosis over better parent was estimated to range from -32.76 to 104.05 with an average of 25.17 and critical difference of 7.85 and 10.40 at 5 and 1 per cent significance levels, respectively. Out of the total 48 crosses, 20 crosses exhibited significant positive heterosis over better parent and two of the crosses HB 86 x HB 43 (-32.76%) and HB-(M)-1 x HB-14 (-23.04%) exhibited significant negative heterosis for number of pods per plant. The crosses Vikrant x EC 628938 (104.05%), HB-(M)-1 x EC 117705 (93.15%), HB-85 x HB 43 (78.87%), Vikrant x EC-117705 (71.63%) and HB 85 x EC 117705 (65.53%) performed better than all other crosses.

The per cent heterosis over better parent for number of seeds per pod ranged from -14.99 to 12.22 with an average of 0.63 and critical difference of 0.23 and 0.30 at 5 and 1 per cent significance levels, respectively. Out of the total 48 crosses, only five crosses viz., Vikrant x HB 43 (12.22%), Vikrant x HB 36 (9.67%), Vikrant x EC 591864 (9.67%), Vikrant x EC 628938 (9.16%) and Vikrant x HB 49 (8.44%) exhibited significant positive heterosis over better parent and seven of the crosses viz., HB 86 x EC 117705 (-6.73%), HB-86 x EC 628938 (-6.91%), HB-(M)-1 x HB 43 (-7.32%),

TABLE 2
Significant and non-significant per cent heterosis over better parent in all the 48 hybrids

S. No.	Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pod clusters/ plant	Pod length (cm)	No. of pods/ plant	No. of seeds/ pod	100-seed weight (g)	Seed yield/ plant (g)
1.	HB 85 x HB 8	-2.75	-2.19	20.17**	44.17**	54.25**	1.48	45.20**	4.85	0.6	40.55**
2.	HB 85 x HB 14	-2.7	-4.52**	6.53	41.81**	40.69**	-6.23*	30.80**	-3.9	1.6	21.05*
3.	HB 85 x HB 23	-16.67**	-5.57**	5.79	14.1	28.74*	6.15	16.51	-1.79	-3.7	1.66
4.	HB 85 x HB 36	-5.34*	-5.57**	3.31	32.27**	29.64**	-4.76	19.04*	-2.85	1.22	9.55
5.	HB 85 x HB 43	-21.23**	-5.82**	8.24	83.18**	79.38**	11.29**	78.87**	2.64	1.21	103.23**
6.	HB 85 x HB 46	-14.50**	-6.61**	-6.51	-1.22	-4.67	0.85	-12.01	-1.37	1.39	-20.84*
7.	HB 85 x HB 49	-7.46**	-7.87**	10.23	19.04*	9.45	5.99	5.05	1.16	-0.41	5.29
8.	HB 85 x EC 117705	-20.91**	-6.40**	13.08*	64.40**	64.97**	13.33**	65.53**	2.64	1.41	65.71**
9.	HB 85 x EC 321682	-13.00**	-6.19**	-6.99	24.21*	16.58	2.63	9.53	0.32	11.82**	16.59
10.	HB 85 x EC 247640	-9.09**	2.3	9.87	45.48**	36.93**	9.65**	22.80*	4.01	2.67	22.73*
11.	HB 85 x EC 628938	-15.10**	-2.11	23.11**	31.87**	25.88**	-2.75	16.97	-1.58	-1.61	4.09
12.	HB 85 x EC 591864	-14.21**	-7.29**	-2.72	48.74**	45.08**	-4.48	35.05**	4.43	-0.73	30.95**
13.	HB 86 x HB 8	-18.95**	-2.19	20.17**	44.17**	54.25**	1.48	45.20**	4.85	0.6	40.55**
14.	HB 86 x HB 14	-2.33	-4.52**	6.53	41.81**	40.69**	-6.23*	30.80**	-3.9	1.6	21.05*
15.	HB 86 x HB 23	3.65	-5.57**	5.79	14.1	28.74*	6.15	16.51	-1.79	-3.7	1.66
16.	HB 86 x HB 36	-11.35**	-5.57**	3.31	32.27**	29.64**	-4.76	19.04*	-2.85	1.22	9.55
17.	HB 86 x HB 43	-7.42**	-5.82**	8.24	83.18**	79.38**	11.29**	78.87**	2.64	1.21	103.23**
18.	HB 86 x HB 46	-7.38**	-6.61**	-6.51	-1.22	-4.67	0.85	-12.01	-1.37	1.39	-20.84*
19.	HB 86 x HB 49	-18.61**	-7.87**	10.23	19.04*	9.45	5.99	5.05	1.16	-0.41	5.29
20.	HB 86 x EC 117705	-21.93**	-6.40**	13.08*	64.40**	64.97**	13.33**	65.53**	2.64	1.41	65.71**
21.	HB 86 x EC 321682	-11.11**	-6.19**	-6.99	24.21*	16.58	2.63	9.53	0.32	11.82**	16.59
22.	HB 86 x EC 247640	-11.42**	2.3	9.87	45.48**	36.93**	9.65**	22.80*	4.01	2.67	22.73*
23.	HB 86 x EC 628938	-11.01**	-2.11	23.11**	31.87**	25.88**	-2.75	16.97	-1.58	-1.61	4.09
24.	HB 86 x EC 591864	-15.88**	-7.29**	-2.72	48.74**	45.08**	-4.48	35.05**	4.43	-0.73	30.95**
25.	HB (M)-1 x HB 8	-14.02**	-14.78**	15.83**	22.50*	18.35	7.38*	-11.07	3.36	4.93	22.17*
26.	HB (M)-1 x HB 14	-24.77**	-20.59**	3.69	-5.88	-18.87	10.25**	-23.04*	2.58	6.89**	-11.89
27.	HB (M)-1 x HB 23	-3.27	-8.98**	13.46**	63**	2.83	2.08	-2.83	-3.36	12.46**	6.68
28.	HB (M)-1 x HB 36	-3.74	0.39	30.95**	61.46**	69.45**	9.80**	63.53**	-1.12	-7.69**	52.94**
29.	HB (M)-1 x HB 43	-17.29**	-13.66**	8.11	26.98**	28.64**	1.58	24.21**	-7.32*	3.04	57.66**
30.	HB (M)-1 x HB 46	-15.89**	-10.10**	-14.27**	44.58**	53.37**	-4	44.26**	-1.64	7.55**	51.08**
31.	HB (M)-1 x HB 49	-21.96**	-19.28**	43.04**	54.05**	45.88**	-1.58	42.02**	3.36	9.50**	95.16**
32.	HB (M)-1 x EC 117705	-12.62**	-16.09**	24.88**	85.05**	100.20**	12.56**	93.15**	-14.99**	9.64**	116.55**
33.	HB (M)-1 x EC 321682	-0.47	-10.10**	-8.78	19.14	8.98	1.13	4.7	-1.89	-0.51	2.5
34.	HB (M)-1 x EC 247640	-7.23**	-9.72**	-17.91**	5.88	-9.53	-2.25	-10.71	-4.39	1.41	-16.58
35.	HB (M)-1 x EC 628938	-25.99**	-14.97**	-8.61	7.72	-2.07	-4.14	-4.8	-4.91	-7.76**	-15.99
36.	HB (M)-1 x EC 591864	-15.42**	-16.09**	1.75	41.21**	41.35**	5.57	33.18**	-13.26**	3.87	25.90**
37.	Vikrant x HB 8	3	-6.89**	2.42	15.46	-4.54	-0.62	-17.45	-1.32	5.58*	-14.45
38.	Vikrant x HB 14	-6.13**	-16.03**	12.50*	44.20**	20.95	1.53	12.24	0.21	0.42	24.1
39.	Vikrant x HB 23	-5.62*	1.51	0.59	7.63	-6.67	10.93**	-10.78	7.05	9.32**	5.69
40.	Vikrant x HB 36	-13.23**	-19.20**	31.20**	28.61**	19.51	8.30**	13.37	9.67*	11.78**	38.91**
41.	Vikrant x HB 43	-18.31**	-19.39**	31.29**	43.73**	29.50**	12.62**	32.22**	12.22**	9.77**	59.96**
42.	Vikrant x HB 46	-8.67**	-11.74**	10.14	-26.20*	-14.01	4.6	-21.68	0	7.99**	-18.17
43.	Vikrant x HB 49	-0.04	-5.21**	20.81**	65.82**	51.32**	4.73	49.27**	8.44*	12.83**	70.88**
44.	Vikrant x EC 117705	-7.73**	-19.58**	55.97**	63.39**	68.75**	8.26*	71.63**	2.09	13.55**	90.29**
45.	Vikrant x EC 321682	-4.02	-4.84**	4.7	17.28	20.05	10.28**	18.42	0	-1.11	14.45
46.	Vikrant x EC 247640	-7.23**	-11.37**	19.97**	3.37	8.58	2.41	7.69	-0.22	2.71	24.08
47.	Vikrant x EC 628938	-17.82**	-16.57**	21.61**	122.40**	119.00**	-6.29*	104.05**	9.16*	22.34**	183.35**
48.	Vikrant x EC 591864	-11.20**	-13.79**	1.81	27.50**	25.44*	-0.06	30.10*	9.67*	-2.46	40.86**
	Range	-25.99 to 3.65	-20.59 to 2.30	-17.91 to 55.97	-10.95 to 122.40	-34.27 to 119.00	-6.29 to 13.33	-32.76 to 104.05	-14.99 to 12.22	-7.76 to 22.34	-20.84 to 183.35
	C. D. (P=0.01)	2.89	4.9	10.7	0.76	4.02	0.35	7.85	0.23	1.49	7.89
	C. D. (P=0.01)	3.83	6.49	14.18	1.01	5.33	0.46	10.4	0.3	1.97	10.44

*,**Significant at P=0.05 and P=0.01 levels, respectively.

HB 86 x HB 8 (-10.23), HB 86 x EC 247640 (-11.36%), HB-(M)-1 x EC-591864 (-13.26%) and HB-(M)-1 x EC 117705 (-14.99%) exhibited significant negative heterosis for number of seeds per pod.

The 100-seed weight is an important yield contributing trait in fababean and in the present study 21 crosses exhibited significant positive heterosis over better parent and three of the crosses viz., Vikrant x HB 8 (5.58%), HB-(M)-1 x HB 36 (-7.69%) and HB-(M)-1 x EC 628938 (-7.76%) exhibited significant negative heterosis for this trait. The per cent heterosis over better parent ranged from -7.76 to 22.34 with an average of 3.48 and critical difference of 1.49 and 1.97 at 5 and 1 per cent significance levels, respectively. The crosses Vikrant x EC 628938 (22.34%), HB 86 x HB 46 (20.27%), HB 86 x HB 23 (16.45%), Vikrant x EC 117705 (13.55%) and Vikrant x HB 49 (12.83%) expressed maximum significant and positive heterosis in100-seed weight over the better parent.

As in other crops, seed yield per plant is a complex trait in fababean also and improvement of seed yield remains the most important objective of the faba bean improvement programmes. In the present study, the per cent heterosis over better parent for seed yield ranged from -20.84 to 183.35 with an average of 31.40 and critical difference of 7.89 and 10.44 at 5 and 1 per cent significance levels, respectively. Out of the total 48 crosses, 21 crosses exhibited significant positive heterosis over better parent and one of the crosses viz., HB 85 x HB 46 (-20.84%) exhibited significant negative heterosis for 100-seed weight. The best performing crosses were Vikrant x EC 628938 (183.35%), HB-(M)-1 x EC 117705 (116.55%), HB 85 x HB-43 (103.23%), HB-(M)-1 x HB 9 (95.16%) and Vikrant x EC 117705 (90.29%) which exhibited highest significant positive heterosis for the complex trait seed yield per plant.

From the present study, it can be concluded that the partially allogamous *Vicia faba* exhibits both positive and negative significant heterosis over better parent in various characters and the magnitude of expression of heterosis whether it is positive or negative is relatively high in number of days to 50 per cent flowering, number of days to maturity, plant height, number of pods per plant, 100-seed weight and seed yield per plant and relatively low in number of branches per plant, number of pod clusters per plant, pod length and number of seeds per pod. The fact that the traits on which observations were made and heterosis was estimated in this study constitutes the yield component traits were confirmed by the earlier studies carried out by Abdalla (1977) and Berthelem *et al.* (1991). The mean performance of the parental genotypes originating from diverse locations around the world and their hybrids differed significantly which is in agreement with Abdalla *et al*. (2015). Furthermore, the results of the present study are in agreement with those of Musallam *et al.* (2004) and Bishnoi *et al*. (2012) who have suggested that outcrossing is associated with increased seed yields in fababean and results in significantly greater seed yields than self-fertilization. Significant negative and positive heterosis over better parent in plant height, number of branches per plant, number of pods per plant, number of seeds, 100-seed weight and seed yield per plant were observed by Zeinab and Helal (2014) which are in agreement with the present study. As suggested by Zeinab and Helal (2014), these results could confirm the possibility of selection for the studied traits through hybridization of respective parents. Thus, allowing plant breeders to build future breeding strategy to realize yield potential in fababean. Significant positive and negative heterosis relative to the better parent for the traits plant height, number of branches per plant, number of pods per plant, number of seeds per plant, seed yield per plant and 100-seed weight is in agreement with Abdalla *et al*. (2015).

Saad *et al.* (2015) observed significant positive and negative heterosis over better parent in number of days to 50 per cent flowering, significant negative heterosis in number of days to maturity, significant positive and negative heterosis in plant height, number of branches per plant, significant positive heterosis in number of pods per plant and significant negative heterosis in 100-seed weight and concluded that in general, the results indicated that most crosses were significantly earlier and higher yielding than their better parent, suggesting the important role of non-additive gene action in the inheritance of studied traits. The results of the present study are in full agreement with those of Saad *et al.* (2015).

The study is also in agreement with that of El-Hady *et al.* (2007) who suggested that the heterotic effects in *Vicia faba* might range from significantly positive to significantly negative for different traits depending on genetic makeup of parents and with Link (2006) who observed that the F_1 hybrids of fababean outyield their inbred parents mostly by more than 30 per cent. El-Hady *et al*. (2007) also suggested that the superiority of hybrids over the mid and better parents for seed yield is associated with the manifestations of the heterotic effects for yield component traits. Bishnoi *et al*. (2012) reviewed that positive and significant heterosis over mid-parent and better parent is exhibited by F_1 fababean hybrids for seed yield, number of stems per plant, number of branches per plant, first fruiting node, podded nodes and seeds per plant, number of pods per plant, number of seeds per pod, number of pods per node and seeds per pod, seed weight, plant height, and maturity date which varied according to cross combinations and trait. The present study is in full agreement with the observations made in the above mentioned study. The results of the present study indicate the presence of significant genetic variability among the genotypes used as parents reflected in their hybrid combinations which have exhibited both significantly positive and significantly negative heterosis over the better parent. The range of the heterosis in various traits is quite wide which represents the degree of heterozygosity and genetic divergence among the parents. A further study involving more cross combinations from the parents used in the present study may reveal more clear heterotic patterns among the hybrids of different parents.

REFERENCES

Abdalla, M. M. F. 1977 : Performance of F_1 and F_2 hybrids of *Vicia faba* L. *Egypt J. Genet. Cytol.,* **6** : 106-121.

Abdalla, M. M. F., M. M. Shafik, M. I. Abd-El-Mohsen, S. R. E. Abo-Hegazy, and Heba A. M. A Saleh. 2015 : Investigation on fababeans, *Vicia faba* L. 36. Heterosis, inbreeding effects, gca and sca of diallel crosses of ssp Paucijuga and Eu-faba. *J. Amer. Sci.,* **11** : 1-7.

Alghamdi, S. Salem. 2009 : Heterosis and combining ability in a diallel cross of eight fababean (*Vicia faba* L.) genotypes. *Asian J. Crop Sci.,* **1** : 66-76.

Berthelem, P., G. Duc, and J. Le Guen. 1991 : In : Present status and future prospects of fababean production and improvement in the Mediterranean countries, Cubero, J. I. and Saxena, M. C. (eds.). *Zaragoza : CIHEAM.* pp. 41-49.

Bishnoi, S. K., J. S. Hooda, I. S. Yadav, and Ravish Panchta. 2012 : Advances in heterosis and hybrid breeding in fababean (*Vicia faba* L.). *Forage Res*., **38** : 24-27.

El-Hady, M. M., A. M. A. Rizk, M. M. Omranand, and S. B. Ragheb. 2007 : Genetic behaviour of some fababean (*Vicia faba* L.) genotypes and its crosses. *Ann. Agric. Sci.,* **45** : 49-60.

Link, W. 2006 : In : *International Workshop on Fababean Breeding and Agronomy,* Avila, C. M., Cubero, J. I., Moreno, M. T., Suso, M. J. and Torres, A. M. (eds.). *Junta de Andalucý´a, Co´ rdoba,* Spain. pp. 35-40.

Maalouf, F. 2011 : Fababean improvement at ICARDA : Constraints and challenges. *Grain Legumes,* **56** : 13-14.

Musallam, I. W., Nizar J. Haddad, Abdel-Rahman, M. Tawaha and Osama S. Migdadi. 2004 : The importance of bee-pollination in four genotypes of fababean (*Vicia faba* L.). *Int. J. Agril. & Bio*., **6** : 9-12.

Rashid, K. Y., and Bernier. 1994 : Gene transfer in fababean by honeybees under cages. *Newsletter (ICARDA). Fababean Information Service,* pp. **34/35** : 10-3.

Saad, E. Hussein, Zaghloul, and Atef Pasha Sirri. 2015 : Assessment of heterosis and features of gene activity for yield and its components in fababean (*Vicia faba* L.). *Int. J. Agril. Sci.,* **5** : 676-681.

Somerville, D. 2002 : Honeybees in fababean pollination, Agnote DAI-128, New South Wales Department of Agriculture. No. Reg. 166/26.

Zeinab, G. E., and A. G. Helal : 2014 Diallel analysis and separation of genetic variance components in eight fababean genotypes. *Annals of Agric. Sci.,* **59** : 147-154.