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Estimation of heterosis in cowpea (*Vigna unguiculata* (L.) Walp.) genotypes for dual purpose

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Abstract
A study was conducted to estimate the level of heterosis for green fodder yield, seed yield and its contributing traits for dual purpose in cowpea. Five lines and three testers were crossed in a line × tester mating design. A total of fifteen F_1 hybrids along with eight parents were evaluated for plant height (cm), leaf to stem ratio, days to fifty per cent flowering, days to maturity, number of pods per plant, seed yield per plant (g), green fodder yield per plant (g), dry matter content (%), and crude protein content (%). Analysis of variance revealed a significant difference in the mean sum of squares among the parents for all the characters except days to maturity indicating that there was sufficient variability among genotypes.The crosses UPC-622 × PL-3, MFC-09-12 × PGCP-12, showed significant negative heterosis for days to fifty per cent flowering, for seed yield per plant MFC-09-12 × PL-3 and EC-4216 × PL-1 crosses showed significant standard heterosis. The crosses MFC-08-14 × PL-3 and MFC-09-12 × PGCP-12 showed significant standard heterosis for green fodder yield per plant whereas for crude protein content MFC-09-12 × PL-3 and UPC-622 × PL-3 crosses showed significant standard heterosis. Among the cross combinations, MFC-09-12 × PGCP-12 and MFC-08-14 × PL-3 performed exceedingly well and recorded significantly higher standard heterosis for green fodder yield per plant, seed yield per plant and its contributing characters. These crosses could be utilized in breeding programmes for improving yield in cowpea.

Keywords: Cowpea, Crude protein, Dual purpose, Green fodder, Heterosis, Yield

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is diploid with a chromosome number of 2n=22 belonging to the tribe *Phaseolae* of family *Fabaceae*. It is an important *kharif* food legume and forms an integral part of traditional cropping systems for the semi-arid regions of the tropics where other food legumes may not perform well. The use of cowpea as a dual-purpose crop, providing both grain and fodder, is attractive in mixed crop/ livestock systems where land and feed are becoming increasingly scarce (Tarawali *et al*., 1997), especially in the dry season. Despite the high grain and fodder yields, the haulms of improved dual-purpose varieties have higher crude protein content (17-18%) and dry matter digestibility (64-71%) compared to the local varieties. Etana *et al*. (2013) stressed upon the need to develop dual-purpose lines for the future animal feed improvement programme. An ideal dual-purpose cowpea cultivar for intercropping/ mixed farming would be a type with semi-determinate growth habit and intermediate maturity (85-95 days) and several such varieties have been developed at International Institute of Tropical Agriculture (IITA) that yield 1.5-2.5 t/ha grain and 3-5t/ha fodder and most of them are of erect growth habit. Similarly, the development of dual-purpose types was reported by Pal and Kumar (2009) in barley and Sah *et al.* (2016) in maize.

Utilization of heterosis is essential for maximization of green fodder yield, seed yield and crude protein content in cowpea which would provide scope to develop high yielding dual purpose cowpea genotypes. Vigour of hybrids is estimated over mid parent, better parent and standard parent. Heterosis is largely an effect of non-additive gene action *i.e.,* dominance and interactions (Hecker, 1968). Knowledge on the magnitude of heterosis for various characters is essential to locate better combinations to exploit them through heterosis breeding. Overdominance is attributed towards heterobeltiosis, while commercial superiority of the hybrid can be assessed by evaluating with a standard commercial check (Swaminathan *et al*., 1972). Estimation of heterosis over better parent may be useful in identifying true heterotic cross combinations but these crosses can be of immense practical value if they show superiority over better parent or best variety of the area. Keeping this in view, the hybrids generated in the present investigation were evaluated and selected on the basis of their standard heterosis with MFC-08-14 and MFC-09-1 as checks. The present study was carried out to estimate heterosis for green fodder yield, seed yield and its components along with crude protein for selection of dual purpose genotypes in cowpea.

Materials and Methods

Experimental materials and site: The experimental materials comprised eight parents including five lines (fodder types) and three testers (grain types) were crossed in line × tester mating design to obtain fifteen F_1 hybrids. The experimental materials were sown during *kharif*, 2016 in the experimental fields of ICAR-IGFRI, Southern Regional Research Station, Dharwad. Fifteen hybrids along with their parents and checks (MFC-08-14 and MFC-09-1) were evaluated in randomized block design with two replications. Each line was sown in a 3 m row length at a spacing of 45 x 15 cm accommodating 20 plants per row. All recommended package of practices were followed.

Observations: At first flowering stage, plants were harvested for green fodder yield leaving three nodes from the base of the plant, observations like plant height, green fodder yield per plant, leaf to stem ratio, dry matter content and crude protein content were recorded prior to harvest. Observations *viz.,* days to fifty per cent flowering, number of pods per plant, seed yield per plant and days to maturity were recorded from the five plants left uncut per replication.

Statistical analysis: Relative heterosis/ mid parental heterosis, heterobeltiosis/ better parent heterosis and economic heterosis/ standard heterosis were estimated and tested by using the standard formulae (Turner, 1953; Hayes *et al.,* 1955).

Results and Discussion

Heterosis for forage traits: The analysis of variance (Table 1) revealed a significant difference in the mean sum of squares among the parents for all the characters studied except days to maturity indicating that material used had significant variability for different traits. Variances due to crosses were also significant for all the characters. Variations due to lines *vs* testers were also found significant for all the traits except for days to maturity. Variances due to line × tester interaction were also notable for all the characters except for days to maturity, dry matter content and crude protein content. Variations due to parents *vs* crosses were also found significant for all the traits except for plant height, days to fifty per cent flowering, green fodder yield per plant and crude protein content. This indicated that there was sufficient variability among the genotypes as well as parents and F_1s for the characters under study and thus there has been a chance for the improvement through appropriate breeding methods. These results were in accordance with Ushakumari *et al*. (2010) and Anitha *et al.* (2016).

The primary objective of heterosis breeding is to achieve a quantum jump in yield of crop plants. Heterosis per cent over standard parents and checks for nine characters were recorded (Table 2-5). The per se performance of parents and crosses were also recorded (Table 6). The crosses MFC-08-14 × PL-3 and MFC-09-12 × PGCP-12 showed significant standard heterosis for green fodder yield per plant whereas for crude protein content MFC-09-12 × PL-3 and UPC-622 × PL-3 crosses showed significant standard heterosis. Among the cross combinations, MFC-09-12 × PGCP-12 and MFC-08-14 × PL-3 performed exceedingly well and recorded significantly higher standard heterosis for green fodder yield per plant, seed yield per plant and its contributing characters. Several workers reported substantial heterosis for various agronomic characters.

***Morphological growth traits*:** Five crosses showed significant positive heterosis for plant height (cm) (Table 2) over the mid parent, two crosses showed significant positive heterosis over the better parent. The cross UPC-622 × PL-3 exhibited the highest positive significant heterosis over the check (MFC-09-1). The present findings were in close association with the results reported earlier (Ushakumari *et al*., 2010; Anitha *et al*., 2016; Sarath and Reshma, 2017).

Six crosses exhibited significant negative heterosis over the mid parent, nine over better parent twelve over standard check MFC-08-14 for the leaf to stem ratio (Table 2). The range of heterosis noted for mid, better parent, standard check MFC-08-14 and MFC-09-1 were -33.64 to 2.55,-37.66 to 8.76, -32.71 to 2.80 and -25.77 to 13.40 per cent, respectively. These results were in confirmation with the results reported by Aravindhan and Das (1996), Keerthiga (2014) and Anitha *et al*. (2016).

***Floral traits*:** The maximum beneficial negative heterosis over the standard check for days to fifty per cent flowering was exhibited by hybrid UPC-622 × PL-3 (Table 3). The

Table 1. ANOVA of heterosis for different traits in cowpea

Source of Variations	df	Plant height (cm)	Leaf to stem ratio	Days to 50 % flowering	Days to maturity	No. of pods/ plant	Seed yield/ plant (g)	Green fodder yield/plant (g)	Dry matter content (%)	Crude protein (%)
Replications	1	245.28	0.01	0.65	1.97	0.09	0.72	84.05	1.07	0.29
Treatments	22	562.52**	0.04**	84.44**	148.21**	27.89**	27.78**	1648.45**	2.64**	3.01**
Parents	7	505.63**	0.05**	88.08**	73.6	14.04**	25.89**	2940.84**	3.74**	5.02**
Lines	4	302.07*	0.06**	52.12	68.06	9.99	18.11**	1006.4**	3.54**	0.97
Testers	2	650.64**	0.03**	74.81	37.63	1.71	43.86**	924.66*	1.78	4.92**
Lines vs Testers	1	1029.87**	0.07**	258.42**	167.7	54.96**	21.10**	14711.00**	8.45**	21.46**
Parents vs Crosses	1	85.5	0.08**	76.82	638.72**	280.96**	240.28**	110.14	5.64*	0.04
Crosses	14	625.04**	0.02**	83.18**	150.48**	16.73**	13.55**	1112.13**	1.87*	2.21**
Line × Tester effect	8	442.21**	0.0176*	71.27*	71.77	15.83**	14.77**	800.11**	1.19	0.98
Error	22	81.75	0.01	22.2	39.19	3.75	2.3	208.14	0.74	0.44

*Significant at P < 0.05; **Significant at P < 0.01

range of heterosis noted for the mid, better parent, standard check MFC-08-14 and MFC-09-1 were -17.76 to 24.71, -19.23 to 22.22, -35.53 to -1.97 and -32.28 to 2.05 per cent, respectively. The results were also supported by the findings of Ushakumari *et al.* (2010), Anitha *et al.* (2016) and Raut *et al.* (2017).

Five hybrids expressed significant negative heterosis over standard check MFC-08-14 and three over MFC-09-1 for days to maturity (Table 3). MFC-09-12 × PL-1 exhibited the maximum beneficial negative heterosis over mid and better parents. The range of heterosis over mid, better parent, standard checks MFC-08-14 and MFC-09-1 were -11.04 to 31.59, -12.98 to 31.30, -24.27 to 4.42 and -20.92 to 5.11 per cent, respectively.These results are in confirmation with the results reported earlier (Patel *et al.*, 2013; Anitha *et al.*, 2016; Raut *et al.*, 2017).

***Yield components*:** For the number of pods per plant, five hybrids exhibited significant positive heterosis over MFC-08-14, six hybrids over standard check MFC-09-1(Table 4). The maximum beneficial positive heterosis over standard checks MFC-08-14 and MFC-09-1 was exhibited by MFC-08-14 × PL-3 hybrid to the extent of 34.04 and 40.63 per cent, respectively. The range of heterosis noted for mid parent, better parent, standard check (MFC-08-14) and MFC-09-1 were -0.83 to 49.93, -16.06 to 44.04, -11.06 to 34.04 and -6.70 to 40.63 per cent, respectively. Similar results were also obtained by Ushakumari *et al.* (2010), Raut *et al.* (2017) and Sarath and Reshma (2017).

***Yield and quality*:** For seed yield per plant, seven hybrids exhibited significant positive heterosis over standard check MFC-08-14 and nine over MFC-09-1(Table 4). The maximum beneficial positive heterosis over standard check MFC-08-14 and MFC-09-1 was observed in hybrid MFC-09-12 × PL-3 to the extent of 26.20 and 30.47 per cent, respectively. The range of heterosis noted for mid, better parent, standard check MFC-08-14 and MFC-09-1 were -0.65 to 76.53, -9.42 to 53.89, -3.06 to 23.14 and -9.01 to -30.47 per cent, respectively. The results were in agreement with the findings of Ushakumari *et al.* (2010), Raut *et al.* (2017) and Sarath and Reshma (2017).

Two hybrids registered significant positive heterosis over mid parent and standard check for green fodder yield per plant (Table 5). None of the hybrids registered significant positive heterosis over better parent. The range of heterosis noted for mid, better parent, standard check MFC-08-14 and MFC-09-1 were -4.86 to 28.82, -22.08 to

11.03, -20.80 to 11.03 and -14.53 to19.81 per cent, respectively. Considerable heterosis for this trait was also reported earlier by Aravindhan and Das (1996) and Anitha *et al*. (2016).

Table 2. Magnitude of heterosis over mid parent (MP), better parent (BP) and standard checks for plant height (cm) and leaf to stem ratio in cowpea

Crosses	Heterosis (%)							
	Plant height (cm)				Leaf to stem ratio			
	MP	BP	MFC-08-14	MFC-09-1	MP	BP	MFC-08-14	MFC-09-1
EC-4216 × PGCP-12	18.54*	-3.88	2.63	18.97	2.13	-7.18	-21.50**	-13.4
EC-4216 × PL-1	2.34	-5.46	0.95	17.02	-8.52	-21.08**	-24.77**	-17.01*
EC-4216 × PL-3	-11.42	-15.61	-9.89	4.46	-19.79**	-34.20**	-28.97**	-21.65*
MFC-09-12 × PGCP-12	2.47	-11.23	-19.56*	-6.76	-2.08	-7.39	-12.15	-3.09
MFC-09-12 × PL-1	25.00**	24.92*	13.2	31.22**	-28.26**	-28.43**	-31.78**	-24.74**
MFC-09-12 × PL-3	-12.31	-15.06	-17.88*	-4.8	-33.64**	-37.66**	-32.71**	-25.77**
MFC-08-14 × PGCP-12	20.17*	-0.03	-0.03	15.89	-8.35	-15.42*	-15.42*	-6.7
MFC-08-14 × PL-1	4.49	-0.47	-0.47	15.37	-14.35*	-16.36*	-16.36*	-7.73
MFC-08-14 × PL-3	-11.35	-12.82	-12.82	1.07	-1.12	-4.76	2.8	13.4
MFC-09-1 × PGCP-12	3.3	-8.61	-21.16*	-8.61	12.53	8.76	-1.4	8.76
MFC-09-1 × PL-1	-6.48	-8.67	-17.34*	-4.18	-12.06	-14.22	-18.22*	-9.79
MFC-09-1 × PL-3	-12.84	-17.54	-20.27*	-7.58	-23.76**	-29.87**	-24.30**	-16.49*
UPC-622 × PGCP-12	18.22*	-6.02	5.74	22.58*	2.55	-11.05	-24.77**	-17.01*
UPC-622 × PL-1	3.21	-6.88	4.76	21.44*	-5.64	-22.06**	-25.70**	-18.04*
UPC-622 × PL-3	30.04**	20.89*	36.01**	57.67**	-19.23*	-36.36**	-31.31**	-24.23**
SEm. ±	7.83	9.04	9.04	9.04	0.06	0.07	0.07	0.07
C D (P< 0.05)	16.79	19.39	19.39	19.39	0.13	0.15	0.15	0.15
C D (P< 0.01)	23.31	26.92	26.92	26.92	0.19	0.22	0.22	0.22

Table 3. Magnitude of heterosis over mid parent (MP), better parent (BP) and standard checks for days to fifty per cent flowering and days to maturity in cowpea

Crosses	Heterosis (%)							
	Days to fifty per cent flowering				Days to maturity			
	MP	BP	MFC-08-14	MFC-09-1	MP	BP	MFC-08-14	MFC-09-1
EC-4216 × PGCP-12	8.15	-5.62	-19.08**	-15.75*	5.17	-0.9	-14.39*	-10.61
EC-4216 × PL-1	7.15	-0.25	-14.47*	-10.96	18.50*	13.8	-1.69	2.65
EC-4216 × PL-3	-7.81	-11	-23.68**	-20.55**	2.94	1.82	-12.04	-8.15
MFC-09-12 × PGCP-12	6.91	-2.54	-24.34**	-21.23**	7.62	5.74	-16.27*	-12.57
MFC-09-12 × PL-1	21.56**	18.64*	-7.89	-4.11	31.59**	31.30**	4.42	-20.92**
MFC-09-12 × PL-3	-0.56	-1.92	-21.71**	-18.49*	-1.72	-4.81	-19.57**	-16.01*
MFC-08-14 × PGCP-12	19.62**	-1.97	-1.97	2.05	12.52	-0.75	-0.75	3.63
MFC-08-14 × PL-1	-3.91	-16.45*	-16.45*	-13.01	6.9	-4.05	-4.05	0.2
MFC-08-14 × PL-3	-8.54	-17.76*	-17.76*	-14.38*	-5.67	-12.98*	-12.98*	-9.14
MFC-09-1 × PGCP-12	12.7	-6.16	-9.87	-6.16	8.73	-2.26	-6.4	-2.26
MFC-09-1 × PL-1	-0.13	-11.64	-15.13*	-11.64	14.84*	5.11	0.66	5.11
MFC-09-1 × PL-3	-7.23	-15.07*	-18.42*	-15.07*	5.94	-0.29	-4.52	-0.29
UPC-622 × PGCP-12	8.35	-0.85	-23.68**	-20.55**	7.9	2.02	-12.51	-8.64
UPC-622 × PL-1	24.71**	22.22*	-5.92	-2.05	16.11*	11.89	-4.05	0.2
UPC-622 × PL-3	-17.76*	-19.23*	-35.53**	-32.88**	-11.04	-11.69	-24.27**	-20.92**
SEm. ±	4.08	4.71	4.71	4.71	5.48	6.33	6.33	6.33
C D (P< 0.05)	8.75	10.11	10.11	10.11	11.76	13.58	13.58	13.58
C D (P< 0.01)	12.15	14.03	14.03	14.03	16.32	18.84	18.84	18.84

Table 4. Magnitude of heterosis over mid parent (MP), better parent (BP) and standard checks for number of pods per plant and seed yield per plant (g) in cowpea

Crosses	Heterosis (%)							
	Number of pods/plant				Seed yield/plant (g)			
	MP	BP	MFC-08-14	MFC-09-1	MP	BP	MFC-08-14	MFC-09-1
EC-4216 × PGCP-12	20.91*	16.02	1.7	6.7	23.78**	15.64*	6.55	10.16
EC-4216 × PL-1	31.57**	20.87*	5.96	11.16	76.53**	53.89**	23.14**	27.31**
EC-4216 × PL-3	14.36	9.22	-4.26	0.45	-0.65	-9.42	11.99	-9.01
MFC-09-12 × PGCP-12	28.21**	12.85	19.57*	25.45*	18.52**	12.58	15.28*	19.19*
MFC-09-12 × PL-1	-0.83	-16.06	-11.06	-6.7	44.68**	14.37*	17.12*	21.08**
MFC-09-12 × PL-3	37.92**	20.88*	28.09**	34.38**	26.48**	23.24**	26.20**	30.47**
MFC-08-14 × PGCP-12	19.24*	7.66	7.66	12.95	17.05*	12.45	12.45	16.25*
MFC-08-14 × PL-1	20.25*	4.26	4.26	9.38	47.10**	17.31*	17.31*	21.29**
MFC-08-14 × PL-3	49.11**	34.04**	34.04**	40.63**	20.04**	18.34*	18.34*	22.35**
MFC-09-1 × PGCP-12	25.32**	15.63	10.21	15.63	15.14*	12.42	8.73	12.42
MFC-09-1 × PL-1	22.07*	8.04	2.98	8.04	14.33	-7.67	10.7	-7.67
MFC-09-1 × PL-3	36.09**	25.00*	19.15*	25.00*	9.46	9.21	6.11	9.71
UPC-622 × PGCP-12	22.40*	21.24	-0.43	4.46	37.46**	26.87**	16.90*	20.86**
UPC-622 × PL-1	49.93**	41.97**	16.6	22.32*	41.06**	24.37*	-3.06	0.23
UPC-622 × PL-3	46.12**	44.04**	18.30*	24.11*	29.10**	16.34*	13.03	16.86*
SEm. ±	1.68	1.94	1.94	1.94	1.29	1.49	1.49	1.49
C D (P< 0.05)	3.6	4.15	4.15	4.15	2.77	3.2	3.2	3.2
C D (P< 0.01)	4.99	5.76	5.76	5.76	3.85	4.45	4.45	4.45

Table 5. Magnitude of heterosis over mid parent (MP), better parent (BP) and standard checks for green fodder yield per plant (g) and dry matter content (%) in cowpea

Crosses	Heterosis (%)							
	Green fodder yield/plant (g)				Dry matter (%)			
	MP	BP	MFC-08-14	MFC-09-1	MP	BP	MFC-08-14	MFC-09-1
EC-4216 × PGCP-12	0.64	-22.08**	-9.98	-2.87	4.71	4.42	4.84	0.78
EC-4216 × PL-1	4.28	-13.62*	-0.22	7.67	3.85	1.57	6.65	2.52
EC-4216 × PL-3	7.29	-8.52	5.67	14.03	15.72*	9.68	10.12	5.85
MFC-09-12 × PGCP-12	28.82**	4.36	6.61	15.04*	20.42**	19.31*	19.11*	14.5
MFC-09-12 × PL-1	-1.05	-13.78*	-11.92	-4.96	9.57	5.91	11.21	6.9
MFC-09-12 × PL-3	2.58	-7.81	-5.82	1.63	24.33**	19.22*	16.81*	12.29
MFC-08-14 × PGCP-12	1.32	-17.24*	-17.24*	-10.7	10.77	10.69	10.69	6.4
MFC-08-14 × PL-1	4.29	-8.3	-8.3	-1.05	11.41	8.76	14.19	9.77
MFC-08-14 × PL-3	22.37**	11.03	11.03	19.81**	23.06**	16.85*	16.85*	12.33
MFC-09-1 × PGCP-12	1.52	-14.53*	-20.80**	-14.53*	4.91	2.79	6.94	2.79
MFC-09-1 × PL-1	-4.86	-13.49	-19.83**	-13.49	-9.03	-9.45	-4.92	-8.6
MFC-09-1 × PL-3	9.49	2.87	-4.67	2.87	24.82**	16.36*	21.05*	16.36*
UPC-622 × PGCP-12	14.25	-2.41	-12.72	-5.81	0.26	-5.73	6.9	2.75
UPC-622 × PL-1	-2.48	-9.88	-19.40**	-13.02	-0.63	-4.3	8.51	4.3
UPC-622 × PL-3	-0.38	-4.82	-14.87*	-8.14	25.27**	12.3	27.34**	22.40**
SEm. ±	12.36	14.28	14.28	14.28	0.76	0.88	0.88	0.88
C D (P< 0.05)	26.52	30.62	30.62	30.62	1.63	1.88	1.88	1.88
C D (P< 0.01)	36.81	42.5	42.5	42.5	2.26	2.61	2.61	2.61

Five crosses exhibited significant positive heterosis over standard checks MFC-08-14 and two over MFC-09-1 for dry matter content (%) (Table 5).The maximum beneficial significant positive heterosis exhibited by UPC-622 × PL-3 over mid parent, standard checks MFC-08-14 and MFC-09-1 was 25.27, 27.34 and 22.40 per cent, respectively. The range of heterosis noted for mid, better parent, standard checks MFC-08-14 and MFC-09-1 were -9.03 to 25.27, -9.45 to 19.31, -4.92 to 27.34 and -8.60 to 22.40 per cent, respectively for dry matter content (%). The results were in agreement with the findings of Sangwan and Lodhi (2002) and Anitha *et al.* (2016).

For crude protein content (%) eight crosses exhibited significant positive heterosis over standard checks MFC-08-14 and MFC-09-1 (Table 6). The hybrid MFC-09-12 × PL-3 exhibited the highest positive heterosis to the tune of 10.10, 20.47 and 21.26 per cent over mid parent and standard checks MFC-09-1 and MFC-08-14, respectively. The range of heterosis noted for mid, better parent, standard check MFC-08-14 and MFC-09-1 were -5.21 to 10.10, -8.14 to 8.45, -1.09 to 21.26 and 0.43 to 20.47 per cent, respectively. These results were in confirmation with Kadam *et al.* (2013), Anitha *et al*. (2016) and Sarath and Reshma (2017).

Table 6. Magnitude of heterosis over mid parent (MP), better parent (BP) and standard checks for crude protein content (%) in cowpea

Crosses	Heterosis (%)			
	Crude protein (%)			
	MP	BP	MFC-09-1	MFC-08-14
EC-4216 × PGCP-12	-2.15	-8.14*	4.11	3.43
EC-4216 × PL-1	-2.45	-6.23	1.09	0.43
EC-4216 × PL-3	3.7	-2.03	9.54*	8.83*
MFC-09-12 × PGCP-12	2.46	0.26	13.62**	12.89**
MFC-09-12 × PL-1	-2.54	-2.83	5.39	4.7
MFC-09-12 × PL-3	10.10**	8.45*	21.26**	20.47**
MFC-08-14 × PGCP-12	-1.99	-7.76	4.54	3.86
MFC-08-14 × PL-1	3.92	0.16	7.97	7.27
MFC-08-14 × PL-3	6.06	0.45	12.32**	11.59*
MFC-09-1 × PGCP-12	5.77	-0.15	13.16**	12.43**
MFC-09-1 × PL-1	2.83	-0.58	7.17	6.48
MFC-09-1 × PL-3	9.37*	3.91	16.18**	15.43**
UPC-622 × PGCP-12	1.92	-1.17	12.00*	11.28*
UPC-622 × PL-1	-5.21	-5.8	1.55	0.89
UPC-622 × PL-3	8.15*	5.55	18.02**	17.25**
SEm. ±	0.74	0.85	0.85	0.85
C D (P< 0.05)	1.58	1.83	1.83	1.83
C D (P< 0.01)	2.2	2.54	2.54	2.54

As observed in the present study, the degree of heterosis varied from the cross to cross for all the characters. The results were in agreement with the findings of Anitha *et al*. (2016) and Raut *et al*. (2017). Considerably high heterosis in the certain crosses and low in the others revealed that the nature of gene effects varied with the genetic architecture of the parents. It was also observed that none of the hybrids exhibited standard heterosis for all the studied characters.

Most of the hybrids which were heterotic for the characters like green fodder yield per plant and seed yield per plant, were also heterotic for days to fifty percent flowering, the number of pods per plant, dry matter and crude protein contents. Thus the heterotic effects for yield per plant were found to be mostly influenced by heterosis for either one or more of these yield contributing characters. Almost all the hybrids exhibited higher mean values than the high yielding parents. It was, therefore, essential to consider the per se performance in addition to its heterotic effects for seed yield and other characters, while selecting a particular hybrid.

Conclusion

It was concluded that MFC-09-12 × PGCP-12, and MFC-08-14 × PL-3 hybrids exhibited very high heterobeltiosis for green fodder yield per plant and seed yield per plant.Therefore, such hybrid combinations would provide better opportunity to select desirable individuals for dual purpose, having high green fodder yield and seed yield with more intensity of expression of other characters in further generations.

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