Electronic Journal of Plant Breeding, 7(4): 1208-1215 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00168.X

Research Note

Heterosis for yield and it's components in fodder cowpea (*Vigna unguiculata* (L.) Walp.)

K.R. Anitha, K. Thiyagarajan, S. Pechiappan Bharathi and R. Rajendran
Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi-642 103
E-mail: anitha.kr99@yahoo.com

(Received: 31 Jan 2016; Accepted: 11 Nov 2016)

Abstract
A study was conducted to estimate the level of heterosis for yield and it's contributing traits in fodder cowpea. Three lines and twelve testers were crossed in a line × tester mating design. A total of thirty six F_1 hybrids along with 15 parents were evaluated for days to 50 % flowering, plant height, number of branches per plant, number of leaves per plant, leaf : stem ratio, green fodder yield, dry fodder yield, crude protein content, crude fibre content and crude fat content. Among the 36 cross combinations, the hybrids CO (FC) 8 x FD 2288, TNFC 0924 x FD 2307, CO 5 x FD 2288, TNFC 0924 x CL 88 and TNFC 0924 x UPC 9103 performed exceedingly well and recorded significantly higher standard heterosis for fodder yield and it's contributing characters. These promising crosses could be utilized in breeding programmes for improving earliness, fodder yield and quality in fodder cowpea.

Key words
Fodder cowpea, line × tester, heterosis, standard heterosis

Fodder cowpea (*Vigna unguiculata* (L.) Walp) is a very important annual herbaceous and leafy legume. It is native to Cental Africa and wide spread throughout the tropical areas between 30^{o}C to 40^{o}C and below 2000 m altitude. Farmers can choose to harvest them for grains or to harvest forage for their livestock depending on economical or climatological constraints. During the dry season stored cowpea fodder become an important feed for livestock. Development of high yielding fodder cowpea genotypes would be helpful to the farmers for sustainable livestock farming. A greater understanding of heterosis, would provide a useful platform to develop high yielding fodder cowpea genotypes. The superiority or inferiority of hybrid over its parents is called heterosis. Heterosis is largely an effect of non-additive gene action *i.e.,* dominance and interactions (Hecker, 1968). Various hypothesis have been advanced to explain the phenomenon, the theory of heterozygosity (Shull, 1908 and 1911; East, 1908), theory of dominance (Davenport, 1908 and Bruce, 1910), theory of intra allelic interaction (East, 1936) and the over-dominance or super dominance hypothesis (Hull, 1945) are some among the hypotheses put forth. If the heterosis is computed as deviation of F_1 from higher parents, it is referred as heterobeltiosis, deviation of F_1 value from mid parent value is referred as relative heterosis and the standard heterosis is the deviation of F_1 value from the standard variety.

The present study on heterosis of forage yield and quality traits in fodder cowpea was carried out using 36 hybrids, obtained by crossing 15 parents (3 lines and 12 testers) in line × tester mating design. The experimental materials were sown during *rabi*, 2014 in the experimental fields of Vanavarayar Institute of Agriculture, Pollachi. Each genotype including parents and hybrids were sown in single rows, each of 1.5 m length, adopting randomized block design, replicated twice. The row to row and plant to plant spacing was 30 and 15 cm, respectively. All the recommended agronomic and plant protection measures were carried out. Observations were recorded on five plants chosen randomly in each replication, for ten characters namely, days to 50 per cent flowering, plant height, number of branches per plant, number of leaves per plant, leaf : stem ratio, green fodder yield, dry fodder yield, crude protein content, crude fibre content and crude fat content. Relative heterosis, heterobeltiosis and standard heterosis were estimated and tested by using the formulae suggested by Tuner (1953).

Knowledge on the magnitude of heterosis for various characters is essential to locate better combinations to exploit them through heterosis breeding. Over dominance is attributed towards heterobeltiosis, while commercial superiority of the hybrid can be assessed by evaluating with a standard commercial check (Swaminathan *et al.,* 1972). Rather than mid parent heterosis and heterobeltiosis the standard heterosis reflecting the actual superiority over the best existing cultivar, appears to be more relevant and practical. With this point of view the hybrids generated in the present investigation were evaluated and selected on the basis of their standard heterosis. CO (FC) 8 was chosen as check for the present study.

The estimate of heterosis for all the ten characters over mid, better and standard parents are given in Tables 1 to 5. Early flowering is a desirable feature of a genotype. Therefore, negative heterosis for days to 50 % flowering was considered desirable. The relative heterosis and heterobeltiosis were higher in CO5 x IFC 8401 (3.55%) and CO5 x UPC 9103 (1.92%), respectively for days to 50 per cent flowering. The standard heterosis ranged from

DOI: 10.5958/0975-928X.2016.00168.X

-19.13 (CO (FC) 8 x CL88 and TNFC 0924 x FD 2303) to -1.74 per cent (CO (FC) 8x FD 2288). All the hybrids recorded significant negative standard heterosis for 50 per cent flowering. Significant negative standard heterosis for days to 50 per cent flowering was also reported by Hira Lal *et al*. (2007), Prakash *et al.* (2010) and Keerthiga (2014).

Among the 36 hybrids, significant positive relative heterosis for plant height were observed in 27 hybrids, whereas, negative heterosis were recorded in two hybrids and it ranged from -18.12 (TNFC 0924 x FD 2288) to 77.33 (CO (FC) 8 x FD 2307). Thirteen hybrids recorded significant positive and eight hybrids recorded significant negative heterobeltiosis and the value ranged from -38.45 (TNFC 0924 x FD 2288) to 53.26 (CO5 x FD 2307). The standard heterosis fluctuated from -20.00 % (TNFC 0924 x FD 2303) to 75.84 % (CO(FC) 8 x UPC 9103). A total of 13 hybrids recorded significant positive standard heterosis for plant height. Significant positive heterosis for this trait was reported by Patel *et al.* (2009) and Kajale *et al.* (2013).

The heterosis over mid parent and better parent for number of branches was maximum in TNFC 0924 x FD 2303 (56.28%) and CO (FC) 8 × UPC 9103 (41.23 %) respectively. Positive significant standard heterosis was recorded by 34 hybrids and none of the hybrids exhibited significant negative standard heterosis. The standard heterosis ranged from 0.88 (CO (FC) 8 × UPC 953) to 70.80 (TNFC 0924 x FD 2303). Significant positive heterosis for number of branches per plant was reported by Hira Lal *et al*. (2007).

For number of leaves per plant 20, 12 and seven out of 36 hybrids recorded significant positive relative heterosis, heterobeltiosis and standard heterosis, respectively. The values ranged from -16.49 (CO(FC) 8 x TNFC 0926) to 40.52 (TNFC 0924 x FD 2307) for relative heterosis, -36.13 (TNFC 0924 x FD2288) to 29.98 (TNFC 0924 x IFC 8401) for heterobeltiosis and -37.17 (TNFC 0924 x CL 88) to 31.69 (CO(FC) 8 x UPC 9103) for standard heterosis. Most recently, significant positive heterosis for this trait was reported by Keerthiga (2014) in cowpea and Jain and Patel (2014) in fodder sorghum, as in the present study.

The range of heterosis over mid parent for leaf:stem ratio varied between -44.97 (TNFC 0924 x IFC 8401) and 49.23 (CO 5 x UPC 953). Fourteen hybrids showed significant positive and 11 hybrids exhibited significant negative relative heterosis. The heterobeltiosis ranged from- 62.13 (TNFC 0924 x IFC 8401) to 29.33 (CO 5 x UPC 953). Out of 36 hybrids, 7 and 19 hybrids exhibited significant positive and negative heterobeltiosis, respectively, whereas 11 and 10 hybrids recorded significant positive and negative standard Heterosis, respectively. The hybrid TNFC 0924 x FD 2303 recorded the highest standard heterosis (38.49).Significant positive standard heterosis for this trait was reported by Aravindhan (1993) and Keerthiga (2014).

A total of 25 hybrids recorded significant positive and five hybrids recorded significant negative mid parent heterosis for green fodder yield. The mid parent heterosis ranged from -21.15 (CO (FC) 8 x UPC 219) to 70.99 (TNFC 0924 x FD 2307). The heterobeltiosis and standard heterosis were high in the hybrid TNFC 0924 x FD 2307 (68.10) and CO (FC) 8 x FD 2288 (29.44), respectively. Twenty hybrids recorded significant positive heterobeltiosis and 11 hybrids recorded significant negative heterobeltiosis out of 36 hybrids studied.. Ten hybrids showed significant positive and 19 hybrids showed significant negative standard heterosis. Positive standard heterosis for green fodder yield was earlier reported by Lodhi *et al.* (1990) and Aravindhan (1993) in fodder cowpea.

The highest mid parent heterosis (79.18 %) and better parent heterosis (74.87 %) for dry fodder yield were noticed in TNFC 0924 x FD 2307 . The standard heterosis was highest in the cross CO 5 x UPC 9103 (26.08 %). Among the 36 hybrids, six and 30 hybrids recorded significant positive and negative standard heterosis, respectively. Recently Keerthiga (2014) also reported positive significant heterosis for this trait.

Significantly positive relative heterosis was observed in 19 hybrids for crude protein content. The relative heterosis varied from -20.78 (TNFC 0924 x IFC 8401) to 29.42 (TNFC 0924 x CL88). The heterobeltiosis ranged from -27.06 (CO 5 x TNFC 0926) to 23.91% (TNFC 0924 x CL 88). The standard heterosis for crude protein content fluctuated from -17.75 (TNFC 0924 x IFC 8401) to 20.12 (TNFC 0924 x CL 88). Fourteen and 16 out of 36 hybrids exhibited significant positive heterobeltiosis and standard heterosis, respectively. Similar results were observed by Aravindhan (1993) and Mohammed and Talib (2008) in cowpea for crude protein content.

The maximum significant positive mid parent and better parent heterosis for crude fibre content was observed inCO5 x UPC 219 (95.68) and CO5 x FD 2307 (55.18), respectively. Eighteen hybrids registered significant positive standard heterosis, which ranged from-47.87 (CO(FC) 8x FD 2295) to 47.34 (CO5 x FD 2307).Significant negative standard heterosis for crude fibre content were earlier reported by Keerthiga (2014) in fodder cowpea, Mohammed and Talib (2008) and Tariq *et al*. (2014) in fodder sorghum.

The relative heterosis for crude fat content ranged from -64.38 (CO5 x UPC 219) to 232.84 (TNFC 0924x CS98). Sixteen and 19 hybrids recorded

 DOI: 10.5958/0975-928X.2016.00168.X

significant positive and negative relative heterosis, respectively for crude fat content. The heterosis over better parent ranged from -78.33 in CO 5 × UPC 219 to 153.26 in TNFC 0924 x FD 2307. Seven hybrids recorded significant positive and 29 hybrids exhibited significant negative heterobeltiosis. A total 13 and 23 hybrids recorded significant positive and negative standard heterosis, respectively. The standard heterosis varied from -60.75 (TNFC 0924 x FD 2288) to 86.26 (TNFC 0924x FD 2307).Significant positive heterosis for this trait was most recently reported by Keerthiga (2014) in fodder cowpea, Pratiksha Mishra *et al*. (2014) and Tariq *et al*. (2014) in Oats.

In general, it was observed that the hybrids, CO (FC) 8 x FD 2288, TNFC 0924 x FD 2307, CO (FC) 8 x UPC 9103 and CO 5 x FD 2288 outperformed, by exhibiting significant standard heterosis for green fodder yield and other important yield contributing traits like, number of branches per plant, number of leaves per plant, dry fodder yield, crude protein content and crude fat content. These cross combinations would provide better source population for exercising selection of desirable genotypes. More than 95 per cent of hybrids were earlier than the better parent (earlier flowering plant) in their cross combinations. Hybrids with negative better parent heterosis for earliness had atleast one parent either with medium or high crude protein as well as high green fodder yield. The results indicate the possibilities of developing early duration fodder cowpea genotypes, coupled with high green fodder yield and crude protein content.

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Table 1. Expression of relative heterosis (d_i), heterobeltiosis (d_{ii}) and standard heterosis (d_{iii}) for days to 50 % flowering and plant height

S. No.	Hybrids	Days to 50 per cent flowering			Plant height		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1.	CO (FC) 8 × TNFC 0926	0.47	-6.96**	-6.96**	12.01**	0.19	0.19
2.	CO (FC) 8 × CL 88	-9.71**	-19.13**	-19.13**	22.08**	2.86	2.86
3.	CO (FC) 8 × FD 2295	0.47	-7.83**	-7.83**	19.78**	6.75	6.75
4.	CO (FC) 8 × FD 2307	1.37	-3.48	-3.48	77.33**	52.92**	52.92**
5.	CO (FC) 8 × FD 2288	3.20	-1.74	-1.74	-2.59	-20.54**	25.84**
6.	CO (FC) 8 × FD 2303	-4.15	-9.57**	-9.57**	-1.09	-5.39	-5.39
7.	CO (FC) 8 × UPC 953	0.46	-4.35	-4.35	39.87**	26.06**	57.08**
8.	CO (FC) 8 × IFC 8401	-3.85	-13.04**	-13.04**	14.47**	0.79	0.79
9.	CO (FC) 8 × UPC 9103	-3.20	-7.83**	-7.83**	34.73**	9.19**	75.84**
10.	CO (FC) 8 × CS 98	-9.25**	-10.43**	-10.43**	-6.76	-9.55*	-9.55*
11.	CO (FC) 8 × IFC 95101	-1.90	-10.43**	-10.43**	29.77**	10.39**	10.39**
12.	CO (FC) 8 × UPC 219	0.48	-8.70**	-8.70**	42.87**	29.74**	29.74**
13.	TNFC 0924 × TNFC 0926	-5.83*	-10.19**	-15.65**	26.89**	26.22**	0.65
14.	TNFC 0924 × CL 88	-5.53*	-12.96**	-18.26**	22.03**	13.44**	-9.55*
15.	TNFC 0924 × FD 2295	0.00	-5.56*	-11.30**	9.08*	8.06	-13.83**
16.	TNFC 0924 × FD 2307	-6.60**	-8.33**	-13.91**	24.66**	18.97**	-5.13
17.	TNFC 0924 × FD 2288	-1.89	-3.70	-9.57**	-18.12**	-38.45**	-2.52
18.	TNFC 0924 × FD 2303	-11.43**	-13.89**	-19.13**	-6.45	-12.38**	-20.00**
19.	TNFC 0924 × UPC 953	-8.49**	-10.19**	-15.65**	52.91**	25.38**	56.23**
20.	TNFC 0924 × IFC 8401	-3.48	-10.19**	-15.65**	11.50**	8.96	-13.12**
21.	TNFC 0924 × UPC 9103	-11.32**	-12.96**	-18.26**	25.24**	-6.37**	50.78**
22.	TNFC 0924 × CS 98	-3.64	-5.36*	-7.83**	44.02**	33.08**	25.13**
23.	TNFC 0924 × IFC 95101	-5.42*	-11.11**	-16.52**	15.51**	8.55	-13.44**
24.	TNFC 0924 × UPC 219	-2.97	-9.26**	-14.78**	-0.60	-1.75	-19.81**
25.	CO 5 × TNFC 0926	-0.99	-3.85	-13.04**	9.67*	1.04	-5.39
26.	CO 5 × CL 88	-1.54	-7.69**	-16.52**	9.49*	-5.20	-11.23**
27.	CO 5 × FD 2295	-1.00	-4.81	-13.91**	19.76**	9.92*	2.92
28.	CO 5 × FD 2307	-1.92	-1.92	-11.30**	72.79**	53.26**	43.51**
29.	CO 5 × FD 2288	-0.96	-0.96	-10.43**	8.37**	-13.78**	36.56**
30.	CO 5 × FD 2303	-5.83*	-6.73*	-15.65**	-6.66	-7.83	-13.69**
31.	CO 5 × UPC 953	-5.77*	-5.77*	-14.78**	-15.80**	-26.26**	-8.12*
32.	CO 5 × IFC 8401	3.55	-1.92	-11.30**	18.38**	7.30	0.47
33.	CO 5 × UPC 9103	1.92	1.92	-7.83**	18.26**	-6.49**	50.58**
34.	CO 5 × CS 98	-6.48**	-9.82**	-12.17**	48.24**	47.93**	39.09**
35.	CO 5 × IFC 95101	2.51	-1.92	-11.30**	13.88**	0.42	-6.75
36.	CO 5 × UPC 219	-1.01	-5.77*	-14.78**	7.11	0.24	-6.14
	CD @ 5%	2.01	2.77	2.77	5.07	5.85	5.85

* Significant at P = 0.05 ** Significant at P = 0.01

Table 2. Expression of relative heterosis (d_i), heterobeltiosis (d_{ii}) and standard heterosis (d_{iii}) for number of branches per plant and number of leaves per plant

S. No.	Hybrids	Number of branches per plant			Number of leaves per plant		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1.	CO (FC) 8 × TNFC 0926	9.96**	7.63*	12.39**	-16.49**	-29.95**	-29.95**
2.	CO (FC) 8 × CL 88	10.29**	3.08	18.58**	-9.16**	-23.47**	-23.47**
3.	CO (FC) 8 × FD 2295	-1.64	-8.40**	6.19	-0.30	-8.04**	-8.04**
4.	CO (FC) 8 × FD 2307	13.56**	8.94**	18.58**	3.81	-1.24	9.41**
5.	CO (FC) 8 × FD 2288	21.05**	5.23*	42.48**	12.05**	3.29	22.44**
6.	CO (FC) 8 × FD 2303	5.34*	-7.38**	22.12**	-6.57*	-12.33**	-12.33**
7.	CO (FC) 8 × UPC 953	-4.60	-9.52**	0.88**	-10.28**	-15.16**	-15.16**
8.	CO (FC) 8 × IFC 8401	34.26**	28.32**	28.32**	13.84**	-10.23**	-10.23**
9.	CO (FC) 8 × UPC 9103	41.85**	41.23**	42.48**	28.69**	25.83**	31.69**
10.	CO (FC) 8 × CS 98	40.26**	37.29**	43.36**	21.23**	18.90**	18.90**
11.	CO (FC) 8 × IFC 95101	5.35*	-1.54	13.27**	-6.21*	-16.53**	-16.53**
12.	CO (FC) 8 × UPC 219	-2.83	-10.45**	6.19**	-1.35	-12.97**	-12.97**
13.	TNFC 0924 × TNFC 0926	19.44**	9.32**	14.16**	18.69**	4.85	-28.95**
14.	TNFC 0924 × CL 88	7.02*	-6.15*	7.96*	4.32	-8.27	-37.17**
15.	TNFC 0924 × FD 2295	23.14**	7.63**	24.78**	3.88	-16.11**	-29.13**
16.	TNFC 0924 × FD 2307	38.46**	24.39**	35.40**	40.52**	3.22	14.34**
17.	TNFC 0924 × FD 2288	0.40	-17.65**	11.50**	-11.19**	-36.13**	-24.29**
18.	TNFC 0924 × FD 2303	56.28**	29.53**	70.80**	35.78**	8.12*	-5.21
19.	TNFC 0924 × UPC 953	28.57**	14.29**	27.43**	37.48**	8.81*	-3.01
20.	TNFC 0924 × IFC 8401	42.29**	38.83**	26.55**	36.80**	29.98**	-24.98**
21.	TNFC 0924 × UPC 9103	44.34**	34.21**	35.40**	11.72**	-16.40**	-12.51**
22.	TNFC 0924 × CS 98	8.33**	-0.85	3.54	9.86**	-15.38**	-18.63**
23.	TNFC 0924 × IFC 95101	21.05**	6.15*	22.12**	16.37**	-3.04	-24.38**
24.	TNFC 0924 × UPC 219	27.59**	10.45**	30.97**	39.97**	17.56**	-10.14**
25.	CO 5 × TNFC 0926	14.40**	8.33**	26.55**	3.92	-11.04**	-15.34**
26.	CO 5 × CL 88	29.77**	28.79**	50.44**	24.00**	6.62*	1.46
27.	CO 5 × FD 2295	-6.46**	-6.82*	8.85**	-16.32**	-21.02**	-24.84**
28.	CO 5 × FD 2307	8.24**	4.55	22.12**	-5.99*	-12.61**	-3.20
29.	CO 5 × FD 2288	14.39**	6.54**	44.25**	21.97**	9.94**	30.32**
30.	CO 5 × FD 2303	12.46**	6.04*	39.82**	14.49**	9.98**	4.66
31.	CO 5 × UPC 953	10.85**	8.33**	26.55**	10.41**	6.91*	1.74
32.	CO 5 × IFC 8401	4.68	-6.82*	8.85**	-3.35	-22.36**	-26.12**
33.	CO 5 × UPC 9103	12.20**	4.55	22.12**	-9.05**	-13.18**	-9.13**
34.	CO 5 × CS 98	5.60*	-0.00	16.81**	5.78*	5.22	1.19
35.	CO 5 × IFC 95101	24.43**	23.48**	44.25**	19.94**	9.12**	3.84
36.	CO 5 × UPC 219	27.82**	26.87**	50.44**	24.96**	12.67**	7.21*
	CD @ 5%	0.309	0.36	0.36	2.79	3.23	3.23

* Significant at P = 0.05 ** Significant at P = 0.01

Electronic Journal of Plant Breeding, 7(4): 1208-1215 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00168.X

Table 3. Expression of relative heterosis (d_i), heterobeltiosis (d_{ii}) and standard heterosis (d_{iii}) for leaf : stem ratio and green fodder yield

S. No.	Hybrids	Leaf : stem ratio			Green fodder yield		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1.	CO (FC) 8 × TNFC 0926	-4.76	-8.73	-8.73	-3.16	-11.78**	-11.78**
2.	CO (FC) 8 × CL 88	-14.82**	-26.67**	1.59	-0.37	-16.17**	-16.17**
3.	CO (FC) 8 × FD 2295	27.56**	22.39**	33.17**	18.80**	3.11	3.11
4.	CO (FC) 8 × FD 2307	-12.43*	-15.50**	-9.13	25.01**	7.50**	7.50**
5.	CO (FC) 8 × FD 2288	27.35**	15.48**	15.48**	29.64**	29.44**	29.44**
6.	CO (FC) 8 × FD 2303	-11.74*	-15.58**	-7.54	-7.05**	-26.73**	-26.73**
7.	CO (FC) 8 × UPC 953	11.11*	5.16	5.16	-10.34**	-31.85**	-31.85**
8.	CO (FC) 8 × IFC 8401	-34.06**	-52.53**	7.94	5.55*	-16.35**	-16.35**
9.	CO (FC) 8 × UPC 9103	-8.37	-12.04*	-4.37	49.53**	24.23**	24.23**
10.	CO (FC) 8 × CS 98	-25.77**	-34.55**	-14.29*	1.06	-6.84**	-6.84**
11.	CO (FC) 8 × IFC 95101	0.17	-11.78**	15.87**	3.70	-1.48	-1.48
12.	CO (FC) 8 × UPC 219	-23.04**	-31.31**	-12.50*	-21.15**	-28.47**	-28.47**
13.	TNFC 0924 × TNFC 0926	18.23**	14.29*	4.76	11.13**	5.94*	-12.93**
14.	TNFC 0924 × CL 88	21.48**	-1.75	36.11**	-1.86	-5.96*	-29.93**
15.	TNFC 0924 × FD 2295	-6.08	-16.12**	-8.73	33.42**	32.59**	-1.21
16.	TNFC 0924 × FD 2307	-19.03**	-27.31**	-21.83**	70.99**	68.10**	25.25**
17.	TNFC 0924 × FD 2288	-2.52	-4.92	-18.65**	-11.18**	-22.40**	-22.64**
18.	TNFC 0924 × FD 2303	41.99**	26.45**	38.49**	52.10**	34.90**	0.51
19.	TNFC 0924 × UPC 953	21.65**	19.11**	6.35	51.76**	28.86**	-3.99
20.	TNFC 0924 × IFC 8401	-44.97**	-62.13**	-13.89*	13.92**	1.69	-24.23**
21.	TNFC 0924 × UPC 9103	27.45**	13.87*	23.81**	28.14**	20.96**	-9.87**
22.	TNFC 0924 × CS 98	-22.29**	-35.76**	-15.87**	16.81**	9.99**	-7.20**
23.	TNFC 0924 × IFC 95101	21.55**	0.36	31.83**	15.23**	5.30*	-5.21**
24.	TNFC 0924 × UPC 219	-0.86	-17.13**	5.56	42.22**	36.17**	10.90**
25.	CO 5 × TNFC 0926	3.03	-11.69	-19.05**	-6.66**	-9.50**	-20.80**
26.	CO 5 × CL 88	34.99**	-0.60	37.70**	18.08**	5.10*	-8.03**
27.	CO 5 × FD 2295	21.13**	-2.99	5.56	-2.22	-10.01**	-21.25**
28.	CO 5 × FD 2307	-40.83**	-52.40**	-48.81**	5.70*	-3.68	-15.71**
29.	CO 5 × FD 2288	-1.08	-10.73	-27.38**	30.53**	22.56**	22.18**
30.	CO 5 × FD 2303	-7.48	-26.09**	-19.05**	46.15**	21.21**	6.08**
31.	CO 5 × UPC 953	49.23**	29.33**	15.48**	64.28**	30.97**	14.61**
32.	CO 5 × IFC 8401	-34.80**	-58.01**	-4.52	14.73**	-4.28	-16.23**
33.	CO 5 × UPC 9103	4.78	-16.06**	-8.73	29.39**	13.60**	-0.59
34.	CO 5 × CS 98	-4.24	-28.18**	-5.95	12.43**	10.41**	-3.38
35.	CO 5 × IFC 95101	20.90**	-9.37*	19.05**	27.96**	26.18**	13.59**
36.	CO 5 × UPC 219	34.57**	1.87	29.76**	25.26**	20.92**	5.81**
	CD @ 5%	0.12	0.14	0.14	10.06	11.61	11.61

* Significant at P = 0.05 ** Significant at P = 0.01

Electronic Journal of Plant Breeding, 7(4): 1208-1215 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00168.X

Table 4. Expression of relative heterosis (d_i), heterobeltiosis (d_{ii}) and standard heterosis (d_{iii}) for dry fodder yield and crude protein content

S. No.	Hybrids	Dry fodder yield			Crude protein content		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1.	CO (FC) 8 × TNFC 0926	2.11	-12.36**	-12.36**	-4.60**	-10.10**	1.61
2.	CO (FC) 8 × CL 88	-10.87**	-27.71**	-27.71**	7.76**	1.67	1.67
3.	CO (FC) 8 × FD 2295	-1.59	-15.48**	-15.48**	-3.87**	-10.85**	4.30**
4.	CO (FC) 8 × FD 2307	42.66**	12.55**	12.55**	11.21**	4.30**	4.30**
5.	CO (FC) 8 × FD 2288	21.06**	16.02**	16.02**	4.63**	-0.21	9.95**
6.	CO (FC) 8 × FD 2303	-18.23**	-38.10**	-38.10**	11.16**	-0.23	-0.23
7.	CO (FC) 8 × UPC 953	-14.12**	-31.41**	-31.41**	12.51**	4.86**	4.86**
8.	CO (FC) 8 × IFC 8401	-9.72**	-30.43**	-30.43**	9.19**	3.91**	15.04**
9.	CO (FC) 8 × UPC 9103	44.42**	21.60**	21.60**	-7.53**	-10.40**	-10.40**
10.	CO (FC) 8 × CS 98	-9.35**	-14.11**	-14.11**	-3.60**	-4.14**	-3.05*
11.	CO (FC) 8 × IFC 95101	-20.57**	-30.63**	-30.63**	12.17**	7.01**	17.86**
12.	CO (FC) 8 × UPC 219	-15.23**	-25.32**	-25.32**	15.70**	6.56**	6.56**
13.	TNFC 0924 × TNFC 0926	10.91**	2.43	-26.59**	-15.73**	-21.73**	-11.53**
14.	TNFC 0924 × CL 88	-3.35	-4.52	-40.58**	29.42**	23.91**	20.12**
15.	TNFC 0924 × FD 2295	15.99**	7.06	-23.16**	-4.34**	-12.54**	2.32
16.	TNFC 0924 × FD 2307	79.18**	74.87**	6.17*	18.57**	12.83**	9.38**
17.	TNFC 0924 × FD 2288	16.62**	-3.07	-11.15**	-8.02**	-13.55**	-4.75**
18.	TNFC 0924 × FD 2303	60.04**	47.77**	-10.28**	19.50**	8.75**	5.43**
19.	TNFC 0924 × UPC 953	41.42**	40.29**	-14.83**	-1.18	-6.55**	-9.41**
20.	TNFC 0924 × IFC 8401	16.68**	10.34*	-33.01**	-20.78**	-25.71**	-17.75**
21.	TNFC 0924 × UPC 9103	23.29**	16.36**	-20.41**	11.15**	9.34**	5.99**
22.	TNFC 0924 × CS 98	19.60**	0.36	-10.17**	-15.81**	-17.55**	-16.62**
23.	TNFC 0924 × IFC 95101	22.62**	11.16**	-16.99**	-16.20**	-21.22**	-13.23**
24.	TNFC 0924 × UPC 219	12.41**	0.99	-23.05**	0.02	-6.55**	-9.41**
25.	CO 5 × TNFC 0926	-1.79	-3.63	-28.25**	-19.05**	-27.06**	-17.55**
26.	CO 5 × CL 88	19.75**	9.91*	-18.16**	15.85**	14.59**	3.90**
27.	CO 5 × FD 2295	-2.31	-4.07	-28.57**	-16.18**	-25.61**	12.97**
28.	CO 5 × FD 2307	3.93	-7.70*	-31.28**	12.15**	10.22**	-0.06
29.	CO 5 × FD 2288	32.38**	19.95**	9.96**	5.74**	-3.62**	6.19**
30.	CO 5 × FD 2303	39.98**	18.31**	-11.90**	19.05**	11.72**	1.30
31.	CO 5 × UPC 953	25.48**	13.08**	-15.80**	16.07**	13.34**	2.77*
32.	CO 5 × IFC 8401	-0.00	-13.66**	-35.71**	-9.42**	-17.62**	-8.79**
33.	CO 5 × UPC 9103	76.52**	69.33**	26.08**	-9.96**	-11.45**	-16.96**
34.	CO 5 × CS 98	13.53**	3.99	-6.93*	1.33	-3.91**	-2.83*
35.	CO 5 × IFC 95101	6.68*	6.52	-20.45**	4.63**	-4.62**	5.06**
36.	CO 5 × UPC 219	23.85**	22.44**	-6.71*	13.69**	9.63**	-0.59
	CD @ 5%	2.29	2.63	2.63	0.35	0.41	0.41

* Significant at P = 0.05   ** Significant at P = 0.01

Electronic Journal of Plant Breeding, 7(4): 1208-1215 (December 2016)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2016.00168.X

Table 5. Expression of relative heterosis (d_i), heterobeltiosis (d_{ii}) and standard heterosis (d_{iii}) for crude fibre content and crude fat content

S. No.	Hybrids	Crude fibre content			Crude fat content		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1.	CO (FC) 8 × TNFC 0926	-9.69**	-11.97**	-11.97**	110.52**	77.41**	77.41**
2.	CO (FC) 8 × CL 88	-24.08**	-36.70**	-36.70**	-21.06**	-45.08**	-45.08**
3.	CO (FC) 8 × FD 2295	-39.88**	-47.87**	-47.87**	126.04**	83.29**	83.29**
4.	CO (FC) 8 × FD 2307	-17.86**	-20.48**	-20.48**	54.41**	22.56**	22.56**
5.	CO (FC) 8 × FD 2288	-35.53**	-42.82**	-42.82**	71.16**	33.32**	33.32**
6.	CO (FC) 8 × FD 2303	-31.62**	-32.71**	-32.71**	111.88**	37.14**	37.14**
7.	CO (FC) 8 × UPC 953	-32.83**	-40.43**	-40.43**	-17.33**	-36.35**	-36.35**
8.	CO (FC) 8 × IFC 8401	-0.61	-13.30**	-13.30**	11.05**	-11.86**	-11.86**
9.	CO (FC) 8 × UPC 9103	-9.57*	-22.07**	-22.07**	-22.89**	-41.40**	-41.40**
10.	CO (FC) 8 × CS 98	22.09**	-0.80	-0.80	-9.06**	-41.13**	-41.13**
11.	CO (FC) 8 × IFC 95101	25.00**	-2.27	-0.27	-39.70**	-46.17**	-31.46**
12.	CO (FC) 8 × UPC 219	28.70**	-1.60	-1.60	-36.56**	-55.83**	-55.83**
13.	TNFC 0924 × TNFC 0926	17.65**	14.97**	14.36**	-17.31**	-20.12**	-41.25**
14.	TNFC 0924 × CL 88	27.04**	6.15	5.59	12.96**	-13.46**	-36.35**
15.	TNFC 0924 × FD 2295	1.23	-12.03**	-12.50**	-13.43**	-20.12**	-41.25**
16.	TNFC 0924 × FD 2307	14.33**	10.96**	10.37**	181.59**	153.26**	86.26**
17.	TNFC 0924 × FD 2288	44.06**	28.07**	27.39**	-39.31**	-46.64**	-60.75**
18.	TNFC 0924 × FD 2303	5.96	4.55	3.99	14.08**	-20.12**	-41.25**
19.	TNFC 0924 × UPC 953	38.05**	22.73**	22.07**	-0.17	-13.46**	-36.35**
20.	TNFC 0924 × IFC 8401	20.80**	5.61	5.05	3.81**	-6.63**	-31.33**
21.	TNFC 0924 × UPC 9103	30.03**	12.30**	11.70**	9.21**	-6.80**	-31.46**
22.	TNFC 0924 × CS 98	59.61**	29.95**	29.26**	232.84**	133.11**	71.44**
23.	TNFC 0924 × IFC 95101	19.73**	-4.28	-4.79	-31.76**	-46.17**	-31.46**
24.	TNFC 0924 × UPC 219	52.88**	17.11**	16.49**	4.17**	-20.12**	-41.25**
25.	CO 5 × TNFC 0926	38.66**	38.66**	31.65**	-56.89**	-70.29**	-46.15**
26.	CO 5 × CL 88	28.95**	9.80*	4.26	-4.46**	-41.91**	5.29**
27.	CO 5 × FD 2295	49.76**	32.77**	26.06**	-20.24**	-46.44**	-2.52**
28.	CO 5 × FD 2307	56.28**	55.18**	47.34**	3.30**	-31.61**	23.96**
29.	CO 5 × FD 2288	51.23**	37.25**	30.32**	19.49**	-21.87**	41.62**
30.	CO 5 × FD 2303	30.65**	29.40**	25.27**	-39.59**	-64.89**	-36.35**
31.	CO 5 × UPC 953	51.54**	37.54**	30.59**	-24.20**	-50.82**	-10.85**
32.	CO 5 × IFC 8401	41.29**	26.05**	19.68**	-10.14**	-40.51**	7.84**
33.	CO 5 × UPC 9103	31.96**	16.25**	10.37**	38.68**	-10.77**	61.73**
34.	CO 5 × CS 98	82.43**	51.26**	43.62**	-44.13**	-67.52**	-41.13**
35.	CO 5 × IFC 95101	50.09**	22.13**	15.96**	-28.21**	-38.88**	10.78**
36.	CO 5 × UPC 219	95.68**	52.38**	44.68**	-64.38**	-78.33**	-60.73**
	CD @ 5%	1.22	1.40	1.40	0.02	0.02	0.02.

* Significant at P = 0.05 ** Significant at P = 0.01