Electronic Journal of Plant Breeding, 6(1): 43-53 (Mar 2015)
ISSN 0975-928X

Research Article

Genetic analysis for fodder yield and component traits in maize (*Zea mays* L.)

M. Dhasarathan*, C. Babu and K. Iyanar
Department of Forage Crops,Centre for Plant Breeding and Genetics,
Tamil Nadu Agricultural University, Coimbatore – 641003(Tamil Nadu), India
E-mail: maadhasarathan@gmail.com

(Received: 04 Sep 2014; Accepted:23 Feb 2015)

Abstract
An investigation was carried out to assess the possibility of exploiting heterosis for green fodder yield in maize and to identify parents with desirable genetic effects. Seven maize parents having forage value along with fodder maize variety African Tall were utilized to produce 21 hybrids through Diallel (without reciprocal) mating design. The hybrids along with parents were subjected to study general and specific combining ability for fodder yield and its contributing traits. The analysis of variance revealed that significant differences for general and specific combining ability which indicated the presence of additive as well as non additive gene effects controlling the fodder yield component traits. However, relative magnitude of these variances showed that non additive gene effects were more prominent for most of the traits studied except for leaf length, stem girth, leaf stem ratio and green fodder yield. The parent African Tall was identified as the best general combiner for fodder yield and its contributing characters. The crosses showing significant *sca* effect for fodder yield involved low × low and low × high *gca* parents which could be exploited for hybrid vigour. The mid and better parent heterosis expressed by the different crosses were ranged from -26.14 to 97.08% and -55.69 to 70.12% respectively for green fodder yield. Two crosses *viz*., FDM 7 x African Tall and FDM 37 x African Tall proved to be better and may be studied in future to produce promising fodder maize hybrids which would help to sustain the economic wellbeing of dairy farmers.

Key words:
Maize **,** Fodder**,** GCA, Heterosis, SCA

Introduction

India has about 0.5 per cent of the global pastures against more than 15 per cent of the animal population (Bhagirath Ram *et al*., 2007). To sustain this animal population and maintain its productivity, a large quantity of green fodder is required. Maize (*Zea mays* L.) is an important cereal fodder crop because of some desirable characters *viz*., high fodder yield, palatability and absence of toxic substances like Oxalic acid, HCN *etc*. Hence, it is quite popular among dairy farmers. However, in India less attention has been given for the genetic improvement of this fodder crop and the gap still remain to be filled up through development of improved forage maize hybrids/varieties.

Exploitation of hybrid vigour and selection of parents based on combining ability has been used as an important breeding approach in crop improvement. Developments of high fodder yielding F_1s along with other favourable traits are receiving considerable attention. For developing desirable hybrids, information about combining ability of the parents and the resulting crosses are essential. The present study involving 7 x 7 diallel analysis (without reciprocal) aimed to determine the better general and specific combining parents for evolving productive fodder maize hybrids.

Material and methods

Seven inbred lines of fodder maize were crossed in a diallel fashion excluding the reciprocals during the *kharif* season in 2010. The resulting 21 F_1s and their parents were raised in a Randamized Block Design (RBD) with two replications during *rabi* season of 2010-11. Each plot consisted of two rows of 5m length and spacing between rows and plants adopted were 30 and 20 cm respectively. One plant per hill was maintained and recommended package of practices was followed to raise a healthy crop. Observations on fodder yield and its component traits*viz*. days to 50 % tasseling (DFT), plant height (PHT), number of leaves per plant (NOL), leaf length (LLT), leaf width (LWD), stem girth (SGR), leaf stem ratio (LSR), green fodder yield per plant (GFY) and dry matter yield (DMY) were recorded on five randomly selected plants from each plot.

Data were analysed for variance of all the characters studied. General combining ability (*gca*) and specific combining ability (*sca)* were estimated by following Model-I, Method-II of Griffing (1956). Based on general combining ability effects, the parents were classified into low (*gca*value in negative sign) and high (*gca* value in positive sign with significant) combining parents. The mean squares for GCA and SCA were tested against error variance desired. Mean data were used to estimate heterosis over mid and better parent according to Rai (1979).

Results and discussion

The analysis of variance revealed the presence of significant amount of variability among the parents and hybrids for all the traits. Presence of significant differences among parents and hybrids revealed the choice of exploitation of heterosis for all the characters studied.

The analysis of variance for combining ability observed to be highly significant for both *gca* as well as *sca* for most of the characters studied (Table 1). Thus, both additive and non-additive gene actions were found to be important for controlling thesetraits. However, variances due to *gca* were much higher in magnitude than *sca* for the characters *viz.,* leaf length, stem girth, leaf stem ratio and green fodder yield.The ratio of the components revealed that the magnitude of *sca* components were much higher than that of *gca* in all crosses for five characters *viz.,* days to 50 % tasseling, plant height, number of leaves per plant, leaf width and dry matter yield. Some earlier workers were also reported similar phenomena for plant height (Geetha and Jayaraman, 2000; Prakashand Ganguly, 2004) and number of leaves per plant (Jayakumar and Sundaram, 2007).

General combining ability effects (*gca*): The best parents chosen in the present study based on mean performance and high *gca* effects are given in Table 2. The desirable mean value and *gca* effects were possessed by the parent African Tall for seven characters *viz*., days to 50 % tasselling, plant height, number of leaves per plant, leaf length, stem girth, green fodder yield per plant and dry matter yield per plant (Table 5) and the parent FDM 37 exhibited desirable mean and high *gca* effects for leaf length. It is known from the study that the parents differ in their combining ability for different traits and also noticed that none of the parents could be a good combiner for all traits. However, the parentAfrican Tall was the best among the seven parents as it showed desirable mean and *gca* effects for most of the traits studied. So this parent could be used extensively in hybrid breeding program with a view to increase fodder yield level.

Similar to the present investigation, high *gca* effects were reported for the following characters *viz*., plant height (Vacaro *et al*., 2002; Malik *et al*., 2004 and Shalim Uddin *et al*., 2006), number of leaves per plant (Reddy and Agarwal, 1992), leaf length (Pooran Chand, 1999) and green fodder yield per plant (Satyanarayana *et al*., 1994).

Specific combining ability effects (*sca*):The *sca* effects of the hybrids denote the deviation in the mean performance of different crosses from the expected performance on the basis of their parents. This is helpful in deciding whether the specific single cross could be further utilized as hybrids or let allow for developing composites.

In the present study, desirable and significant *sca* effects (Table 3 and 6) were recorded in 11 hybrids each for number of leaves and green fodder yield per plant, 17 hybrids for plant height, seven hybrids for leaf length, ten hybrids each for leaf width and dry matter yield per plant, four crosses each for stem girth and days to 50 % tasseling and two crosses for leaf stem ratio. Similar results of desirable *sca* have been reported for fodder yield and other traits by Glover *et al.* (2005) and Katna *et al.* (2005). None of the traits observed unique way of combinations. These desirable *sca* effects may be due to the combination of favourable genes from corresponding traits of parents coupled with non additive gene action.

Out of 21crosses, 11 crosses had shown highly significant positive *sca* effect for fodder yield. These crosses involved low × low and low × high general combining parents. Although the cross FDM 10 x FDM 36 involved low × low general combiners, exhibited the highest significant positive *sca* effect. The cross FDM 37 x African Tallwhich involved low × high general combiner exhibited third highest significant *sca* effect and possessed high mean value. Among the 21 crosses, three crosses *viz.,* FDM 7 x African Tall, FDM 37 x African Tall and FDM 12 x African Tall were expressed *sca* effect along with mean performance for fodder yield and many other fodder yield contributing traits.

For more effective selection of a hybrid, besides mean performance and *sca* effect, the hybrid should have either the parents or at least any one of the parents as a good combiner. Richharia and Singh (1983) also opined that a hybrid should have at least one parent as a good combiner. Hence, going by above statement, it was noticed that the two hybrids *viz.,* FDM 7 x African Tall and FDM 37 x African Tall recorded higher mean performance and *sca* effect for green fodder yield per plant which involved one good combiner and one poor combiner for that trait. Such occurrence of good hybrids by the combination of one good and one poor combiner may be due to the accumulation of favourable genes and partly due to dominance and recessive interaction (Prakash *et al*., 2010). Moll and Stuber (1974) reported any combination among the parents may produce hybrid vigour over the parents, which might be due to dominant, over dominant or epistatic gene action. So, the crosses showing desirable *sca* effects could be used in future breeding programme. Hence, it is concluded that these FDM 7 x African Tall and FDM 37 x African Tall hybrids could be exploited as promising hybrids for achieving green fodder yield after confirmative testing.

Heterosis: The expression of heterosis in 21 hybrids involving seven parents was measured in terms of relative heterosis in relation to mid parents and heterobeltosisin relation to better parent (Table 4). All the traits responded differently in the expression of heterosis in their respective combinations. For days to 50 % tasseling, none of the hybrids showed positive significant heterosis over mid and better parent. This clearly indicated that the hybrids flowered earlier than their respective inbred parents.The heterosis over mid and better parent for plant height was ranged from 19.85 to 110.98% and -16.86 to 84.04% respectively, and the cross FDM 12 x FDM 36 exhibited highest percentage of significant positive heterosis over mid parent as well as better parent for plant height. The cross FDM 10 x FDM 37 showed highest percentage of both the heterosis for number of leaves per plant and relative heterosis range varied from 6.02 to 26.55, while heterobeltosis ranged from – 2.26 to 22.73%. With respect to leaf length, the crosses FDM 10 x FDM 36 and FDM 8 x FDM 12 were exhibited maximum of heterosis over mid and better parent respectively, mid and better parent heterosis was found to occur between 2.44 to 40.27% and -17.47 to 32.34%. Heterosis per cent over better parent ranged from -5.62 to 22.36% and the cross FDM 8 x FDM 12 was expressed higher magnitude of heterosis for leave width. None of the hybrids recorded positively significant mid and better parent heterosis for stem girth and leaf stem ratio.

For green fodder yield per plant, the range of relative heterosis and heterobeltosis was varied from -26.14 to 97.08% and -55.69 to 70.12% respectively. Higher manifestation of heterosis was exhibited by FDM 7 x FDM 12 and FDM 7 x FDM 37over mid and better parent for green fodder yield per plant. The range of heterosis over mid and better parent was found to occur between -20.67 to 109.51% and -46.90 to 107.41% for dry matter yield and best hybrids for this trait was FDM 7 x FDM 12 and FDM 10 x FDM 12.

Hybrids suitable for heterosis breeding should satisfy the criteria *viz*., mean performance, *sca* and heterosis. Hence, the hybrids were analysed based on all these criteria to suggest them for heterosis breeding. A hybrid is commercially valuable only when it exhibits high heterosis over its better parent and the best locally adopted variety or hybrid. Bhandari (1978) reported the importance of heterobeltiosis for exploitation of heterotic hybrids. Based on desirable and significant *sca* effects and high manifestation of heterobeltiosis (Table 6) were observed in five hybrids *viz*., FDM 10 x FDM 12, FDM 7 x FDM 37,FDM 8 x FDM 7, FDM 37 x FDM 36, FDM 7 x FDM 12for green fodder yield. This manifestation of heterosis might be due to significance in *sca* effects. Gains in fodder yield offered by heterosis have prompted use of hybrids in maize. It is also commonly accepted that greater heterotic response is associated with greater genetic diversity of the parents (Lamkey *et al*., 1988). In this study, inbred lines were found to give some reasonably good heterosis for certain plant characters with its different origins in certain combinations. These findings would be very helpful in determining the heterotic groups and also identifying good combinations which, ultimately, could lead towards high fodder yielding maize hybrids.

African Tall was the best among the seven parents as it showed desirable mean and *gca* effects for most of the traits studied except for the leaf stem ratio. So, this parent could be used extensively in hybrid breeding program with a view to increase fodder yield level. Based on mean and *sca* effects two hybrids *viz*., FDM 7 x African Tall and FDM 37 x African Tall were proved to be the best to increase the fodder yield. Based on *sca* and mid parental heterosis, five hybrids *viz*., FDM 10 x FDM 7, FDM 10 x FDM 36, FDM 8 x FDM 7, FDM 7 x FDM 12 and FDM 8 x FDM 12 were found to be good to increase the fodder yield. Hence, these hybrids could be exploited as promising hybrids for getting green fodder yield. For varietal development, these crosses could also be utilized for exploiting promising recombinants and it could be useful towards enhancing maize green fodder yield.

References

Bhagirath Ram, K., Sharma,C.and Sastry, E. V. D. 2007. Genetic variability, correlation and path analysis in fodder yield and related traits in pearl millet (*Pennisetum glaucum* (L.) R. Br.). *Agric. Sci. Digest,*27 (1): 8-12.

Geetha, K. and Jayaraman. 2000. Genetic analysis of yield in maize. *Madras Agric. J.,* 87(10-12): 638-640.

Glover, M. A.;Willmot, D. B., Darrah,L. L., Hibbard,B. E.,and Zhu,X. 2005. Diallel analyses of agronomic traits using Chinese and U.S. maize germplasm. *Crop Sci.,*45: 1096-1102.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Aust. J. Boil. Sci.,*9: 463-493.

Jayakumar,J. and Sundram,T.2007. Combining ability studies for grain yield and other yield components in maize. *Crop Res.*,33(1):179-186.

Katna, G., Singh,H. B., Sharma,J. K.and Guleria, S. K.2005. Heterosis and combining ability studies for yield and its related traits in maize. *Crop Res.*,30(2): 221-226.

Lamkey, K. R..,Hallauer, A. R.and Robertso, D. S. 1988. Contribution of long arm of chromosome 10 to the total heterosis observed in five maize hybrids. *Crop Sci.*,28: 896-901.

Malik, S. I.; Malik,H. N., Minhas, N. M.and Munir, M. 2004. General and Specific combining ability studies in maize. *Int. J. Agric. Biol.*,6(5): 856-859.

Moll, R. H. and Stuber, C. W. 1974. Quantitative genetics empirical results relevant to plant breeding. *Ad.Agron. J*.,26: 277-313.

Pooran Chand. 1999. Combining ability of maize grown in winter region. *Madras Agric. J.*,83(9): 573-575.

Prakash, R.,Ganesamurthy,K., Nirmalakumari,A.and Nagarajan, P. 2010. Combining ability for fodder yield and its components in Sorghum (*Sorghum bicolor* L.). *Electron. J. Plant Breed.*,1(2):124-128.

Prakash, S. and Ganguly, D. K. 2004. Combining ability for various yield component characters in maize (*Zea mays* L.). *J. Res. (BAU)*,16(1): 55-60.

Rai, B. 1979. Heterosis breeding. Agrobiological publications, Delhi- 110051, India.

Reddy, K. H. D. and Agarwal, B. P. 1992. Estimation of genetic variation in an improved population of maize (*Zea mays* L.).*Madras Agric. J.*,79: 714-719.

Richharia, A. K. and Singh, R. S. 1983. Heterosis in relation to *per se*performance and effects of general combining ability in rice. *In*: Pre congress scientific meeting in genetics and improvement of heterotic systems, Tamil Nadu Agricultural University, Coimbatore.

Satyanarayana, E.;Saikumar,R.and Sharma,M. Y.1994. Inheritance studies of maturity components and yield in selected hybrids of maize (*Zea mays L*.). *Mysore J. Agric. Sci.*,28:25-30.

ShalimUddin, M.,Khatun,F., Ahmed,S.,Ali,M. R.and Bagum, S. A. 2006. Heterosis and combining ability in corn (*Zea mays* L.). *Bangladesh J. Bot.*,35(2): 109-116.

Vacaro, E., Barbosa Neto,J.F., Pegoraro,D. G., Nuss, C. N.and Conceicao,L. D. H.2002. Combining ability of twelve maize populations. *Pesquisa Agropecuaria Brasilerira,* 37: 67-72.

Table 1. ANOVA for combining ability and estimates of variance

Sources	DFT	PHT	NOL	LLT	LWD	SGR	LSR	GFY	DMY
GCA	11.7302**	4196.179**	3.4036**	332.1448**	0.3252	1.2997**	0.007**	39625.18**	4.3385**
SCA	7.7659**	1260.862**	1.1347**	40.714**	0.4912**	0.2098	0.0002	3019.43*	3.2477**
Error	2.0552	283.3287	0.6513	16.7371	0.3556	0.2532	0.001	2638.906	0.0286
$\sigma^2 gca$	1.1892	450.5016	0.342	35.9751	0.0164	0.1303	0.0007	4256.192	0.4805
$\sigma^2 sca$	6.7383	1119.197	0.809	32.3455	0.3134	0.0832	0.0003	1699.977	3.2334
$\sigma^2 gca$ / $\sigma^2 sca$	0.1765	0.4025	0.4227	1.1122	0.0523	1.5671	2.6682	2.5037	0.1486

*P=0.05, **P=0.01, GCA = General Combining Ability; SCA = Specific Combining Ability; DFT = Days to 50% tasseling; PHT = Plant height (cm); NOL = Number of leaves; LLT = Leaf length (cm); LWD = Leaf width (cm); SGR = Stem girth (cm); LSR = Leaf stem ratio; GFY = Green fodder yield per plant (g); DMY = Dry matter yield (g)

Table 2. Estimates of mean and general combining ability effects (*gca*) of the parents for different fodder maize characters

Parents	DFT		PHT		NOL		LLT	
	Mean	*gca*	Mean	*gca*	Mean	*gca*	Mean	*gca*
FDM 10	71.00	0.52	90.00	-19.40**	11.34	-0.63**	45.50	-4.88**
FDM 8	72.00	0.47	99.17	-12.09**	11.84	-0.32	50.34	-4.88**
FDM 7	70.50	-0.53	111.84	-0.31	12.84	0.35	47.84	-6.64 **
FDM 12	72.50	-0.14	69.84	-14.62**	11.84	-0.21	49.67	-1.37
FDM 37	70.50	-1.86**	127.50	9.81*	10.34	-0.48*	73.50**	5.89**
African Tall	76.00**	1.85**	232.34**	43.74**	14.84**	1.16**	79.17**	9.28**
FDM 36	71.50	-0.31	94.00	-7.13	12.67	0.13	64.50	2.61**
Mean	72.00		117.81		12.24		58.65	
SE_d	1.43		16.83		0.80		4.09	
CD at 5%	2.94		34.50		1.65		8.39	
$SE(_{gi})$		0.31		3.67		0.18		0.89

*P=0.05, **P=0.01, *gca*= General Combining Ability; DFT = Days to 50% tasseling; PHT = Plant height (cm); NOL = Number of leaves; LLT = Leaf length (cm)

Table 2. Contd...

Parents	LWD		SGR		LSR		GFY		DMY	
	Mean	***gca***	**Mean**	***gca***	**Mean**	***gca***	**Mean**	***gca***	**Mean**	***gca***
FDM 10	7.12	0.07	5.00	-0.47**	0.38	0.03**	113.92	-61.91**	17.07	0.06
FDM 8	6.69	0.00	5.57	-0.23*	0.32	0.00	166.89	-28.49*	26.48	0.10*
FDM 7	6.77	-0.05	6.72	0.47**	0.35	0.01	175.60	6.36	28.12	-1.07**
FDM 12	5.90	-0.11	4.69	-0.19	0.38	0.02**	92.24	-37.69**	16.89	0.92**
FDM 37	6.90	-0.19	4.97	-0.21	0.32	-0.01	164.10	-11.45	30.61	0.66**
African Tall	7.82	0.38**	7.32**	0.51**	0.23	-0.05**	563.93**	141.79 **	87.81**	-0.66**
FDM 36	7.45	-0.10	6.15	0.13	0.33	-0.01	192.10	-8.60	34.93	-0.02
Mean	6.95		5.77		0.33		209.83		34.55	
SE_d	0.59		0.50		0.03		51.37		8.70	
CD at 5%	1.22		1.03		0.07		105.31		17.87	
$SE_{(gi)}$		0.13		0.11		0.01		11.21		1.90

*P=0.05, **P=0.01, *gca*= General Combining Ability; LWD = Leaf width (cm); SGR = Stem girth (cm); LSR = Leaf stem ratio; GFY = Green fodder yield per plant (g); DMY = Dry matter yield (g)

Table 3.Estimates of mean and specific combining ability effects (*sca*) of the hybrids for different fodder maize characters

Hybrids	DFT		PHT		NOL		LLT	
	Mean	***sca***	**Mean**	***sca***	**Mean**	***sca***	**Mean**	***sca***
FDM 10 x FDM 8	68.50	-1.52**	138.17	1.89	13.16	0.51*	56.83	1.33
FDM 10 x FDM 7	68.50	-0.52	166.17	18.11**	12.84	-0.49*	54.83	1.10
FDM 10 x FDM 12	69.50	0.08	150.17	16.43**	13.34	0.56*	65.67	6.65**
FDM 10 x FDM 37	66.50	-1.19**	176.67	18.48**	13.50	1.01**	67.00	0.73
FDM 10 x African Tall	71.50*	0.08	193.17	1.05	14.67	0.53*	65.33	-4.33**
FDM 10 x FDM 36	70.50	1.25**	163.17	21.93**	13.00	-0.10	77.50*	14.50**
FDM 8 x FDM 7	70.50	1.52**	166.67	11.30*	13.84	0.19	51.83	-1.90
FDM 8 x FDM 12	70.00	0.63	172.83	31.78**	13.84	0.75**	66.17	7.15**
FDM 8 x FDM 37	68.50	0.86*	180.17	14.67**	13.00	0.19	67.00	0.73
FDM 8 x African Tall	68.00	-3.36**	207.67	8.24	14.50	0.04	71.83	2.17
FDM 8 x FDM 36	67.00	-2.19**	169.50	20.95**	14.00	0.58*	63.83	0.84
FDM 7 x FDM 12	65.50	-2.86**	177.83	25.00**	13.67	-0.08	63.00	5.74**
FDM 7 x FDM 37	64.00	-2.63**	195.67	18.39**	14.66	1.19**	65.67	1.15
FDM 7 x African Tall	69.00	-1.36**	224.50*	13.30*	15.83*	0.71**	70.33	2.43*
FDM 7 x FDM 36	69.00	0.80	184.83	24.51**	15.50	1.42**	61.00	-0.24
FDM 12 x FDM 37	62.50	-4.52**	188.33	25.37**	13.84	0.92**	68.50	-1.29
FDM 12 x African Tall	69.50	-1.25**	208.67	11.78*	15.34	0.77**	79.50**	6.32**
FDM 12 x FDM 36	69.00	0.41	173.00	26.98**	13.34	-0.19	67.67	1.15
FDM 37 x African Tall	70.50	1.47**	236.17**	14.84**	14.66	0.38	86.83**	6.39**
FDM 37 x FDM 36	62.50	-4.36**	198.50	28.04**	14.16	0.92**	73.17	-0.60
African Tall x FDM 36	68.50	-2.08**	201.00	-3.38	14.66	-0.23	73.50	-3.66**
Mean	68.05		184.42		14.06		67.48	
SE_d	1.43		16.83		0.80		4.09	
CD at 5%	2.94		34.50		1.65		8.39	
$SE_{(sij)}$		0.91		10.68		0.51		2.59

*P=0.05, **P=0.01, *sca*= Specific Combining Ability; DFT = Days to 50% tasseling; PHT = Plant height (cm); NOL = Number of leaves; LLT = Leaf length (cm)

Table 3. Contd...

Hybrids	LWD		SGR		LSR		GFY		DMY	
	Mean	***sca***	**Mean**	***sca***	**Mean**	***sca***	**Mean**	***sca***	**Mean**	***sca***
FDM 10 x FDM 8	8.15	0.35	4.80	-0.07	0.35	-0.01	161.92	-8.08	29.56	-0.92
FDM 10 x FDM 7	8.10	0.35**	5.97	0.38*	0.37	-0.01	249.38	44.54**	46.69	14.79**
FDM 10 x FDM 12	8.06	0.38**	4.97	0.04	0.39	0.01	193.93	33.15*	35.26	4.78
FDM 10 x FDM 37	7.27	-0.35	4.80	-0.10	0.37	0.01	193.95	6.92	34.37	0.04
FDM 10 x African Tall	8.09	-0.10	4.57	-1.05**	0.34	0.02*	250.37	-89.90**	46.64	-8.83*
FDM 10 x FDM 36	8.59	0.88**	5.28	0.05	0.37	0.01	248.57	58.68**	38.74	5.70*
FDM 8 x FDM 7	8.00	0.33	5.53	-0.29	0.34	0.01	270.58	32.31*	40.10	2.56
FDM 8 x FDM 12	8.57	0.95**	5.43	0.27	0.36	0.01	241.76	47.55**	44.93	8.83**
FDM 8 x FDM 37	7.75	0.21	4.72	-0.43**	0.32	0.01	210.71	-9.74	37.65	-2.31
FDM 8 x African Tall	8.65	0.54**	5.32	-0.54**	0.29	0.01	358.95	-14.75	66.91*	5.81*
FDM 8 x FDM 36	7.32	-0.30	5.65	0.17	0.31	-0.01	249.08	25.77	43.93	5.26*
FDM 7 x FDM 12	8.03	0.47*	5.74	-0.14	0.37	0.01	264.32	35.25*	48.02	10.49**
FDM 7 x FDM 37	7.73	0.24	5.76	-0.08	0.32	-0.01	293.27	37.96*	44.73	3.35
FDM 7 x African Tall	8.68	0.62**	6.61*	0.04	0.29	0.01	443.54**	34.98*	46.63	-15.90**
FDM 7 x FDM 36	7.25	-0.32	5.91	-0.27	0.37	0.03*	268.16	10.01	46.49	6.39*
FDM 12 x FDM 37	7.95	0.53**	5.63	0.44**	0.34	0.01	217.95	6.69	39.50	-0.46
FDM 12 x African Tall	8.30	0.30	6.35	0.44**	0.29	-0.01	407.28*	42.79**	76.13**	15.03**
FDM 12 x FDM 36	8.09	0.57**	5.52	-0.01	0.32	-0.02*	234.20	20.09	38.42	-0.25
FDM 37 x African Tall	8.40	0.48*	6.30	0.41**	0.25	-0.02*	442.90**	52.16**	80.29**	15.34**
FDM 37 x FDM 36	7.22	-0.22	5.67	0.16	0.29	-0.02*	293.15	52.80**	52.92	10.41**
African Tall x FDM 36	7.55	-0.46*	5.52	-0.71**	0.26	-0.01	328.41	-65.17**	48.76	-14.90**
Mean	7.99		5.53		0.33		277.26		46.98	
SE_d	0.59		0.50		0.03		51.37		8.70	
CD at 5%	1.22		1.03		0.07		105.31		17.87	
$SE_{(sij)}$		0.38		0.32		0.01		32.60		5.53

*P=0.05, **P=0.01, *sca*= Specific Combining Ability; LWD = Leaf width (cm); SGR = Stem girth (cm); LSR = Leaf stem ratio; GFY = Green fodder yield per plant (g); DMY = Dry matter yield (g)

Table 4. Heterosis over mid and better parent for different fodder yield component traits

Hybrids	DFT		PHT		NOL		LLT		LWD	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
FDM 10 x FDM 8	-4.20*	-4.86*	46.08 **	39.33*	15.31 *	11.24	17.98.*	12.90	19.11 *	16.43
FDM 10 x FDM 7	-3.18	-3.52	64.65 **	48.58 **	7.70	0.00	16.88 *	14.63	17.65*	15.71
FDM 10 x FDM 12	-3.14	-4.14*	87.91 **	66.86 **	16.79*	12.67	37.27 **	32.20 **	25.04 **	15.21
FDM 10 x FDM 37	-6.01 **	-6.34 **	62.45 **	38.56 **	26.55 **	22.73 **	12.13	-8.84	4.53	3.79
FDM 10 x African Tall	-2.72	-5.92 **	19.85*	-16.86 *	13.57*	-1.11	4.40	-17.47 **	9.15	3.45
FDM 10 x FDM 36	-1.05	-1.40	77.35 **	73.58 **	9.87	2.65	40.27 **	20.16 **	18.82*	15.23
FDM 8 x FDM 7	-1.05	-2.08	58.10 **	49.03 **	11.42	7.79	5.96	3.67	16.19 *	14.29
FDM 8 x FDM 12	-3.11	-3.45	104.74**	74.58 **	16.09*	15.29*	32.78 **	32.34 **	32.79 **	22.36*
FDM 8 x FDM 37	-3.86*	-4.86 *	59.09 **	41.31 **	16.41 *	8.33	8.50	-8.84	11.51	10.71
FDM 8 x African Tall	-8.11 **	-10.53 **	25.35 **	-10.62	8.07	-2.26	11.22	-9.27	16.77*	10.68
FDM 8 x FDM 36	-6.62 **	-6.94 **	75.65 **	71.21 **	13.52*	10.54	11.50	-1.03	1.31	-1.74
FDM 7 x FDM 12	-8.07 **	-9.66 **	95.60 **	58.78 **	10.09	5.15	29.01 **	26.84 **	24.50**	14.71
FDM 7 x FDM 37	-8.90 **	-9.22 **	63.39 **	53.46 **	25.69 **	12.81 *	8.09	-10.66	11.22	10.43
FDM 7 x African Tall	-5.48 **	-9.21 **	30.40**	-3.37	13.74*	6.71	10.62	-11.15*	17.18*	11.07
FDM 7 x FDM 36	-2.47	-3.50	79.45 **	65.03 **	20.79 **	19.23 **	8.44	-5.43	0.35	-2.68
FDM 12 x FDM 37	-12.28**	-13.19 **	90.72 **	47.71 **	23.89 **	15.29*	10.93	-6.80	23.26**	15.22
FDM 12 x African Tall	-6.08 **	-8.55 **	38.04 **	-10.19	14.29*	3.37	23.10 **	0.42	20.16*	6.21
FDM 12 x FDM 36	-3.83 *	-4.17 *	110.98**	84.04 **	8.13	5.29	18.20 **	4.91	20.22*	8.52
FDM 37 x African Tall	-3.42	-7.24 **	31.08 **	1.65	18.10 **	-1.15	13.39 **	9.69	13.40	7.49
FDM 37 x FDM 36	-11.66 **	-12.59 **	78.83 **	55.08 **	24.99 **	11.84	5.65	-1.13	-0.14	-3.15
African Tall x FDM 36	-7.12 **	-9.87 **	23.31 *	-13.36	6.02	-2.23	2.44	-6.96	-2.27	-5.62
SE	1.24	1.43	14.58	16.83	0.70	0.81	3.54	4.09	0.52	0.60
CD at 5%	2.54	2.94	29.91	34.53	1.43	1.65	7.27	8.39	1.06	1.22

*P=0.05, **P=0.01, MP = Mid parent; BP = Better parent; DFT = Days to 50% tasseling; PHT = Plant height; NOL = Number of leaves; LLT = Leaf length; LWD = Leaf width

Table 4: **Contd...**

Hybrids	SGR		LSR		GFY		DMY	
	MP	BP	MP	BP	MP	BP	MP	BP
FDM 10 x FDM 8	-9.13	-13.75	0.00	-7.89	15.29	-2.98	35.93	11.59
FDM 10 x FDM 7	1.84	-11.17	0.00	-3.95	72.22*	42.02	106.98 **	66.06 *
FDM 10 x FDM 12	2.53	-0.70	3.27	2.60	88.07	70.12	108.08*	107.41 *
FDM 10 x FDM 37	-3.66	-4.00	4.29	-3.95	39.48	18.19	44.35	12.25
FDM 10 x African Tall	-25.78 **	-37.53 **	9.84	-11.84	-26.14	-55.60**	-11.01	-46.89 **
FDM 10 x FDM 36	-5.20	-14.07	4.23	-2.63	62.41*	29.39	49.19	10.89
FDM 8 x FDM 7	-12.94	-17.57.	1.49	-2.86	57.96*	54.09	48.17	42.59
FDM 8 x FDM 12	1.73	-9.42	0.71	-7.79	86.52*	44.77	109.51 **	72.81 *
FDM 8 x FDM 37	-14.00	-21.42 *	1.56	1.56	27.28	26.18	32.99	22.96
FDM 8 x African Tall	-20.09 **	-27.27 **	5.45	-9.38	-1.78	-36.35 **	17.58	-23.80 *
FDM 8 x FDM 36	-7.00	-8.13	-6.15	-7.58	38.72	29.66	44.17	25.73
FDM 7 x FDM 12	-1.84	-18.07 *	-0.68	-5.19	97.08 **	50.18	113.95 **	71.50*
FDM 7 x FDM 37	-3.64	-17.64.	-2.99	-7.14	72.46.	66.63 *	52.62	46.10
FDM 7 x African Tall	-7.58	-9.57	0.00	-17.14	19.89	-21.35 *	-19.47	-46.90 **
FDM 7 x FDM 36	-10.04	-15.50.	7.35	4.29	45.70	39.60	47.72	33.06
FDM 12 x FDM 37	13.00	12.60	-3.55	-11.69	70.21	32.82	65.89 *	29.01
FDM 12 x African Tall	3.13	-13.19	-7.32	-25.97**	24.19	-27.78 **	45.26 **	-13.31
FDM 12 x FDM 36	-0.99	-10.24	-10.49	-16.88	64.87*	21.92	47.93	9.96
FDM 37 x African Tall	2.31	-13.88	-9.09	-21.87*	21.69	-21.46 *	35.16*	-8.56
FDM 37 x FDM 36	1.70	-7.80	-10.77	-12.12	64.64.	52.60	60.54 *	51.50*
African Tall x FDM 36	-16.12.	-21.21 **	-7.14	-21.21*	-13.13	-41.77	-20.67	-44.59 **
SE	0.44	0.50	0.03	0.03	44.49	51.37	7.54	8.70
CD at 5%	0.89	1.03	0.03	0.03	91.27	105.4	15.47	17.87

*P=0.05, **P=0.01, MP = Mid parent; BP = Better parent; SGR = Stem girth; LSR = Leaf stem ratio; GFY = Green fodder yield per plant; DMY = Dry matter yield

Table 5.Best parents chosen based on mean performance and high *gca* effects

S. No.	Traits	*Per se*	*gca* effects	Over all
1	Days to 50 % tasseling	African Tall	African Tall	African Tall
2	Plant height	African Tall	African Tall, FDM 37	African Tall
3	Number of leaves per plant	African Tall	African Tall	African Tall
4	Leaf length	African Tall, FDM 37	African Tall, FDM 37, FDM 36	African Tall, FDM 37
5	Leaf width	-	African Tall	-
6	Stem girth	African Tall	African Tall, FDM 7	African Tall
7	Leaf stem ratio	-	FDM 10, FDM 12,	-
8	Green fodder yield per plant	African Tall	African Tall	African Tall
9	Dry matter yield per plant	African Tall	African Tall	African Tall
		Best parent: African Tall		

Table 6. Best hybrids selected based on mean performance, high *sca* effects and heterobeltiosis

Characters	*Per se*	*sca* effects	Heterobeltiosis
Days to 50 % tasseling	FDM 10 x African Tall	FDM 8 x FDM 7, FDM 37 x African Tall, FDM 10 x FDM 36, FDM 8 x FDM 37,	-
Plant height	FDM 37 x African Tall, FDM 7 x African Tall	FDM 8 x FDM 12, FDM 37 x African Tall, FDM 37 x FDM 36, FDM 12 x FDM 36, FDM 12 x FDM 37, FDM 7 x FDM 12, FDM 7 x FDM 36, FDM 10 x FDM 36, FDM 8 x FDM 36, FDM 10 x FDM 37, FDM 7 x FDM 37, FDM 10 x FDM 8, FDM 10 x FDM 12, FDM 8 x FDM 37, FDM 7 x African Tall, FDM 12 x African Tall, FDM 8 x FDM 7,	FDM 12 x FDM 36, FDM 8 x FDM 12, FDM 10 x FDM 36, FDM 8 x FDM 36, FDM 10 x FDM 12
Number of leaves	FDM 7 x African Tall	FDM 7 x FDM 36, FDM 7 x FDM 37, FDM 10 x FDM 37, FDM 12 x FDM 37, FDM 37 x FDM 36, FDM 12 x African Tall, FDM 8 x FDM 12, FDM 7 x African Tall, FDM 8 x FDM 36, FDM 10 x FDM 12, FDM 10 x African Tall, FDM 10 x FDM 8	FDM 10 x FDM 37, FDM 7 x FDM 36, FDM 12 x FDM 37, FDM 8 x FDM 12, FDM 7 x FDM 37
Leaf length	FDM 37 x African Tall, FDM 12 x African Tall, FDM 10 x FDM 36	FDM 10 x FDM 36, FDM 8 x FDM 12, FDM 10 x FDM 12, FDM 37 x African Tall, FDM 12 x African Tall, FDM 7 x FDM 12, FDM 7 x African Tall	FDM 8 x FDM 12, FDM 10 x FDM 12,FDM 7 x FDM 12, FDM 10 x FDM 36
Leaf width	-	FDM 8 x FDM 12, FDM 10 x FDM 36, FDM 7 x African Tall, FDM 12 x FDM 36, FDM 8 x African Tall, FDM 12 x African Tall, FDM 37 x African Tall, FDM 7 x FDM 12, FDM 10 x FDM 37, FDM 10 x FDM 8	FDM 8 x FDM 12
Stem girth	FDM 7 x African Tall	FDM 12 x FDM 37, FDM 12 x African Tall, FDM 37 x African Tall, FDM 10 x FDM 7	-
Leaf stem ratio	FDM 10 x FDM 12	FDM 7 x FDM 36	-
Green fodder yield per plant	FDM 7 x African Tall, FDM 37 x African Tall, FDM 12 x African Tall	FDM 10 x FDM 36, FDM 37 x FDM 36, FDM 37 x African Tall, FDM 8 x FDM 12, FDM 10 x FDM 7,FDM 12 x African Tall, FDM 7 x FDM 37, FDM 7 x FDM 12, FDM 7 x African Tall, FDM 10 x FDM 12, FDM 8 x FDM 7	FDM 10 x FDM 12, FDM 7 x FDM 37,FDM 8 x FDM 7, FDM 37 x FDM 36, FDM 7 x FDM 12
Dry matter yield per plant	FDM 37 x African Tall, FDM 12 x African Tall, FDM 8 x African Tall	FDM 37 x African Tall, FDM 12 x African Tall, FDM 10 x FDM 7, FDM 7 x FDM 12, FDM 37 x FDM 36, FDM 8 x FDM 12, FDM 7 x FDM 36, FDM 8 x African Tall, FDM 10 x FDM 36, FDM 8 x FDM 36	FDM 10 x FDM 12, FDM 8 x FDM 12, FDM 7 x FDM 12, FDM 10 x FDM 7, FDM 37 x FDM 36