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Assessment of Economic Heterosis in Dual Purpose Sorghum [*Sorghum bicolor* (L.) Moench]

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ABSTRACT

10 lines and 3 tester using L x T mating design consisted of 46 entries including 10 lines, 3 testers, 30 hybrids and three checks *viz.*, CSV 23, CSV 27 and CSH25. These were evaluated in RBD with three replications during *kharif* 2015 in four environments *viz*., 22.5 x 5 cm (E_1), 30 x 10 cm (E_2), 45 x 10 cm (E_3) and 60 x 10 cm (E_4) at Rajasthan college of Agriculture, Udaipur in RBD with three replications. 24 crosses exhibited economic heterosis. Therefore these crosses may be identified as superior crosses for these characters. Three crosses L_2 x T_3, L_6 x T_3 and L_1 x T_3 having economic heterosis for grain yield in E_2. Where cross L_2 x T_3 and L_6 x T_3 also having economic heterosis for dry fodder yield in E_2. These crosses had good SCA effects and involving at least one good general combiner parent. This indicates superiority of F_1 on account of accumulation of dominant genes. Two dual purpose crosses ICSA 29004 × SPV 1822 (L_2 x T_3) and ICSA 29012 × SPV 1822 (L_6 x T_3) were identified for multilocation testing as these were having economic heterosis more than 15 per cent for grain yield and dry fodder yield. Grain purpose cross ICSA 29003 × SPV 1822 (L_1 x T_3) is also identified for multilocation testing as it had very high economic heterosis for grain yield (56.65%) in medium spacing environment *i.e.*30 x 10 cm along with good nicking in flowering and taller male parent.

Introduction

Sorghum bicolor (L.) Moench (2n = 20), family poaceae is one of the most important crops in the world because of its adaptation to a wide range of ecological conditions, suitability for low input cultivation and diverse uses (Doggett, 1988).

Sorghum green fodder is one of the cheapest sources of feed for milch, meat and draft animals. Among the cereals, sorghum plays an important role being grain cum fodder crop. Mainly three type of sorghum is cultivated i.e. grain, fodder and multicut sorghum. Grain sorghum is having low plant height and high harvest index, fodder sorghum having tall plants and multicut is leafy, thin stem and more tillering ability.

L x T mating designs was used the estimation for economic heterosis in present investigation and information to be derived. Maintenance of plant population in per unit area is very difficult. Buffering ability of the genotypes is the only way to cope up with the available space. Therefore, breeding for buffering ability is another important aspect in genetic improvement of crop plants. Development of such a hybrid/variety, which gives a constant and desirable performance over wide range of spacing, is needed. For this, it is desirable to see the impact of various spacing on the yield of sorghum genotypes and identification of genotypes having buffering ability.

Hybrid vigor and its commercial exploitation have paid rich dividends in *kharif* sorghum leading to quantum jump in sorghum production. However, still it is far below in comparison to maize and pearl millet therefore there is a need for critical studies on combining ability and heterosis involving diverse source of male sterile lines and R lines.

In view of the above facts, present investigation entitled "Assessment of Economic Heterosis in Dual Purpose Sorghum [*Sorghum bicolor* (L.) Moench]" was planned and genotypes were evaluated during kharif, 2014 and *kharif*, 2015 at Instructional Farm, Rajasthan college of Agriculture,

Materials and Methods

The present investigation entitled "Assessment of Economic Heterosis in Dual Purpose Sorghum [*Sorghum bicolor* (L.) Moench]" was conducted at Instructional farm, Rajasthan College of Agriculture, Udaipur during kharif 2014 and *kharif* 2015. On the basis of days to flowering and suitability for dual purpose 36 lines were received from ICRISAT. After evaluation at this station 10 lines were identified on the basis of nicking of flowering. Three testers were identified on the basis of availability of restorer gene and past performance. Checks CSV 23, CSV 27 and CSH 25 were national checks in coordinated trials.

The experimental material comprised of 10 male sterile lines *viz.*, ICSA 29003 (L_1), ICSA 29004 (L_2), ICSA 29006 (L_3), ICSA 29010 (L_4), ICSA 29011 (L_5), ICSA 29012 (L_6), ICSA 29013 (L_7), ICSA 29014 (L_8), ICSA 29015 (L_9) and ICSA 29016 (L_{10}), three restorer testers *viz.*, SPV 245 (T_1), SPV 1430 (T_2) and SPV 1822 (T_3) and three checks *viz.* CSV 23, CSV 27, and CSH 25. These 10 lines and three testers were crossed in factorial fashion to obtain the 30 hybrids. The crossing programme was attempted at Udaipur during kharif 2014 and at Warangal during rabi 2014-15.In this experiment total 46 genotypes (10 lines, 3 testers, 30 crosses and 3 checks) were grown in a randomized block design with three replications in four different environments during *kharif* 2015 at Instructional farm, Rajasthan College of Agriculture, Udaipur (Rajasthan).

Each genotype was sown in a single row plot of 2 meter length maintaining a separate crop geometry (spacing) for each environments. The row to row and plant to plant spacing was 22.5 cm x 5 cm, 30 cm x 10 cm, 45 cm x 10 cm and 60 cm x 10 cm in $E_{1,}$ $E_{2,}$ E_3 and $E_{4,}$ respectively observations were recorded on days to 50 % flowering, days to maturity, plant height (cm), green fodder yield (q ha^{-1}), dry fodder yield (q ha^{-1}), stay greenness (0-1 scale), ear head length (cm), number of primaries per plant, number of seeds per primaries, seed index, harvest index (%),grain yield (q ha^{-1}), protein content in fodder (%) and protein content in grain (%). To record different observation five competitive plants in each plot were tagged at random. Plot means of all the characters were subjected to various statistical analysis except stay greenness.

Analysis of variance

The plot means of each character were subjected to analysis of variance for individual environment as well as over the environment where error variance in different environment were homogeneous using least square technique of Fisher (1932).

Economic heterosis

Economic heterosis, expressed as per cent deviation toward desirable direction over standard check. Economic heterosis were calculated according to the method suggested Meredith and Bridge (1972) for individual as well as over the environments where mean square due to crosses were significant. Whereas, over the environment heterosis was calculated where error variance was homogeneous and mean square due to crosses were significant.

$$Economic\ heterosis\ (\%) = \frac{\left(\overline{F_1} - \overline{BC}\right)}{\overline{BC}} \times 100$$

It's significance was tested by using student 't' test.

$$t_{EDF} = \frac{\overline{F_1} - \overline{BC}}{SE_{\left(\overline{F_1} - \overline{BC}\right)}}$$

$$SE_{\left(\overline{F_1} - \overline{BC}\right)} = \sqrt{\frac{2MSE}{n}}$$

Where,

$\overline{F_1}$	=	Mean value of hybrid
$\overline{BC}$	=	Mean value of best check
n	=	Divisor in respective conditions *i.e.* r in case of individual environment and rs in case of over the environments.
r,s	=	Number of replications and environments, respectively.
MSE	=	Error mean square for individual and over the environments, respectively.
t_{EDF}	=	Student's 't' at error degree of freedom

To calculate economic heterosis parent and check had higher mean values were considered desirable for all the characters except traits like days to 50 per cent flowering and days to maturity where lower mean value was considered desirable and economic heterosis was calculated in desirable directions only.

Results and Discussion

The magnitude of economic heterosis expressed as per cent increase or decrease of F_1 value standard check (standard heterosis or economic heterosis) for various trait under different environments and pooled over the environment are presented in table 1 to 4. The character wise results are summarized in following paragraphs:

Days to 50 flowering

Analysis of variances revealed significant difference between crosses in all the four environments. The mean square parents vs crosses were significant in E_1, E_2, E_3 and E_4. The economic heterosis was significant for L_8 x T_1 (-11.94 %) and L_4 x T_2 (-17.41 %) in E_1; L_8 x T_1 (-8.28 %) in E_2 and L_2 x T_1 (-8.22 %), L_4 x T_1 (-10.96 %), L_5 x T_1 (-5.94 %), L_7 x T_1 (-10.05 %), L_8 x T_1 (-14.61 %), L_9 x T_1 (-5.48 %), L_5 x T_2 (-9.59 %), L_6 x T_2 (-14.16 %), L_8 x T_2 (-14.16 %), L_{10} x T_2 (-7.31 %), L_4 x T_3 (-10.05 %), L_6 x T_3 (-5.94 %), L_7 x T_3 (-9.13 %) and L_8 x T_3 (-13.24 %) in E_3 (Table 1).

Days to maturity

Analysis of variances revealed significant difference between crosses in all the four environments.

The P Vs C was significant in E_1, E_2, E_3 and E_4. Economic heterosis was not significant in any of the cross (Table 1).

Plant height

Difference between crosses and P Vs C were significant in all the four environments and over the environments.

The economic heterosis was significant for 3 and 1 crosses in E_2 and E_3 respectively. Crosses exhibited significant economic heterosis were L_3 x T_3 (21.88 %), L_5 x T_3 (18.01 %) and L_7 x T_3 (12.19 %) in E_2 and L_6 x T_3 (12.50%) in E_3 (Table 1).

Green fodder yield (q ha^{-1})

Analysis of variances revealed significant difference between crosses in all the four environments.

The P Vs C were significant in E_2, E_3 and E_4. Economic heterosis was significant for L_3 x T_3 (20.64 %), L_5 x T_3 (26.81 %) and L_{10} x T_3 (17.75 %) in (E_2) only.

Maximum economic heterosis was 26.81 per cent (L_5 x T_3 in E_2) (Table 2).

Dry fodder yield (q ha^{-1})

Analysis of variances revealed significant difference between crosses in all the four environments. The P Vs C were significant in E_1, E_2, E_3 and E_4. The economic heterosis was significant in E_2 only. Crosses exhibited significant economic heterosis in E_2 were L_3 x T_3 (16.63 %) and L6 x T_3 (37.97 %). (Table 2)

Ear head length

Analysis of variances revealed significant difference between crosses and P Vs C for all the four environments and over the environments.

Economic heterosis was not significant in any cross in any environment. (Table 2)

Number of primaries per plant

Analysis of variances revealed significant difference between crosses in all the four environments. The P Vs C were significant in E_2, E_3 and E_4. Economic heterosis was not significant in any cross in any environment (Table 3).

Number of seeds per primary

Analysis of variances revealed significant difference between crosses and P Vs C in all the four environments. Economic heterosis was significant for L_8 x T_1 (11.72 %), L_4 x T_2 (27.43 %) and L_7 x T_3 (11.47 %) in E_1, L_7 x T_2 (39.18 %) in E_2 and L_2 x T_1 (19.68 %), L_4 x T_2 (34.54 %), L_2 x T_3 (15.66 %), L_4 x T_3 (36.95 %) in E_3 (Table 3)

Seed index

Analysis of variances revealed significant difference between crosses and P Vs C in all the four environments. Economic heterosis was significant for 3 crosses viz., L_3 x T_1 (7.69), L_3 x T_2 (5.86) and L_5 x T_3 (4.30) only in E_4 (Table 3)

Harvest index

Analysis of variances revealed significant difference between crosses in E_3 and E_4 only and P Vs C was non-significant in all the four environments.

The heterosis for harvest index ranged from 46.10 (L_{10} x T_1) to -53.75 per cent (L_3 x T_3) in E_3 and 26.54 (L_7 x T_3) to -14.24 per cent (L_1 x T_2) in E_4. Positive heterosis was significant for 8 crosses in E_3 and 6 crosses in E_4 where as negative heterosis was significant for 3 crosses in E_3 and 5 crosses in E_4. Heterobeltiosis was significant for cross L_{10} x T_1 (36.80 %) in E_3 and L_2 x T_1 (10.33%) crosses in E_4. Economic heterosis was not significant in any cross in any environment (Table 4).

Grain yield

Difference between crosses and P Vs C were significant in all the four environments. Economic heterosis was significant for 3 crosses *viz.*, L_1 x T_3 (56.65 %), L_2 x T_3 (15.27 %) and L_6 x T_3 (20.20 %) in E_2 only (Table 4)

Protein content in grain

Difference between crosses and P Vs C were significant in all the four environments. Economic heterosis was significant for L_1 x T_2 (9.49%) cross in E_3 only (Table 4)

Protein content in fodder

Difference between crosses and P Vs C were significant in all the four environments. Economic heterosis was significant for 2 crosses viz., L_2 x T_3 (8.34%) and L_4 x T_3 (6.66 %) in E_1 (Table 4)

Table.1 Economic heterosis for days to 50% flowering, days to maturity and plant height

S. No.	Crosses	Days to 50% flowering				Days to maturity				Plant height			
		E1	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**
1.	L1 x T1	-	-	-0.91	-	-	-	-	-	-	-	-	-
2.	L2 x T1	-	-	-8.22**	-	0.00	-	-	-	-	2.49	-	-
3.	L3 x T1	-	-	-	-	-	-	-	-	-	-	-	-
4.	L4 x T1	-	-	-10.96**	-	-	-	-	-	-	-	-	-
5.	L5 x T1	-	-0.52	-5.94*	-	-3.61**	-	-	-	-	-	-	-
6.	L6 x T1	-	-	-4.57	-	-3.53**	-	-	-	-	-	-	-
7.	L7 x T1	-	-	-10.05**	-	-4.75**	-	-	-	-	-	-	-
8.	L8 x T1	-11.94*	-	-14.61**	-1.08	-7.28**	-	-	-	-	-	-	-
9.	L9 x T1	-	-	-5.48*	-	-1.27	-	-	-	-	-	-	-
10.	L10 x T1	-	-	-	-	-0.32	-	-	-	2.00	-	-	-
11.	L1 x T2	-	-	-	-	-	-	-	-	-	-	-	-
12.	L2 x T2	-	-	-2.74	-	-	-	-	-	-	-	-	-
13.	L3 x T2	-	-	0.00	-	-	-	-	-	-	-	-	-
14.	L4 x T2	-17.41**	-	-3.20	-	-	-	-	-	-	-	-	-
15.	L5 x T2	-	-	-9.59**	-	-	-	-	-	-	-	-	-
16.	L6 x T2	-0.50	-1.55	-14.16**	-	-	-	-	-	-	-	-	-
17.	L7 x T2	-2.49	-	-1.83	-	-1.00	-	-	-	-	-	-	-
18.	L8 x T2	-9.45	-8.25*	-14.16**	-	-	-	-	-	-	-	-	-
19.	L9 x T2	-	-	-	-	-	-	-	-	-	-	-	-
20.	L10 x T2	-	-	-7.31**	-	-6.33**	-1.07	-1.06	-0.35	-	-	-	-
21.	L1 x T3	-	-	-	-	-4.25**	-	-	-	-	-	7.03	2.60
22.	L2 x T3	-	-	-	-	-0.68	-	-	-	-	5.40	-	-
23.	L3 x T3	-	-	-	-	-	-	-	-	1.33	21.88**	-	2.05
24.	L4 x T3	-	-	-10.05**	-	-4.58**	-	-	-	1.47	-	-	2.46
25.	L5 x T3	-	-	-	-	-3.28**	-	-	-	-	18.01**	-	-
26.	L6 x T3	-	-	-5.94*	-	-1.96	-	-	-	-	5.96	12.50*	-
27.	L7 x T3	-	-	-9.13**	-	-3.27**	-	-	-	0.00	12.19*	-	0.00
28.	L8 x T3	-	0.00	-13.24**	-5.38	-	-	-	-	-	-	1.56	3.55
29.	L9 x T3	-	-	-	-	-	-	-	-	-	-	-	-
30.	L10 x T3	-	-	-	-	-	-	-	-	-	-	4.69	10.79

** Significant at 5 and 1 per cent, respectively.

Table.2 Heterosis for green fodder yield, dry fodder yield and ear head length

S. No.	Crosses	Green fodder yield				Dry fodder yield				Ear head length			
		E1	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**
1.	L1 x T1	-	-	-	-	-	-	-	-	-	-	-	-
2.	L2 x T1	-	-	-	-	-	-	-	-	-	-	-	-
3.	L3 x T1	-	-	-	-	-	-	-	-	-	-	-	-
4.	L4 x T1	-	-	-	-	-	-	-	-	-	-	-	-
5.	L5 x T1	-	-	-	-	-	-	-	-	-	-	-	-
6.	L6 x T1	-	-	-	-	-	-	-	-	-	-	-	-
7.	L7 x T1	-	-	-	-	-	-	-	-	-	-	-	-
8.	L8 x T1	-	-	-	-	-	-	-	-	-	-	-	-
9.	L9 x T1	-	-	-	-	-	-	-	-	-	-	-	-
10.	L10 x T1	-	-	-	-	-	-	-	-	-	-	-	-
11.	L1 x T2	-	-	-	-	-	-	-	-	-	-	-	-
12.	L2 x T2	-	-	-	-	-	-	-	-	-	-	-	-
13.	L3 x T2	-	-	-	-	-	-	-	-	-	-	-	-
14.	L4 x T2	-	-	-	-	-	-	-	-	-	-	-	-
15.	L5 x T2	-	-	-	-	-	-	-	-	-	-	-	-
16.	L6 x T2	-	-	-	-	-	-	-	-	-	-	-	-
17.	L7 x T2	-	-	-	-	-	-	-	-	-	-	-	-
18.	L8 x T2	-	-	-	-	-	-	-	-	-	-	-	-
19.	L9 x T2	-	-	-	-	-	-	-	-	-	-	-	-
20.	L10 x T2	-	-	-	-	-	1.18	-	-	-	-	-	-
21.	L1 x T3	-	-	-	-	-	-	8.63	-	-	-	-	-
22.	L2 x T3	-	-	-	2.33	-	16.63**	-	2.93	-	-	-	2.33
23.	L3 x T3	-	20.64**	-	-	-	10.26	-	-	-	20.64**	-	-
24.	L4 x T3	-	-	-	-	-	-	-	-	-	-	-	-
25.	L5 x T3	-	26.81**	-	-	-	0.71	-	-	-	26.81**	-	-
26.	L6 x T3	-	-	-	-	-	37.97**	-	-	-	-	-	-
27.	L7 x T3	-	-	-	-	-	-	-	-	-	-	-	-
28.	L8 x T3	-	-	-	-	-	-	-	-	-	-	-	-
29.	L9 x T3	-	-	-	-	-	-	-	-	-	-	-	-
30.	L10 x T3	-	14.75**	-	-	-	-	-	-	-	14.75**	-	-

** Significant at 5 and 1 per cent, respectively.

Table.3 Economic heterosis for number of primaries per plant, number of seeds per primary and Seed index

S. No.	Crosses	Number of primaries per plant				Number of seeds per primary				Seed index			
		E1	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**
1.	L1 x T1	-	-	-	-	-	-	-	-	-	-	-	-
2.	L2 x T1	-	-	-	-	-	-	19.68*	-	-	-	-	-
3.	L3 x T1	-	-	-	-	-	-	-	-	-	-	8.35	7.69**
4.	L4 x T1	-	-	-	-	-	-	-	-	-	-	-	-
5.	L5 x T1	-	-	-	-	-	-	-	-	-	-	-	2.38
6.	L6 x T1	-	-	-	-	-	-	-	-	-	-	-	-
7.	L7 x T1	-	-	-	-	-	0.00	-	-	-	-	-	-
8.	L8 x T1	-	-	-	-	11.72*	3.27	-	-	-	-	-	-
9.	L9 x T1	-	-	-	-	2.00	-	-	-	-	-	-	-
10.	L10 x T1	-	-	-	-	-	-	-	-	-	-	-	-
11.	L1 x T2	-	-	-	-	-	-	-	-	-	-	-	-
12.	L2 x T2	-	-	-	-	-	-	0.80	-	-	-	-	-
13.	L3 x T2	-	-	-	-	-	-	-	-	-	-	-	5.86**
14.	L4 x T2	-	-	-	-	27.43**	-	34.54**	-	-	-	-	-
15.	L5 x T2	-	-	-	0.38	-	-	4.82	-	-	-	-	-
16.	L6 x T2	-	-	-	-	-	-	8.03	-	-	-	-	-
17.	L7 x T2	-	-	-	-	-	39.18**	11.24	-	-	-	-	-
18.	L8 x T2	-	-	-	-	-	-	-	-	-	-	-	-
19.	L9 x T2	-	-	-	-	-	-	-	-	-	-	-	-
20.	L10 x T2	-	-	-	-	-	-	-	-	-	-	-	-
21.	L1 x T3	-	-	-	-	-	-	-	0.77	-	-	-	-
22.	L2 x T3	-	-	-	-	-	3.67	15.66*	-	-	-	-	0.82
23.	L3 x T3	-	-	-	-	-	-	-	-	-	-	0.99	2.56
24.	L4 x T3	-	-	-	-	6.48	-	36.95**	-	-	-	0.83	-
25.	L5 x T3	-	-	1.80	-	-	-	-	-	-	-	-	4.30**
26.	L6 x T3	-	-	-	-	-	-	-	-	-	-	-	-
27.	L7 x T3	-	-	-	-	11.47*	-	-	-	-	-	-	-
28.	L8 x T3	-	-	-	-	-	7.76	-	-	-	-	-	0.82
29.	L9 x T3	-	-	-	-	-	-	-	-	-	-	-	-
30.	L10 x T3	-	-	-	-	-	-	-	-	-	-	-	-

** Significant at 5 and 1 per cent, respectively.

Table.4 Economic heterosis for harvest index, grain yield, protein content in grain (g) and protein content in fodder (f)

S. No.	Crosses	Harvest index		Grain yield				Protein content (g)				Protein content (f)	
		E3	**E4**	**E1**	**E2**	**E3**	**E4**	**E1**	**E2**	**E3**	**E4**	**E1**	**E2**
1.	L1 x T1	-	-	-	-	-	-	-	-	-	-	-	-
2.	L2 x T1	-	0.44	-	-	-	-	-	-	-	-	-	-
3.	L3 x T1	-	-	2.62	-	-	-	-	-	-	-	-	-
4.	L4 x T1	-	-	-	-	-	-	-	-	-	-	-	-
5.	L5 x T1	-	-	-	-	-	-	-	-	-	-	-	-
6.	L6 x T1	-	-	-	-	1.50	-	-	-	-	-	-	-
7.	L7 x T1	-	-	-	-	-	-	-	-	-	-	-	-
8.	L8 x T1	-	-	-	-	-	-	-	-	-	-	-	-
9.	L9 x T1	-	-	-	-	-	-	-	-	-	-	-	-
10.	L10 x T1	2.20	-	-	-	-	-	-	-	-	-	1.76	-
11.	L1 x T2	-	-	-	-	-	-	-	2.12	9.49**	-	-	-
12.	L2 x T2	-	-	-	-	-	-	-	-	-	-	-	-
13.	L3 x T2	-	-	-	-	-	-	-	-	-	-	-	-
14.	L4 x T2	-	-	-	-	-	-	-	-	-	-	-	-
15.	L5 x T2	-	-	-	-	-	-	-	-	-	-	-	-
16.	L6 x T2	-	-	-	-	-	-	-	-	-	-	-	-
17.	L7 x T2	-	-	-	-	-	-	-	-	-	-	-	-
18.	L8 x T2	-	-	-	-	-	-	-	-	-	-	-	-
19.	L9 x T2	-	-	-	-	-	-	-	-	-	-	-	-
20.	L10 x T2	-	-	-	-	-	-	-	-	-	-	-	-
21.	L1 x T3	-	-	-	56.65**	-	-	-	-	-	-	-	-
22.	L2 x T3	-	-	-	15.27**	-	-	0.94	-	-	-	8.34**	-
23.	L3 x T3	-	-	-	7.88	-	-	-	-	-	-	-	-
24.	L4 x T3	-	-	-	-	-	-	-	-	-	-	6.66**	-
25.	L5 x T3	-	-	-	2.96	-	-	-	-	-	-	-	-
26.	L6 x T3	-	-	-	20.20**	-	-	-	-	-	-	-	-
27.	L7 x T3	-	-	-	-	-	-	-	-	-	-	-	-
28.	L8 x T3	-	-	-	-	-	-	-	-	-	-	-	-
29.	L9 x T3	-	-	-	-	-	-	-	-	-	-	-	-
30.	L10 x T3	-	-	-	-	-	-	-	-	-	-	-	-

** Significant at 5 and 1 per cent, respectively.

Economic heterosis was significant for nine characters in one or more environments but, different crosses exhibited economic heterosis for different characters. Maximum number of economic heterotic crosses were observed for days to flowering (17) followed by number of seeds per primary (8), plant height (6), grain yield (3), green fodder yield (3), seed index (3), dry fodder yield (2), protein content in fodder (2) and protein content in grain (1). The crosses exhibited economic heterosis in more than one environment were L_8 x T_1, in E_1 and E_3 and L_8 x T_2 in E_2 and E_3 for days to flowering; L_4 x T_2 in E_1 and E_3 for number of seeds per primary; L_3 x T_3 in E_2 and pool for plant height and L_2 x T_3 in E_1, E_2 and E_3, L_4 x T_3 in E_1 and E_3, L_5 x T_3 in E_2 and E_4, L_6 x T_3 in E_2 and E_3 and L_7 x T_3 in E_1, E_2, E_3 and pool for different characters. There were eight crosses exhibited economic heterosis for two characters in an environment *viz*., L_2 x T_1 (E_3), L_8 x T_1 (E_1), L_4 x T_2 (E_1) and L_4 x T_3 (E_3) for days to flowering and number of seed per primary, L_3 x T_3 (E_2) and L_5 x T_3 (E_2) for plant height and green fodder yield and L_2 x T_3 (E_2), L_6 x T_3 (E_2) for grain yield and dry fodder yield. Cross L_6 x T_3 also exhibited economic heterosis for plant height and early flowering in E_3. This indicates that for grain yield three crosses *viz*., L_1 x T_3, L_2 x T_3 and L_6 x T_3 exhibited economic heterosis out of them two crosses *viz.*, L_2 x T_3 and L_6 x T_3 were also heterobeltiosis for dry fodder yield in E_2 that is at spacing 30 x 10 cm.

Apart from above crosses cross L_6 x T_3 had economic heterosis for days to 50 % flowering and plant height in E_3 and for dry fodder yield in E_2 and L_2 x T_3 for dry fodder yield in E_2, protein content in fodder in E_1 and number of primaries per plant in E_3 may be utilized for these characters.

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