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Estimation of Heterosis, Heterobeltiosis and Economic Heterosis in Dual Purpose Sorghum [*Sorghum bicolor* (L.) Moench]

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The present investigation was under taken for 10 lines and 3 tester using line x tester 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 created by using different spacing *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 Instructional farm Rajasthan college of Agriculture, Udaipur in randomized block design with three replications. Some of the parents out crossed the limit of best checks for dry fodder yield, green fodder yield, protein content in grain and protein content in fodder in one or other environments. 24 crosses exhibited economic heterosis. Therefore these crosses may be identified as superior crosses for these characters. Significance of line, tester and line x tester mean square revealed that both additive as well as non additive variance were important in the inheritance of these characters. The contribution of line x testers sum of square was maximum in most of the characters in most of the environments. Three crosses L_2 x T_3, L_6 x T_3 and L_1 x T_3 having economic heherosis 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. Finaly 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 multi location testing as these were having economic heterosis more than 15 per cent for grain yield and dry fodder yield, good SCA, involving one good GCA parents, nicking in flowering in normal spacing environment and male parent taller than the female parent. Apart from above, grain purpose cross ICSA 29003 × SPV 1822 (L_1 x T_3) is also identified for multi location 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. This cross (ICSB 29003 × SPV 1822) also recommended for selection of transgressive segregants in segregating generations as this cross also having good SCA and involved both good general combiner parents.

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 occupies fifth position after wheat, rice, maize and barley at world level, both in area and production. The crop is widely grown for food, feed, fodder, forage and fuel in the semi-arid tropics (SAT) of Asia, Africa, America and Australia. It occupies 58.20 m ha area in the world with an annual grain production of 68.87 m tones and productivity of 1535 kg/ha (FAO, 2015). In India, it covers about 5.82 m ha with an annual grain production of 5.39 m tonnes and productivity of 926 kg/ha (FAO, 2015). India is largest producer of sorghum in the world (FAO, 2015). The major sorghum growing states in India are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan, Tamil Nadu, Uttar Pradesh and Gujarat. Area under sorghum reduced a large since independence.

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. The multicut sorghum fulfills the requirement of green fodder particularly during summer but needs irrigation facilities. The grain and fodder sorghum mainly cultivated in rainy season in north India and in both rainy and post rainy in south India. In Rajasthan area under grain sorghum is very low.

L x T mating designs was used the estimation for heterosis, heterobeltiosis and 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 heterosis, heterobeltiosis and economic heterosis analysis in Dual Purpose Sorghum [*Sorghum bicolor* (L.) Moench] has been 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 **"**heterosis, heterobeltiosis and economic heterosis analysis in dual purpose sorghum [*Sorghum bicolor* (L.) Moench]**"** was conducted at Instructional farm, Rajasthan College of Agriculture, Udaipur during kharif 2014 and *kharif* 2015. To met out the objectives. The study was completed through Line x Tester mating designs.

Geographically Instructional Farm is situated at 24° - 35' North latitude and 73° - 42' East longitude. The elevation of institution farm is 582.17 meters above mean sea level. The

climatic conditions of the area represent subtropical condition with humid climate. The soil of experimental fields was clay loam, deep, well drained, alluvial in origin and having fairly good moisture holding capacity. 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).

Heterosis, heterobeltiosis and economic heterosis

Heterosis is expressed as per cent deviation from mid parent, whereas heterobeltiosis and economic heterosis, expressed as per cent deviation toward desirable direction over better parent and standard check, respectively. Heterosis, heterobeltiosis and economic heterosis were calculated according to the method suggested by Shull (1914), Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively 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.

$$Heterosis \quad (\%) \quad = \quad \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

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

$$t_{EDF} = \frac{\overline{F_1} - \overline{MP}}{SE_{(\overline{F_1} - \overline{MP})}}$$

$$SE_{(\overline{F_1} - \overline{MP})} = \sqrt{\frac{3\,MSE}{2\,n}}$$

$$Heterobeltiosis\ (\%) = \frac{\left(\overline{F_1} - \overline{BP}\right)}{\overline{BP}} \times 100$$

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

$$t_{EDF} = \frac{\overline{F_1} - \overline{BP}}{SE_{(\overline{F_1} - \overline{BP})}}$$

$$SE_{(\overline{F_1} - \overline{BP})} = \sqrt{\frac{2\,MSE}{n}}$$

Economic heterosis:

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

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

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

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

Where,

$\overline{F_1}$ = Mean value of hybrid

$\overline{MP}$ = Mean of two corresponding parents, $F_{1,s}$ i.e. $(P_1 + P_2)/2$

$\overline{BP}$ = Mean value of better parent

$\overline{BC}$ = 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.
MS E = Error mean square from (Table 7 and 8) for individual and over the environments, respectively.
t_{EDF} = Student's 't' at error degree of freedom

To calculate heterobeltiosis and 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 both heterobeltiosis and economic heterosis were calculated in desirable directions only.

Results and Discussion

The magnitude of heterosis expressed as per cent increase or decrease of F_1 value over mid parent (relative heterosis), superiority over better parent (heterobeltiosis) and standard check (standard heterosis or economic heterosis) for various trait under different environments and pooled over the environment are presented in table 1 to 13. 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. Heterosis ranged from -26.71 (L_4 x T_2) to 6.98 per cent (L_5 x T_3) in E_1, -17.59 (L_8 x T_2) to 12.20 per cent (L_3 x T_3) in E_2, -15.70 (L_6 x T_2) to 2.00 per cent (L_3 x T_3) in E_3 and -17.95 (L_8 x T_3) to 16.06 per cent (L_5 x T_2) in E_4. The negative heterosis was significant for 4 (E_1), 15(E_2), 15 (E_3) and 5 (E_4) crosses and positive for 3 (E_2) and 5 (E_4) crosses.

Heterobeltiosis was estimated for earliness. It was significant for 4, 12, 15 and 2 crosses in E_1, E_2, E_3 and E_4, respectively. The highest magnitude of heterobeltiosis was -24.55 (L_4 x T_2), -16.82(L_8 x T_2), -15.38 (L_8 x T_1) and -14.15 (L_8 x T_3) per cent in E_1, E_2, E_3 and E_4, respectively. Cross L_8 x T_2 had consistent significant heterobeltiosis in E_1, E_2, and E_3 environments and L_8 x T_3 in E_2, E_3, and E_4 environments.

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 were significant in E_1, E_2, E_3 and E_4.The magnitude of heterosis ranged from – 11.92 (L_8 x T_2) to 6.10 per cent (L_2 x T_2) in E_1, -11.53 (L_{10} x T_2) to 5.53 per cent (L_3 x T_1) in E_2, -8.10 (L_8 x T_1) to 7.93 per cent (L_3 x T_1) in E3 and – 10.37 (L_{10} x T_2) to 5.21 per cent (L_2 x T_2) in E_4. The 15, 20, 16 and 17 crosses exhibited significant and negative and 6, 7, 9 and 8 crosses exhibited significant and positive heterosis in E_1, E_2, E_3 and E_4, respectively.

For early maturity heterobeltiosis was significant for 9, 9, 9, and 8 crosses in E_1, E_2, E_3 and E_4, respectively. The highest magnitude of heterobeltiosis was -7.37 (L_2 x T_2), -6.67 (L_{10} x T_2), -6.00 (L_{10} x T_2) and -4.75 (L_7 x T_1) in E_1, E_2, E_3 and E4, respectively. Crosses L_{10} x T_2, L_1 x T_3, L_4 x

T_3, L_6 x T_3, L_7 x T_3, L_5 x T_1, L_6 x T_1, L_7 x T_1 and L_8 x T_1 exhibited significant heterobeltiosis in all the four environments and cross L_5 x T_3 in E_3 and E_4. Eonomic heterosis was not significant in any of the cross (Table 2).

Plant height

Difference between crosses and P Vs C were significant in all the four environments and over the environments. The heterosis ranged from -18.54 (L_1 x T_2) to 89.83 per cent (L_{10} x T_1) in E_1, -14.16 (L_7 x T_2) to 58.70 per cent (L_3 x T3) in E_2, 16.85 (L_2 x T_1) to 51.59 per cent (L_4 x T_1) in E_3, 16.75 (L_8 x T_2) to 53.24 per cent (L_4 x T_1) in E_4 and 7.64 (L_2 x T_2) to 44.77 per cent (L_3 x T_3) in pool. The heterosis in negative direction was significant in E_1 and E_2 in one cross each only. In positive direction it was significant in 16, 13, 16, 17 and 22 crosses in E_1, E_2, E_3, E_4 and pool, respectively. The heterobeltiosis in positive direction was significant for 13, 9, 10, 11 and 19 crosses in E_1 E_2, E_3, E_4 and pool respectively. The highest magnitude of heterobeltiosis was 62.65 (L_3 x T_1), 43.13 (L_2 x T_1), 35.87 (L_{10} x T_1), 44.04 (L_5 x T_2) and 40.16 (L_{10} x T_1) in E_1, E_2, E_3, E_4 and pool, respectively. Crosses L_5 x T_1 and L_{10} x T_1 in E_1, E_2, E_3, E_4 and pool, L_4 x T_1, L_6 x T_1, L_5 x T_2, L_3 x T_3, L_6 x T_3 exhibited significant heterobeltioss in more than three environments, L_3 x T_1, L_1 x T_3, L_4 x T_3, L_5 x T_3, L_8 x T_3, L_{10} x T_1 exhibited significant heterobeltioss in more than two 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 3).

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.The heterosis ranged from -49.84 (L_7 x T_1) to 103.85 per cent (L_9 x T_1) in E_1, -58.35 (L_3 x T_1) to 134.65 per cent (L_{10} x T_3) in E_2, -42.24 (L_6 x T_3) to 26.05 per cent (L_2 x T_3) in E_3 and -49.81 (L_6 x T_3) to 74.61 per cent (L_1 x T_2) in E_4. The 9, 15, 19 and 6 crosses exhibited significant negative and 13, 8, 5, and 11 crosses exhibited significant & positive heterosis E_1, E_2, E_3 and E_4, respectively.

Heterobeltiosis in positive direction was significant for 9, 5 and 4 crosses in E_1 E_2 and E_4 respectively. The highest magnitude of heterobeltiosis was 87.12 (L_1 x T_3), 76.36 (L_5 x T_3) and 63.99 per cent (L_1 x T_2) in E_1, E_2 and E_4 respectively. Crosses L_1 x T_2 in E_1 and E_4, L_8 x T_2 and L_2 x T_3 in E_2 and E_4 and L_5 x T_3 in E_1 and E_2 exhibited significant heterobeltiosis in more than one environment.

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 4).

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 heterosis ranged from -58.01 (L_{10} x T_2) to 64.84 per cent (L_1 x T_2) in E_1, -62.77 (L_6 x T_1) to 113.15 per cent (L_2 x T_3) in E_2, -58.01 (L_{10} x T_2) to 61.14 per cent (L_1 x T_3) in E_3 and -39.52 (L_8 x T_1) to 70.56 per cent (L_4 x T_1) in E_4. The 8, 15, 6 and 7 crosses exhibited significant and negative and 16, 9, 12, and 16 crosses exhibited significant and positive heterosis E_1, E_2, E_3 and E_4, respectively.

Heterobeltiosis in positive direction was significant for 10, 5, 4, and 9 crosses in E_1 E_2, E_3 and E_4, respectively. The highest

magnitude of heterobeltiosis was 51.30 (L_1 x T_2), 61.38 (L_6 x T_3), 30.56 per cent (L_1 x T_3) and 46.03 per cent (L_4 x T_1) in E_1, E_2, E_3 and E_4 respectively. Crosses L_3 x T_1 in E_3 and E_4, L_5 x T_1 in E_1 and E_3, L_2 x T_2 and L_3 x T_2 in E_1 and E_4 exhibited significant heterobeltiosis in more than one environment.

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 5).

Ear head length

Analysis of variances revealed significant difference between crosses and P Vs C for all the four environments and over the environments. Heterosis ranged from -16.47 (L_3 x T_1) to 25.00 (L_5 x T_1) in E1, -13.34 (L_6 x T_2) to 21.92 (L_7 x T_1) in E_2, -21.43 (L_{10} x T_2) to 27.61 (L_7 x T_3) in E_3, 13.92 (L_5 x T_1) to 23.64 (L_4 x T_1) in E_4 and -5.77 (L_9 x T_2) to 16.72 (L_5 x T_1) per cent in pool. The negative heterosis was significant for 1, 2, 5 and 3 crosses in E_1, E_2, E_3 and pool, respectively and positive heterosis was significant for 5,4,8,4 and 9 crosses in E_1, E_2, E_3, E_4 and pool, respectively.

Heterobeltiosis was significant for 2, 2, 2, 3 and 4 crosses in E_1, E_2, E_3, E_4 and pool, respectively. The highest magnitude of heterobeltiosis was 25.00 (L_5 x T_1), 20.27 (L_7 x T_1), 19.54 (L_7 x T_3) and 14.10 (L_7 x T_1) per cent in E_1, E_2, E_3, E_4 and pool, respectively. Cross L_7 x T_1 exhibited significant and positive heterobeltiosis in E_2, E_4 and pool. Economic heterosis was not significant in any cross in any environment (Table 6).

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.Magnitude of heterosis ranged from -40.95 (L_{10} x T_2) to 59.06 per cent (L_6 x T_3) in E_1, -37.31 (L_6 x T_2) to 75.65 per cent (L_4 x T_2) in E_2, -30.59 (L_3 x T_1) to 78.42 per cent (L_5 x T_1) in E_3 and -24.65 (L_5 x T_3) to 127.47 per cent (L_5 x T_2) in E_4. The negative heterosis was significant for 7, 4 and 4 crosses in E_2, E_3 and E_4, respectively and positive heterosis was significant for 9, 6 and 8 crosses in E_2, E_3 and E_4, respectively.

The heterobeltiosis in positive direction was significant for 3, 3, 1 and 5 crosses in E_1 E_2, E_3 and E_4, respectively. The highest magnitude of heterobeltiosis was 48.53 (L_6 x T_3), 52.32 (L_{10} x T_2), 25.00 (L_5 x T_1) and 84.03 per cent (L_5 x T_2) in E_1, E_2, E_3 and E_4 respectively. Crosses L_5 x T_1 in E_3 and E_4 and L_5 x T_2 and L_{10} x T_2 in E_2 and E_4 exhibited significant and positive heterobeltioss in more than one environment. Economic heterosis was not significant in any cross in any environment (Table 7).

Number of seeds per primary

Analysis of variances revealed significant difference between crosses and P Vs C in all the four environments. The heterosis ranged from -56.15 (L_1 x T_2) to 155.27 per cent (L_8 x T_1) in E_1, -54.69 (L_2 x T_1) to 80.42 per cent (L_7 x T_2) in E_2, -53.37 (L_{10} x T_3) to 142.75 per cent (L4 x T_2) in E_3 and -47.29 (L_9 x T_3) to 44.72 per cent (L_2 x T_3) in E_4. The negative heterosis was significant for 12, 8, 9 and 13 crosses in E_1, E_2, E_3 and E_4, respectively and positive heterosis was significant for 10, 10, 11 and 4 crosses in E_1, E_2, E_3 and E_4, respectively

The heterobeltiosis in positive direction was significant for 7, 3 and 6 crosses in E_1, E_2 and E_3, respectively. The highest magnitude of heterobeltiosis was 137.04 (L_8 x T_1), 59.35 (L7 x T_2) and 101.81 (L_4 x T_2) percent in E_1, E_2 and E_3, respectively. Crosses L_4 x T_2 and L_4

x T_3 in E_1 and E_3 and L_6 x T_2 and L_7 x T_2 in E_2 and E_3 exhibited significant and positive heterobeltioss in more than than one environment.

The 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 8).

Seed index

Analysis of variances revealed significant difference between crosses and P Vs C in all the four environments. The magnitude of heterosis ranged from 25.92 (L_6 x T_1) to -15.45 per cent (L_3 x T_2) in E_1, 30.53 (L_2 x T_2) to -21.55 per cent (L_3 x T_1) in E_2, 38.94 (L_4 x T_3) to -15.92 per cent (L_5 x T_1) in E_3 and 38.00 (L_{10} x T2) to -13.12 per cent (L_9 x T_1) in E_4. The positive heterosis was significant for 12, 12, 16 and 19 crosses and negative for 8, 12, 2 and 8 crosses in E_1 E_2, E_3 and E_4, respectively.

Heterobeltiosis in positive direction was significant for 6, 6, 11 and 16 crosses in E_1, E_2, E_3 and E_4 respectively. The maximum value of heterobeltiosis was 22.58 (L6 x T1), 24.72 (L_5 x T_3), 38.87 (L_4 x T_3) and 34.39 per cent (L_2 x T_3) in E_1, E_2, E_3 and E_4 respectively. Crosses L_3 x T_1 and L_4 x T_2 exhibited significant and positive heterobeltiosis in E_3 and E_4 and L_2 x T_2 in E_1 and E_2.

The 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 9).

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 10).

Grain yield

Difference between crosses and P Vs C were significant in all the four environments. The magnitude of heterosis ranged from 98.78 (L_2 x T_2) to -56.19 per cent (L_5 x T_2) in E_1, 251.38 (L_1 x T_3) to -57.79 per cent (L_6 x T_1) in E_2, 75.59 (L_2 x T_1) to -38.86 per cent (L_3 x T_2) in E_3 and 143.14 (L_6 x T_1) to -56.08 per cent (L_6 x T_3) in E_4. The positive heterosis was significant for 15, 10, 19 and 9 crosses and negative for 7, 11, 6 and 14 crosses in E_1 E_2, E_3 and E_4, respectively.

Heterobeltiosis in positive direction was significant for 7, 8, 14 and 7 crosses in E_1, E_2, E_3 and E_4 respectively. The maximum value of heterobeltiosis was 73.40 (L_2 x T_2), 158.54 (L_1 x T_3), 73.15 (L_2 x T_1) and 111.36 per cent (L_6 x T_1) in E_1, E_2, E_3 and E_4, respectively. Crosses exhibited significant and positive heterobeltiosis in more than one environment were L_6 x T_1, L_7 x T_1 and L_9 x T_2 in E_3 and E_4, L_5 x T_2 in E_1, E_3 and E_4 and L_2 x T_2 in E_1 and E_4.

The 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 11).

Protein content in grain

Difference between crosses and P Vs C were significant in all the four environments. The magnitude of heterosis ranged from 12.87 (L_7 x T_1) to -19.00 per cent (L_2 x T_2) in E_1, 18.43 (L_{10} x T_1) to -33.31 per cent (L_5 x T_2) in E_2, 17.69 (L_{10} x T_2) to -25.72 per cent (L_8 x T_2) in E_3 and 13.64 (L_3 x T1) to -34.55 per cent (L_1 x T_3) in E_4. The positive heterosis was significant for 4, 5, 5 and 3 crosses and negative for 18, 25, 20 and 27 crosses in E_1 E_2, E_3 and E_4, respectively.

Heterobeltiosis in positive direction was significant for L_7 x T_1 (5.30 %), L3 x T_1 (6.31 %), L_1 x T_2 (10.94 %) and L_3 x T_1 (10.40 %) in E_1, E_2, E_3 and E_4, respectively.

The economic heterosis was significant for L_1 x T_2 (9.49%) cross in E_3 only (Table 12).

Protein content in fodder

Difference between crosses and P Vs C were significant in all the four environments. The heterosis ranged from 28.79 (L_7 x T_3) to -27.59 per cent (L_3 x T_3) in E_1, 30.93 (L_7 x T_3) to -37.27 per cent (L_6 x T_1) in E_2, 31.61 (L_7 x T_3) to -33.33 per cent (L_6 x T_3) in E_3 and 31.55 (L_7 x T1) to -35.73 per cent (L_6 x T_1) in E_4. The negative heterosis was significant for 14, 15, 14 and 15 crosses and positive for 10, 12, 13 and 13 crosses in E_1 E_2, E_3 and E_4, respectively.

Heterobeltiosis in positive direction was significant for 9, 8, 8 and 10 crosses in E_1, E_2, E_3 and E_4, respectively. The maximum value of heterobeltiosis was 21.61 (L_9 x T_2), 15.13 (L_7 x T_2), 16.23 (L_7 x T_2) and 16.52 per cent (L_7 x T_2) in E_1, E_2, E_3 and E_4, respectively. Crosses exhibited significant and positive heterobeltiosis in more than one environments were L_1 x T_1, L_4 x T_2, L_3 x T_3 and L_7 x T_2 in E_2, E_3 E_4 and L_7 x T_1, L8 x T_1, L_2 x T_3 and L_7 x T_3 in E_1, E_2, E_3 and E_4.

The 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 13).

The difference between mean of parents and mean of F_1's was significant for all the characters in all the environments except harvest index in all the environments and green fodder yield and number of primaries per plant in E_1. This suggested significant deviation of F_1 means from parental means. Mean of the F_1's was significantly decreased for days to 50 % flowering, days to maturity, protein content in grain and protein content in fodder in all the four environments whereas, for number of primaries per plant in E_1, green fodder yield in E_3 and number of seeds per primary in E_4. For plant height, grain yield, dry fodder yield, ear head length, number of primaries per plant, number of seeds per primary, seed index the F_1 mean was higher than parental mean except for green fodder yield in E_3, number of primaries per plant in E_1 and number of seeds per primary in E_4. Increase in F_1 mean was also observed for protein content in fodder in E_1. This indicates presence of average heterosis for these characters in above environments. Such average heterosis was also observed by Khapre *et al.*, (2000), Umakanth *et al.*, (2006), Kulkarni *et al.*, (2007), Salini *et al.*, (2008), Murty *et al.*, (2010), Thakare *et al.*, (2011) and Hariprasanna *et al.*, (2012) for different characters. Differences between crosses were significant in all the four environments except harvest index in E_1 and E_2. In the present investigation, significant heterosis over mid parent was observed for all the characters in most of the crosses. For grain yield the magnitude of heterosis ranged from -56.19(L_5 x T_2) to 98.78 (L_2 x T_2) per cent in E_1, from -57.79 (L_6 x T_1) to 251.38 (L_1 x T_3) per cent in E_2, from -38.86 (L_3 x T_2) to 75.59 (L_2 x T_1) per cent in E_3 and from-56.08 (L_6 x T_3) to 143.14 (L_6 x T_1) per cent in E_4.

Table.1 Heterosis for days to 50% flowering

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	0.23	-7.69**	-3.77	-5.01	-	-6.85*	-3.13	-1.49	-	-	-0.91	-
2.	L2 x T1	3.20	3.63	-9.46**	-1.77	-	-	-8.64**	-	-	-	-8.22**	-
3.	L3 x T1	5.26	1.69	-1.33	8.25*	-	-	-0.89	-	-	-	-	-
4.	L4 x T1	-6.18	-11.06**	-11.96**	-1.01	-5.53	-10.05**	-10.96**	-	-	-	-10.96**	-
5.	L5 x T1	-1.42	-8.31**	-8.44**	-4.28	-	-4.46	-8.04**	-2.56	-	-0.52	-5.94*	-
6.	L6 x T1	-0.95	-11.31**	-6.90**	-5.36	-	-10.50**	-6.70*	-	-	-	-4.57	-
7.	L7 x T1	4.74	-11.66**	-11.86**	-8.76**	-	-10.05**	-11.66**	-1.98	-	-	-10.05**	-
8.	L8 x T1	-19.73**	-2.52	-15.96**	-13.62**	-18.43**	-2.29	-15.38**	-8.91*	-11.94*	-	-14.61**	-1.08
9.	L9 x T1	-3.37	-10.36**	-9.21**	0.47	-0.92	-9.13**	-7.59**	-	-	-	-5.48*	-
10.	L10 x T1	-7.09	-2.74	-0.89	-1.65	-6.45	-2.74	-0.89	-	-	-	-	-
11.	L1 x T2	-2.42	-8.92**	0.00	10.29**	0.00	-7.01*	-	-	-	-	-	-
12.	L2 x T2	-4.85	0.98	-3.40	13.54**	-2.26	-	-3.18	-	-	-	-2.74	-
13.	L3 x T2	-5.99	-3.90	-2.01	3.98	-	-	-0.90	-	-	-	0.00	-
14.	L4 x T2	-26.71**	-9.13**	-3.64	9.09*	-24.55**	-7.01*	-3.20	-	-17.41**	-	-3.20	-
15.	L5 x T2	-5.91	-4.81	-11.41**	16.06**	0.00	-1.98	-10.41**	-	-	-	-9.59**	-
16.	L6 x T2	-8.68	-12.59**	-15.70**	5.26	-2.44	-10.75**	-14.93**	-	-0.50	-1.55	-14.16**	-
17.	L7 x T2	-14.60**	-7.94**	-3.15	-1.65	-13.27*	-5.14	-2.71	-	-2.49	-	-1.83	-
18.	L8 x T2	-20.35**	-17.59**	-14.93**	-7.95*	-18.75**	-16.82**	-14.93**	0.00	-9.45	-8.25*	-14.16**	-
19.	L9 x T2	-6.29	5.69*	-1.55	3.61	-5.26	-	-	-	-	-	-	-
20.	L10 x T2	-4.19	-6.24*	-8.76**	-5.80	-1.36	-5.14	-8.14**	-	-	-	-7.31**	-
21.	L1 x T3	2.02	3.89	0.44	-7.11*	-	-	-	-4.39	-	-	-	-
22.	L2 x T3	-0.90	5.88*	-0.22	-1.01	-0.45	-	-	-	-	-	-	-
23.	L3 x T3	4.25	12.20**	2.00	10.49**	-	-	-	-	-	-	-	-
24.	L4 x T3	-5.19	-8.22**	-11.26**	-2.76	-4.55	-6.07*	-10.05**	0.00	-	-	-10.05**	-
25.	L5 x T3	6.98	-0.48	0.67	-3.50	-	-	-	-1.03	-	-	-	-
26.	L6 x T3	3.74	-2.06	-8.44**	-3.24	-	0.00	-8.44**	-	-	-	-5.94*	-
27.	L7 x T3	-0.22	-8.84**	-11.16**	-13.04**	-	-6.07*	-10.76**	-7.32	-	-	-9.13**	-
28.	L8 x T3	-7.38	-10.19**	-14.80**	-17.95**	-7.17	-9.35**	-14.03**	-14.15**	-	0.00	-13.24**	-5.38
29.	L9 x T3	-2.44	-0.23	-3.28	4.43	-1.35	-	-1.78	-	-	-	-	-
30.	L10 x T3	1.58	4.85	-2.00	-1.40	-	-	-1.79	-	-	-	-	-

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

Table.1 continued

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	0.23	-7.69**	-3.77	-5.01	-	-6.85*	-3.13	-1.49	-	-	-0.91	-
2.	L2 x T1	3.20	3.63	-9.46**	-1.77	-	-	-8.64**	-	-	-	-8.22**	-
3.	L3 x T1	5.26	1.69	-1.33	8.25*	-	-	-0.89	-	-	-	-	-
4.	L4 x T1	-6.18	-11.06**	-11.96**	-1.01	-5.53	-10.05**	-10.96**	-	-	-	-10.96**	-
5.	L5 x T1	-1.42	-8.31**	-8.44**	-4.28	-	-4.46	-8.04**	-2.56	-	-0.52	-5.94*	-
6.	L6 x T1	-0.95	-11.31**	-6.90**	-5.36	-	-10.50**	-6.70*	-	-	-	-4.57	-
7.	L7 x T1	4.74	-11.66**	-11.86**	-8.76**	-	-10.05**	-11.66**	-1.98	-	-	-10.05**	-
8.	L8 x T1	-19.73**	-2.52	-15.96**	-13.62**	-18.43**	-2.29	-15.38**	-8.91*	-11.94*	-	-14.61**	-1.08
9.	L9 x T1	-3.37	-10.36**	-9.21**	0.47	-0.92	-9.13**	-7.59**	-	-	-	-5.48*	-
10.	L10 x T1	-7.09	-2.74	-0.89	-1.65	-6.45	-2.74	-0.89	-	-	-	-	-
11.	L1 x T2	-2.42	-8.92**	0.00	10.29**	0.00	-7.01*	-	-	-	-	-	-
12.	L2 x T2	-4.85	0.98	-3.40	13.54**	-2.26	-	-3.18	-	-	-	-2.74	-
13.	L3 x T2	-5.99	-3.90	-2.01	3.98	-	-	-0.90	-	-	-	0.00	-
14.	L4 x T2	-26.71**	-9.13**	-3.64	9.09*	-24.55**	-7.01*	-3.20	-	-17.41**	-	-3.20	-
15.	L5 x T2	-5.91	-4.81	-11.41**	16.06**	0.00	-1.98	-10.41**	-	-	-	-9.59**	-
16.	L6 x T2	-8.68	-12.59**	-15.70**	5.26	-2.44	-10.75**	-14.93**	-	-0.50	-1.55	-14.16**	-
17.	L7 x T2	-14.60**	-7.94**	-3.15	-1.65	-13.27*	-5.14	-2.71	-	-2.49	-	-1.83	-
18.	L8 x T2	-20.35**	-17.59**	-14.93**	-7.95*	-18.75**	-16.82**	-14.93**	0.00	-9.45	-8.25*	-14.16**	-
19.	L9 x T2	-6.29	5.69*	-1.55	3.61	-5.26	-	-	-	-	-	-	-
20.	L10 x T2	-4.19	-6.24*	-8.76**	-5.80	-1.36	-5.14	-8.14**	-	-	-	-7.31**	-
21.	L1 x T3	2.02	3.89	0.44	-7.11*	-	-	-	-4.39	-	-	-	-
22.	L2 x T3	-0.90	5.88*	-0.22	-1.01	-0.45	-	-	-	-	-	-	-
23.	L3 x T3	4.25	12.20**	2.00	10.49**	-	-	-	-	-	-	-	-
24.	L4 x T3	-5.19	-8.22**	-11.26**	-2.76	-4.55	-6.07*	-10.05**	0.00	-	-	-10.05**	-
25.	L5 x T3	6.98	-0.48	0.67	-3.50	-	-	-	-1.03	-	-	-	-
26.	L6 x T3	3.74	-2.06	-8.44**	-3.24	-	0.00	-8.44**	-	-	-	-5.94*	-
27.	L7 x T3	-0.22	-8.84**	-11.16**	-13.04**	-	-6.07*	-10.76**	-7.32	-	-	-9.13**	-
28.	L8 x T3	-7.38	-10.19**	-14.80**	-17.95**	-7.17	-9.35**	-14.03**	-14.15**	-	0.00	-13.24**	-5.38
29.	L9 x T3	-2.44	-0.23	-3.28	4.43	-1.35	-	-1.78	-	-	-	-	-
30.	L10 x T3	1.58	4.85	-2.00	-1.40	-	-	-1.79	-	-	-	-	-

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

Table.2 Heterosis for days to maturity

S.No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	-1.78	-2.43**	-1.79*	-0.96	-0.66	-0.66	-0.66	-	-	-	-	-
2.	L2 x T1	-3.31**	-3.95**	-2.65**	-3.44**	0.00	-0.68	0.00	0.00	-	-	-	-
3.	L3 x T1	5.41**	5.53**	7.93**	4.68**	-	-	-	-	-	-	-	-
4.	L4 x T1	-0.00	-0.00	1.14	0.00	-	-	-	-	-	-	-	-
5.	L5 x T1	-5.54**	-4.55**	-4.23**	-5.31**	-3.97**	-2.65*	-3.29**	-3.61**	-	-	-	-
6.	L6 x T1	-3.86**	-4.32**	-3.38**	-4.14**	-3.55**	-3.86**	-3.23**	-3.53**	-	-	-	-
7.	L7 x T1	-6.85**	-5.92**	-4.85**	-6.96**	-4.17**	-3.82**	-1.94	-4.75**	-	-	-	-
8.	L8 x T1	-10.25**	-8.05**	-8.10**	-9.57**	-7.37**	-5.41**	-4.84**	-7.28**	-	-	-	-
9.	L9 x T1	-1.56	-2.02*	-1.72*	-3.26**	-	-	-	-1.27	-	-	-	-
10.	L10 x T1	-1.71	-2.94**	-1.41	-2.02*	-	0.00	-	-0.32	-	-	-	-
11.	L1 x T2	5.47**	5.80**	5.14**	4.62**	-	-	-	-	-	-	-	-
12.	L2 x T2	6.10**	5.39**	6.06**	5.21**	-	-	-	-	-	-	-	-
13.	L3 x T2	3.46**	3.95**	4.97**	3.09**	-	-	-	-	-	-	-	-
14.	L4 x T2	2.64*	3.63**	3.14**	3.30**	-	-	-	-	-	-	-	-
15.	L5 x T2	4.67**	4.65**	3.31**	1.82*	-	-	-	-	-	-	-	-
16.	L6 x T2	1.97	1.47	2.13*	1.96*	-	-	-	-	-	-	-	-
17.	L7 x T2	-5.73**	-4.78**	-4.93**	-5.86**	-0.67	-0.33	-0.33	-1.00	-	-	-	-
18.	L8 x T2	-1.27	-1.90*	-1.58	-2.53**	-	-	-	-	-	-	-	-
19.	L9 x T2	-0.96	-1.75*	-0.79	-1.11	-	-	-	-	-	-	-	-
20.	L10 x T2	-11.92**	-11.53**	-10.33**	-10.37**	-7.05**	-6.67**	-6.00**	-6.33**	-1.07	-1.06	-0.35	-0.35
21.	L1 x T3	-5.54**	-4.59**	-4.26**	-4.25**	-4.92**	-3.96**	-3.63**	-4.25**	-	-	-	-
22.	L2 x T3	-1.83	-2.50**	-2.50**	-2.50**	-	-0.34	-0.34	-0.68	-	-	-	-
23.	L3 x T3	4.58**	4.07**	4.07**	5.10**	-	-	-	-	-	-	-	-
24.	L4 x T3	-6.65**	-5.06**	-4.58**	-4.58**	-6.49**	-4.90**	-4.26**	-4.58**	-	-	-	-
25.	L5 x T3	-2.78*	-2.79**	-4.09**	-3.44**	-1.66	-1.99	-3.62**	-3.28**	-	-	-	-
26.	L6 x T3	-4.04**	-5.18**	-3.88**	-2.91**	-3.88**	-4.56**	-3.26**	-1.96	-	-	-	-
27.	L7 x T3	-6.42**	-6.77**	-6.92**	-7.06**	-3.24*	-3.58**	-3.58**	-3.27**	-	-	-	-
28.	L8 x T3	-2.96**	-3.60**	-3.60**	-3.45**	-	-	-	-	-	-	-	-
29.	L9 x T3	-0.16	-0.63	-0.94	-0.47	-	-	-	-	-	-	-	-
30.	L10 x T3	-2.81*	-2.50**	-1.26	-1.11	-	-	-	-	-	-	-	-

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

Table.3 Heterosis for plant height

S. No.	Crosses	Heterosis					Heterobeltiosis					Economic Heterosis				
		E1	E2	E3	E4	Pool	E1	E2	E3	E4	pool	E1	E2	E3	E4	Pool
1.	L1 x T1	-8.26	2.01	14.29	23.88*	6.97	-	-	0.00	14.12	4.94	-	-	-	-	-
2.	L2 x T1	11.11	51.02**	16.85*	18.67*	25.30**	-	43.13**	13.04	9.07	16.77**	-	2.49	-	-	-
3.	L3 x T1	82.19**	9.31	26.29**	6.43	28.87**	62.65**	9.07	19.57*	5.81	27.26**	-	-	-	-	-
4.	L4 x T1	66.67**	1.37	51.59**	53.24**	41.80**	46.51**	-	29.35**	41.88**	35.78**	-	-	-	-	-
5.	L5 x T1	61.16**	28.83**	26.37**	48.08**	39.77**	46.25**	22.33**	25.00**	42.30**	33.95**	-	-	-	-	-
6.	L6 x T1	49.55**	31.28**	9.69	23.84**	27.75**	28.35**	29.35**	7.52	21.87*	21.68**	-	-	-	-	-
7.	L7 x T1	0.85	5.20	7.00	21.98*	8.32*	-	-	-	14.43	-	-	-	-	-	-
8.	L8 x T1	-7.50	9.01	17.05*	8.30	6.18	-	7.08	11.96	-	-	-	-	-	-	-
9.	L9 x T1	26.06**	9.51	-1.68	25.00**	14.37**	0.73	7.25	-	21.18*	8.59*	-	-	-	-	-
10.	L10 x T1	89.83**	26.35**	42.05**	23.10*	44.38**	59.38**	26.35**	35.87**	21.65*	40.16**	2.00	-	-	-	-
11.	L1 x T2	-18.54**	1.67	11.11	7.73	-0.63	-	-	-	-	-	-	-	-	-	-
12.	L2 x T2	14.94	7.79	6.15	2.35	7.64*	3.31	2.44	2.15	-	6.45	-	-	-	-	-
13.	L3 x T2	48.56**	-0.10	-4.11	-12.44	6.64	43.37**	-	-	-	1.64	-	-	-	-	-
14.	L4 x T2	7.60	-7.18	-1.27	-0.72	-0.73	2.09	-	-	-	-	-	-	-	-	-
15.	L5 x T2	52.16**	4.87	22.40**	45.44**	29.32**	49.50**	-	20.43*	44.04**	26.97**	-	-	-	-	-
16.	L6 x T2	40.07**	8.28	8.05	7.15	15.09**	29.45**	-	6.47	3.62	13.72**	-	-	-	-	-
17.	L7 x T2	-2.23	-14.16**	9.45	4.50	-1.12	-	-	1.85	2.89	-	-	-	-	-	-
18.	L8 x T2	-8.18	-2.47	20.90**	16.75*	5.82	-	-	15.05	11.65	0.00	-	-	-	-	-
19.	L9 x T2	-0.11	-3.12	35.56**	19.68*	12.16**	-	-	31.18**	10.64	11.19**	-	-	-	-	-
20.	L10 x T2	21.25**	12.83*	2.82	2.15	9.83**	9.38	1.92	-	-	6.44	-	-	-	-	-
21.	L1 x T3	-6.07	32.04**	51.38**	48.13**	28.87**	-	4.94	22.32**	14.48*	10.31**	-	-	7.03	2.60	0.19
22.	L2 x T3	32.52**	30.64**	25.25**	-10.40	18.99**	21.55**	17.44**	10.71	-	6.67*	-	5.40	-	-	-
23.	L3 x T3	52.76**	58.70**	28.73**	37.57**	44.77**	31.03**	35.80**	11.61	13.87*	23.24**	1.33	21.88**	-	2.05	11.93**
24.	L4 x T3	50.69**	4.80	37.85**	47.35**	34.71**	31.21**	-	8.93	14.33*	9.57**	1.47	-	-	2.46	-
25.	L5 x T3	47.96**	46.52**	12.87	-6.36	25.06**	25.00**	31.48**	1.79	-	9.25**	-	18.01**	-	-	-
26.	L6 x T3	43.96**	36.00**	38.59**	-1.92	28.88**	28.45**	18.06**	28.57**	-	13.22**	-	5.96	12.50*	-	2.82
27.	L7 x T3	14.07**	34.55**	11.82	28.31**	22.14**	2.04	25.00**	9.82	11.59	18.94**	0.00	12.19*	-	0.00	8.03**
28.	L8 x T3	-2.63	26.24**	32.65**	29.46**	20.27**	-	9.88	16.07*	15.55*	12.52**	-	-	1.56	3.55	2.19
29.	L9 x T3	9.33	3.45	5.53	5.59	5.99	6.03	-	-	-	-	-	-	-	-	-
30.	L10 x T3	-6.60	12.51*	36.73**	51.45**	23.21**	-	-	19.64**	23.63**	6.42*	-	-	4.69	10.79	-

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

Table.4 Heterosis for green fodder yield

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	68.76**	-53.99**	-16.44*	20.98*	44.58**	-	-	4.85	-	-	-	-
2.	L2 x T1	-12.12	-53.40**	-16.44**	-3.59	-	-	-	-	-	-	-	-
3.	L3 x T1	27.15**	-58.35**	-30.22**	-2.09	18.50**	-	-	-	-	-	-	-
4.	L4 x T1	5.24	-44.35**	-21.41**	24.87*	-	-	-	3.90	-	-	-	-
5.	L5 x T1	12.54	2.00	19.88**	13.53	-	-	-	-	-	-	-	-
6.	L6 x T1	-26.93**	-57.23**	-41.78**	4.91	-	-	-	-	-	-	-	-
7.	L7 x T1	-49.84**	-16.32**	-24.69**	-14.96	-	-	-	-	-	-	-	-
8.	L8 x T1	3.50	-36.61**	-41.64**	-14.12	-	-	-	-	-	-	-	-
9.	L9 x T1	103.85**	-46.75**	-13.94*	-17.38	63.29**	-	-	-	-	-	-	-
10.	L10 x T1	19.05**	-27.51**	-21.53**	-40.22**	-	-	-	-	-	-	-	-
11.	L1 x T2	36.82**	-2.74	6.94	74.61**	25.61**	-	-	63.99**	-	-	-	-
12.	L2 x T2	77.45**	-32.54**	22.05**	32.22**	37.05**	-	-	15.89	-	-	-	-
13.	L3 x T2	13.87*	5.83	-14.92*	-35.96**	-	-	-	-	-	-	-	-
14.	L4 x T2	-39.49**	-16.55*	-31.30**	-23.49	-	-	-	-	-	-	-	-
15.	L5 x T2	-20.17*	14.39*	-20.42**	47.98**	-	-	-	47.98**	-	-	-	-
16.	L6 x T2	38.22**	-13.70**	-37.02**	9.49	24.65**	-	-	0.00	-	-	-	-
17.	L7 x T2	-39.64**	2.67	-28.81**	-13.54	-	-	-	-	-	-	-	-
18.	L8 x T2	-41.57**	58.40**	-25.27**	65.98**	-	24.96**	-	39.63**	-	-	-	-
19.	L9 x T2	2.90	-10.28	-14.22*	16.21	-	-	-	14.47	-	-	-	-
20.	L10 x T2	-5.71	12.92	-34.38**	-26.27*	-	-	-	-	-	-	-	-
21.	L1 x T3	97.50**	14.20*	21.52**	20.04*	87.12**	-	-	0.88	-	-	-	-
22.	L2 x T3	48.60**	10.17	26.05**	41.85**	17.61*	-	-	27.25**	-	-	-	2.33
23.	L3 x T3	22.68**	100.71**	12.48*	4.05	3.59	67.79**	-	-	-	20.64**	-	-
24.	L4 x T3	-29.28**	38.14**	-0.08	14.37	-	4.25	-	-	-	-	-	-
25.	L5 x T3	38.14**	133.58**	1.84	41.45**	21.17*	76.36**	-	13.02	-	26.81**	-	-
26.	L6 x T3	-7.52	-17.71**	-42.24**	-49.81**	-	-	-	-	-	-	-	-
27.	L7 x T3	12.80*	45.20**	-4.78	37.22**	-	25.88**	-	-	-	-	-	-
28.	L8 x T3	-48.18**	-21.32**	-4.14	-7.54	-	-	-	-	-	-	-	-
29.	L9 x T3	-6.03	-19.24**	-32.59**	-46.00**	-	-	-	-	-	-	-	-
30.	L10 x T3	-15.31**	134.65**	-2.73	29.21**	-	59.58**	-	10.77	-	14.75**	-	-

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

Table.5 Heterosis for dry fodder yield

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	52.28**	-51.00**	23.23**	8.02	20.27**	-	4.35	-	-	-	-	-
2.	L2 x T1	-25.39**	-52.63**	-2.56	49.11**	-	-	-	26.85**	-	-	-	-
3.	L3 x T1	-57.80**	-53.00**	41.25**	39.13**	-	-	21.95*	22.74**	-	-	-	-
4.	L4 x T1	-27.86**	-31.33**	21.20*	70.56**	-	-	-	46.03**	-	-	-	-
5.	L5 x T1	39.01**	17.90*	55.31**	-10.28	17.72**	-	30.23**	-	-	-	-	-
6.	L6 x T1	-2.91	-62.77**	-26.69**	51.76**	-	-	-	24.11**	-	-	-	-
7.	L7 x T1	-48.52**	-35.13**	-20.07**	30.05**	-	-	-	15.62*	-	-	-	-
8.	L8 x T1	13.69**	-38.73**	15.05	-39.52**	2.85	-	10.77	-	-	-	-	-
9.	L9 x T1	43.58**	-39.19**	2.20	7.62	36.79**	-	-	-	-	-	-	-
10.	L10 x T1	10.03**	-17.57*	8.30	-26.05**	5.21	-	-	-	-	-	-	-
11.	L1 x T2	64.86**	-48.40**	20.76*	28.29**	51.30**	-	-	8.90	-	-	-	-
12.	L2 x T2	58.54**	-40.50**	27.08**	54.47**	40.69**	-	-	35.91**	-	-	-	-
13.	L3 x T2	30.12**	-14.24*	-14.44	43.83**	23.54**	-	-	31.45**	-	-	-	-
14.	L4 x T2	14.24**	-44.10**	-35.87**	-2.51	-	-	-	-	-	-	-	-
15.	L5 x T2	-52.81**	-32.22**	-11.89	-9.57	-	-	-	-	-	-	-	-
16.	L6 x T2	7.49	-48.63**	-12.56	7.56	-	-	-	-	-	-	-	-
17.	L7 x T2	-8.50	-40.38**	-23.35**	-33.33**	-	-	-	-	-	-	-	-
18.	L8 x T2	-25.27**	10.77	-10.87	-14.17*	-	-	-	-	-	-	-	-
19.	L9 x T2	13.62**	-3.01	29.05**	-11.39	0.33	-	13.85	-	-	-	-	-
20.	L10 x T2	0.34	63.43**	-58.01**	35.31**	-	1.18	-	28.49**	-	1.18	-	-
21.	L1 x T3	51.48**	9.62	61.14**	13.70**	44.37**	-	30.56**	9.11	-	-	8.63	-
22.	L2 x T3	58.67**	113.15**	9.44	60.57**	46.01**	49.85**	-	26.58**	-	16.63**	-	2.93
23.	L3 x T3	34.47**	95.40**	15.60	22.54**	22.96**	41.67**	-	-	-	10.26	-	-
24.	L4 x T3	-34.90**	-3.94	9.93	28.98**	-	-	-	2.25	-	-	-	-
25.	L5 x T3	26.13**	79.60**	48.33**	13.77*	21.21**	29.39**	19.07*	6.08	-	0.71	-	-
26.	L6 x T3	-2.53	68.95**	14.02*	-28.11**	-	61.38**	12.89	-	-	37.97**	-	-
27.	L7 x T3	19.89**	14.64*	4.08	-17.58**	1.13	-	-	-	-	-	-	-
28.	L8 x T3	-6.32	12.82	17.33*	-16.44**	-	-	7.22	-	-	-	-	-
29.	L9 x T3	-48.10**	-24.71**	-37.62**	-30.46**	-	-	-	-	-	-	-	-
30.	L10 x T3	16.26**	75.87**	-0.93	23.96**	-	14.85*	-	4.28	-	-	-	-

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

Table.6 Heterosis for ear head length

S. No.	Crosses	Heterosis					Heterobeltiosis					Economic Heterosis				
		E1	E2	E3	E4	Pool	E1	E2	E3	E4	pool	E1	E2	E3	E4	pool
1.	L1 x T1	1.35	-0.63	-8.54	-5.62	-3.54	-	-	-	-	-	-	-	-	-	-
2.	L2 x T1	-3.23	-0.00	17.58**	3.74	4.94	-	-	5.94	-	-	-	-	-	-	-
3.	L3 x T1	9.55	-12.99*	-3.66	2.35	-1.09	1.18	-	-	0.00	-	-	-	-	-	-
4.	L4 x T1	10.39	8.45	16.00**	23.64**	14.89**	3.66	6.94	7.41	22.89**	13.96**	-	-	-	-	-
5.	L5 x T1	25.00**	14.47*	15.29**	13.29*	16.72**	25.00**	4.60	10.11	8.89	11.54**	-	-	-	-	-
6.	L6 x T1	17.65**	1.28	-3.49	21.21**	8.98**	11.11	-	-	20.48**	4.14	-	-	-	-	-
7.	L7 x T1	7.19	21.92**	14.65**	15.85*	14.84**	1.23	20.27*	11.11	14.46*	14.10**	-	-	-	-	-
8.	L8 x T1	12.58	6.92	-0.00	7.51	6.65*	7.59	-	-	3.33	1.77	-	-	-	-	-
9.	L9 x T1	5.33	9.09	11.24*	5.06	7.77*	1.28	2.44	6.82	0.00	5.26	-	-	-	-	-
10.	L10 x T1	5.00	4.70	-2.96	10.69	4.24	-	1.30	-	6.02	0.91	-	-	-	-	-
11.	L1 x T2	4.29	1.12	-2.62	-4.57	-0.69	-	-	-	-	-	-	-	-	-	-
12.	L2 x T2	-1.18	3.83	-9.09*	-1.94	-2.34	-	3.26	-	-	-	-	-	-	-	-
13.	L3 x T2	3.49	20.23**	-12.04**	-7.94	0.41	2.30	14.29*	-	-	-	-	5.05	-	-	-
14.	L4 x T2	-4.14	5.59	2.82	0.00	1.01	-	-	-	-	-	-	-	-	-	-
15.	L5 x T2	-3.14	5.62	-5.58	0.00	-0.83	-	3.30	-	-	-	-	-	-	-	-
16.	L6 x T2	4.76	-13.14*	-2.51	2.17	-2.20	1.15	-	-	-	-	-	-	-	-	-
17.	L7 x T2	27.38**	11.52	5.43	-2.73	10.00**	22.99**	1.10	-	-	-	9.18	-	-	-	-
18.	L8 x T2	4.82	3.37	2.62	6.25	4.26	0.00	1.10	-	0.00	-	-	-	-	-	-
19.	L9 x T2	0.61	-1.73	-24.49**	5.08	-5.77*	-	-	-	-	-	-	-	-	-	-
20.	L10 x T2	-10.86	7.14	-21.43**	2.25	-6.28*	-	-	-	-	-	-	-	-	-	-
21.	L1 x T3	12.66*	6.51	10.59*	-2.76	6.49*	8.54	3.45	8.05	-	5.87	-	-	-	-	-
22.	L2 x T3	-5.45	8.05	-1.06	-10.53	-2.37	-	2.17	-	-	-	-	-	-	-	-
23.	L3 x T3	8.98	-3.66	14.12**	0.58	5.04	7.06	-	11.49*	0.00	5.04	-	-	-	-	-
24.	L4 x T3	-4.88	14.47*	3.85	9.52	5.63	-	6.10	-	6.98	0.30	-	-	-	-	-
25.	L5 x T3	10.39	6.51	-2.27	4.55	4.59	3.66	3.45	-	2.22	4.44	-	-	-	-	-
26.	L6 x T3	9.20	1.20	2.25	4.76	4.30	8.54	0.00	0.00	2.33	4.14	-	-	-	-	-
27.	L7 x T3	12.88*	1.28	27.61**	6.59	12.17**	12.20	-	19.54**	3.49	8.01*	-	-	-	-	-
28.	L8 x T3	1.86	7.69	4.71	3.41	4.44	0.00	4.60	2.30	1.11	4.13	-	-	-	-	-
29.	L9 x T3	-7.50	-4.88	-9.71*	-3.11	-6.36*	-	-	-	-	-	-	-	-	-	-
30.	L10 x T3	-16.47**	10.69	-0.57	-1.23	-2.10	-	7.32	-	-	-	-	-	-	-	-

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

Table.7 Heterosis for number of primaries per plant

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	15.38*	-1.20	7.64	44.27**	13.21	-	-	23.94**	-	-	-	-
2.	L2 x T1	-40.64**	-11.92	-15.56	14.59	-	-	-	12.77	-	-	-	-
3.	L3 x T1	-6.78	-27.79**	-30.59**	5.76	-	-	-	4.12	-	-	-	-
4.	L4 x T1	18.37**	22.25**	16.86	2.04	6.84	-	16.86	-	-	-	-	-
5.	L5 x T1	37.44**	-9.50	78.42**	77.62**	1.96	-	25.00*	30.85**	-	-	-	-
6.	L6 x T1	17.34*	-37.31**	4.82	12.89	3.92	-	-	9.50	-	-	-	-
7.	L7 x T1	-29.89**	-16.71**	21.07	4.29	-	-	-	-	-	-	-	-
8.	L8 x T1	21.89**	-18.27**	6.98	25.61*	11.35	-	6.98	-	-	-	-	-
9.	L9 x T1	28.77**	-10.47	3.79	-7.20	22.88**	-	3.49	-	-	-	-	-
10.	L10 x T1	-6.33	4.62	-7.93	6.62	-	-	-	-	-	-	-	-
11.	L1 x T2	8.17	-0.68	0.66	41.22**	-	-	-	36.81**	-	-	-	-
12.	L2 x T2	23.31**	-6.99	-21.97*	1.84	2.55	-	-	-	-	-	-	-
13.	L3 x T2	-24.61**	-20.27*	-11.52	4.14	-	-	-	-	-	-	-	-
14.	L4 x T2	-17.10**	75.65**	-8.98	-4.60	-	33.77**	-	-	-	-	-	-
15.	L5 x T2	-20.74**	58.80**	62.77**	127.47**	-	22.52*	16.05	84.03**	-	-	-	0.38
16.	L6 x T2	26.11**	-15.24*	5.65	3.49	1.02	-	-	-	-	-	-	-
17.	L7 x T2	-23.27**	-3.47	38.65**	-14.41	-	-	7.41	-	-	-	-	-
18.	L8 x T2	-18.64**	11.34	-8.98	45.23**	-	7.28	-	21.53	-	-	-	-
19.	L9 x T2	-27.76**	-8.17	21.32*	-10.57	-	-	18.13	-	-	-	-	-
20.	L10 x T2	-40.95**	60.84**	-28.30**	31.87**	-	52.32**	-	25.00*	-	-	-	-
21.	L1 x T3	32.20**	28.70**	-4.27	-14.29*	22.64**	8.82	-	-	-	-	-	-
22.	L2 x T3	10.53	-12.68	-15.34	-4.93	8.09	-	-	-	-	-	-	-
23.	L3 x T3	14.29*	0.29	3.98	-22.27**	-	-	-	-	-	-	-	-
24.	L4 x T3	-14.72*	42.76**	-6.04	-1.71	-	-	-	-	-	-	-	-
25.	L5 x T3	14.29	45.45**	62.59**	24.65**	-	1.96	8.13	-	-	-	1.80	-
26.	L6 x T3	59.06**	-5.51	8.62	-14.66*	48.53**	-	-	-	-	-	-	-
27.	L7 x T3	-40.79**	-27.27**	24.16*	6.74	-	-	-	-	-	-	-	-
28.	L8 x T3	-9.66	-3.49	4.46	11.91	-	-	-	-	-	-	-	-
29.	L9 x T3	-25.09**	-29.68**	-28.42**	-24.17**	-	-	-	-	-	-	-	-
30.	L10 x T3	-25.08**	-17.40*	-10.68	-12.98	-	-	-	-	-	-	-	-

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

Table.8 Heterosis for Number of seeds per primary

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	26.96*	18.72**	-24.84**	0.43	19.67	-	-	-	-	-	-	-
2.	L2 x T1	-38.62**	-54.69**	26.54**	-14.06*	-	-	19.68*	-	-	-	19.68*	-
3.	L3 x T1	-19.36**	-48.56**	-28.78**	-33.90**	-	-	-	-	-	-	-	-
4.	L4 x T1	-14.29	1.20	-19.78*	-22.98**	-	-	-	-	-	-	-	-
5.	L5 x T1	22.61	-30.07**	-20.82**	12.53	-	-	-	-	-	-	-	-
6.	L6 x T1	36.54**	-23.66**	16.07*	-5.57	31.48*	-	-	-	-	-	-	-
7.	L7 x T1	14.81	19.80**	11.73	-33.77**	14.81	0.00	-	-	-	0.00	-	-
8.	L8 x T1	155.27**	14.48**	-41.88**	-3.23	137.04**	3.27	-	-	11.72*	3.27	-	-
9.	L9 x T1	147.13**	-30.41**	-25.00**	-12.02	142.01**	-	-	-	2.00	-	-	-
10.	L10 x T1	100.00**	-10.82	7.12	7.49	83.94**	-	-	-	-	-	-	-
11.	L1 x T2	-56.91**	-14.67*	-51.03**	-17.49*	-	-	-	-	-	-	-	-
12.	L2 x T2	17.36**	-9.80	29.38**	-18.47**	-	-	13.06	-	-	-	0.80	-
13.	L3 x T2	-24.84**	10.48	-8.87	-44.18**	-	8.41	-	-	-	-	-	-
14.	L4 x T2	67.27**	-26.42**	142.75**	-28.36**	41.94**	-	101.81**	-	27.43**	-	34.54**	-
15.	L5 x T2	-28.54**	-10.58	28.26**	-0.25	-	-	8.30	-	-	-	4.82	-
16.	L6 x T2	27.06**	16.07**	61.08**	-4.37	-	13.08*	60.12**	-	-	-	8.03	-
17.	L7 x T2	-3.45	80.42**	79.29**	-18.91*	-	59.35**	66.87**	-	-	39.18**	11.24	-
18.	L8 x T2	4.55	13.38*	21.07	-6.22	-	8.88	9.04	-	-	-	-	-
19.	L9 x T2	-17.58*	-2.11	27.02*	18.41*	-	-	9.04	-	-	-	-	-
20.	L10 x T2	-47.56**	31.09**	-11.49	-6.70	-	9.35	-	-	-	-	-	-
21.	L1 x T3	-30.69**	5.48	-18.09*	16.44*	-	-	-	4.80	-	-	-	0.77
22.	L2 x T3	-50.39**	8.78	44.72**	-15.14*	-	3.67	29.73**	-	-	3.67	15.66*	-
23.	L3 x T3	-25.11**	-7.48	-44.21**	-32.46**	-	-	-	-	-	-	-	-
24.	L4 x T3	56.12**	-4.06	138.46**	9.09	44.26**	-	93.75**	3.20	6.48	-	36.95**	-
25.	L5 x T3	8.35	15.03*	15.11	-5.79	-	0.00	-	-	-	-	-	-
26.	L6 x T3	3.59	-19.06**	13.95	-36.22**	-	-	11.36	-	-	-	-	-
27.	L7 x T3	95.20**	-10.88	28.53**	8.80	51.01**	-	16.48	-	11.47*	-	-	-
28.	L8 x T3	-32.37**	26.01**	26.86*	-20.16**	-	18.92**	11.36	-	-	7.76	-	-
29.	L9 x T3	-11.83	13.40*	7.12	-47.29**	-	-	-	-	-	-	-	-
30.	L10 x T3	-53.37**	6.30	-3.27	-4.51	-	-	-	-	-	-	-	-

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

Table.9 Heterosis for seed index

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	9.33**	-5.44*	23.14**	1.15	3.24	-	11.03*	-	-	-	-	-
2.	L2 x T1	3.87	-14.06**	13.41**	-1.73	2.92	-	13.26*	-	-	-	-	-
3.	L3 x T1	-13.99**	-21.55**	25.37**	14.38**	-	-	23.74**	13.17**	-	-	8.35	7.69**
4.	L4 x T1	13.34**	2.58	5.96	9.34**	10.58*	-	-	-	-	-	-	-
5.	L5 x T1	19.88**	17.16**	-15.92**	11.68**	14.51**	4.01	-	7.60**	-	-	-	2.38
6.	L6 x T1	25.92**	7.09**	-9.45*	2.67	22.58**	2.48	-	-	-	-	-	-
7.	L7 x T1	6.92	-2.06	1.24	-5.20**	3.29	-	-	-	-	-	-	-
8.	L8 x T1	20.69**	-8.21**	-9.73	-12.78**	17.69**	-	-	-	-	-	-	-
9.	L9 x T1	5.44	-14.95**	-3.27	-13.12**	2.65	-	-	-	-	-	-	-
10.	L10 x T1	5.52	14.43**	13.99**	-7.45**	-	-	6.94	-	-	-	-	-
11.	L1 x T2	-0.94	-12.51**	17.56**	3.47*	-	-	16.54*	-	-	-	-	-
12.	L2 x T2	17.25**	30.53**	2.65	2.74	12.39**	24.27**	-	1.72	-	-	-	-
13.	L3 x T2	-15.45**	14.78**	1.59	27.56**	-	-	-	13.65**	-	-	-	5.86**
14.	L4 x T2	7.34*	-4.84	21.39**	13.67**	1.36	-	19.04**	13.32**	-	-	-	-
15.	L5 x T2	7.35*	-8.93**	-3.26	-4.32*	5.98	-	-	-	-	-	-	-
16.	L6 x T2	8.47*	-11.16**	-3.84	13.53**	7.73	-	-	6.75**	-	-	-	-
17.	L7 x T2	16.00**	0.60	-5.88	12.91**	15.87**	0.13	-	6.33**	-	-	-	-
18.	L8 x T2	0.74	27.16**	3.64	21.85**	-	19.83**	-	15.23**	-	-	-	-
19.	L9 x T2	10.76**	-11.32**	36.53**	10.76**	10.00*	-	34.82**	0.00	-	-	-	-
20.	L10 x T2	-5.78	6.51*	13.13*	38.00**	-	3.22	9.34	30.03**	-	-	-	-
21.	L1 x T3	-9.46**	20.11**	38.82**	19.37**	-	11.27**	34.90**	10.61**	-	-	-	-
22.	L2 x T3	1.99	18.22**	12.99*	35.05**	-	17.72**	4.73	34.39**	-	-	-	0.82
23.	L3 x T3	-8.64**	4.63	26.10**	21.98**	-	-	15.34**	10.12**	-	-	0.99	2.56
24.	L4 x T3	-15.10**	21.14**	38.94**	28.74**	-	9.42**	38.87**	26.46**	-	-	0.83	-
25.	L5 x T3	-6.57*	25.11**	14.65**	27.80**	-	24.72**	5.54	18.26**	-	-	-	4.30**
26.	L6 x T3	-11.00**	-10.71**	-10.16*	-12.53**	-	-	-	-	-	-	-	-
27.	L7 x T3	6.79*	3.25	-2.44	24.35**	-	-	-	18.76**	-	-	-	-
28.	L8 x T3	-1.83	-11.75**	16.43**	28.66**	-	-	13.76*	23.40**	-	-	-	0.82
29.	L9 x T3	-1.17	-17.85**	6.53	16.81**	-	-	3.13	6.88**	-	-	-	-
30.	L10 x T3	-8.09**	27.70**	19.46**	6.69**	-	18.48**	17.77**	-	-	-	-	-

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

Table.10 Heterosis for harvest index

S. No.	Crosses	Heterosis		heterobeltiosis		Economic Heterosis	
		E3	E4	E3	E4	E3	E4
1.	L1 x T1	2.92	-10.74*	-	-	-	-
2.	L2 x T1	23.04**	12.22**	9.33	10.33*	-	0.44
3.	L3 x T1	-8.80	-11.55*	-	-	-	-
4.	L4 x T1	15.51	-1.35	11.45	-	-	-
5.	L5 x T1	19.01**	8.52	3.00	4.70	-	-
6.	L6 x T1	-0.23	2.97	-	2.41	-	-
7.	L7 x T1	25.31**	17.14**	14.61	-	-	-
8.	L8 x T1	0.88	16.14**	-	5.17	-	-
9.	L9 x T1	2.58	3.54	0.64	3.49	-	-
10.	L10 x T1	46.10**	3.60	36.80**	-	2.20	-
11.	L1 x T2	-7.42	-14.24**	-	-	-	-
12.	L2 x T2	6.81	-4.61	-	-	-	-
13.	L3 x T2	-12.81	-2.88	-	-	-	-
14.	L4 x T2	22.60**	-4.13	14.98	-	-	-
15.	L5 x T2	18.33*	-2.86	-	-	-	-
16.	L6 x T2	8.76	3.39	-	2.28	-	-
17.	L7 x T2	-4.82	15.46**	-	-	-	-
18.	L8 x T2	12.82	11.42*	-	-	-	-
19.	L9 x T2	-5.36	-6.92	-	-	-	-
20.	L10 x T2	9.34	3.71	-	-	-	-
21.	L1 x T3	18.82*	-8.93*	0.27	-	-	-
22.	L2 x T3	-13.06*	-9.63*	-	-	-	-
23.	L3 x T3	-53.75**	-12.74**	-	-	-	-
24.	L4 x T3	0.49	0.50	-	-	-	-
25.	L5 x T3	3.90	-4.27	2.88	-	-	-
26.	L6 x T3	-22.16**	-11.56*	-	-	-	-
27.	L7 x T3	-11.55	26.54**	-	6.63	-	-
28.	L8 x T3	-7.78	11.30*	-	1.53	-	-
29.	L9 x T3	19.06**	-7.39	5.67	-	-	-
30.	L10 x T3	-7.89	-5.55	-	-	-	-

** Significant at 5 and 1 per cent, respectively

Table.11 Heterosis for grain yield

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	29.61**	-5.73	26.74**	25.84**	1.34	-	0.93	24.44**	-	-	-	-
2.	L2 x T1	-28.77**	-52.42**	75.59**	-34.94**	-	-	73.15**	-	-	-	-	-
3.	L3 x T1	46.82**	35.37**	11.30*	-36.36**	31.54**	-	4.92	-	2.62	-	-	-
4.	L4 x T1	-5.77	-38.94**	61.36**	-1.12	-	-	31.48**	-	-	-	-	-
5.	L5 x T1	36.60**	14.68	39.56**	36.25**	21.48**	-	34.19**	23.86**	-	-	-	-
6.	L6 x T1	-19.82**	-57.79**	52.63**	143.14**	-	-	28.48**	111.36**	-	-	1.50	-
7.	L7 x T1	-52.08**	-34.92**	60.78**	128.97**	-	-	51.85**	88.64**	-	-	-	-
8.	L8 x T1	1.61	-49.24**	3.45	-7.95	-	-	-	-	-	-	-	-
9.	L9 x T1	8.97	-41.07**	33.68**	67.88**	6.04	-	17.59**	30.68**	-	-	-	-
10.	L10 x T1	-8.98	5.61	60.20**	-24.05**	-	-	45.37**	-	-	-	-	-
11.	L1 x T2	71.91**	-10.31	0.58	-10.77*	62.77**	-	-	-	-	-	-	-
12.	L2 x T2	98.78**	-32.99**	-11.32*	61.75**	73.40**	-	-	40.95**	-	-	-	-
13.	L3 x T2	54.72**	25.51**	-38.86**	8.77	38.98**	-	-	-	-	-	-	-
14.	L4 x T2	24.51**	-19.17	23.43**	-50.77**	-	-	0.93	-	-	-	-	-
15.	L5 x T2	-56.19**	1.62	29.46**	-34.46**	-	-	23.93**	-	-	-	-	-
16.	L6 x T2	37.04**	-44.73**	-7.92	11.76*	18.09	-	-	-	-	-	-	-
17.	L7 x T2	-3.00	-15.98	25.12**	-40.74**	-	-	18.69**	-	-	-	-	-
18.	L8 x T2	27.34**	-18.37**	18.61**	-3.63	0.62	-	10.48*	-	-	-	-	-
19.	L9 x T2	27.66**	-31.94**	15.34**	41.56**	6.38	-	1.87	3.81	-	-	-	-
20.	L10 x T2	-0.36	103.31**	-25.13**	41.71**	-	35.29**	-	18.10**	-	-	-	-
21.	L1 x T3	50.49**	251.38**	62.30**	-17.86**	27.05**	158.54**	22.05**	-	-	56.65**	-	-
22.	L2 x T3	23.96**	158.56**	26.72**	-2.24	-	90.24**	15.75**	-	-	15.27**	-	-
23.	L3 x T3	17.50*	139.34**	-33.33**	-22.66**	15.57*	78.05**	-	-	-	7.88	-	-
24.	L4 x T3	-22.81**	2.22	23.08**	-0.71	-	-	-	-	-	-	-	-
25.	L5 x T3	17.65*	143.02**	2.46	-12.21**	14.75	69.92**	-	-	-	2.96	-	-
26.	L6 x T3	0.00	86.26**	-23.51**	-56.08**	-	75.54**	-	-	-	20.20**	-	-
27.	L7 x T3	17.24**	40.78**	41.70**	-9.31*	10.07	17.89*	24.41**	-	-	-	-	-
28.	L8 x T3	-21.83**	-2.49	29.88**	-23.74**	-	-	28.35**	-	-	-	-	-
29.	L9 x T3	-53.61**	-42.70**	1.44	6.28	-	-	-	-	-	-	-	-
30.	L10 x T3	10.10	82.14**	-12.56*	-20.00**	-	24.39**	-	-	-	-	-	-

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

Table.12 Heterosis for protein content in grain

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	-8.14**	-3.31*	8.23*	-7.99**	-	-	6.39	-	-	-	-	-
2.	L2 x T1	-13.37**	-12.36**	-4.22	-5.10**	-	-	-	-	-	-	-	-
3.	L3 x T1	-5.36*	11.91**	4.16	13.64**	-	6.31**	1.58	10.40**	-	-	-	-
4.	L4 x T1	-13.05**	-11.83**	-12.64**	-15.72**	-	-	-	-	-	-	-	-
5.	L5 x T1	3.40	-8.14**	-4.46	-17.39**	1.88	-	-	-	-	-	-	-
6.	L6 x T1	-5.26*	-20.08**	-22.96**	-21.22**	-	-	-	-	-	-	-	-
7.	L7 x T1	12.87**	-14.95**	-17.52**	-13.12**	5.30*	-	-	-	-	-	-	-
8.	L8 x T1	0.15	-22.36**	-20.30**	-18.83**	-	-	-	-	-	-	-	-
9.	L9 x T1	-9.23**	-16.68**	-15.72**	-15.54**	-	-	-	-	-	-	-	-
10.	L10 x T1	4.74*	18.43**	14.03**	12.61**	0.61	0.32	0.61	1.12	-	-	-	-
11.	L1 x T2	5.16*	7.27**	15.08**	-2.48**	-	2.12	10.94**	-	-	2.12	9.49**	-
12.	L2 x T2	-19.00**	-29.67**	-23.80**	-23.08**	-	-	-	-	-	-	-	-
13.	L3 x T2	-18.89**	-16.09**	-25.29**	-24.38**	-	-	-	-	-	-	-	-
14.	L4 x T2	-3.70	-9.36**	-11.34**	-13.42**	-	-	-	-	-	-	-	-
15.	L5 x T2	-16.28**	-33.21**	0.48	-19.92**	-	-	-	-	-	-	-	-
16.	L6 x T2	-5.75*	-19.13**	19.71**	-12.26**	-	-	-	-	-	-	-	-
17.	L7 x T2	-9.55**	-15.01**	-20.22**	-13.93**	-	-	-	-	-	-	-	-
18.	L8 x T2	-1.13	-26.30**	-25.72**	-22.46**	-	-	-	-	-	-	-	-
19.	L9 x T2	-0.56	-29.97**	-23.19**	-19.35**	-	-	-	-	-	-	-	-
20.	L10 x T2	-4.32	17.69**	10.30**	7.22**	-	-	-	-	-	-	-	-
21.	L1 x T3	-14.90**	-28.05**	-24.59**	-34.55**	-	-	-	-	-	-	-	-
22.	L2 x T3	12.23**	-3.59*	-6.98*	-9.87**	1.41	-	-	-	0.94	-	-	-
23.	L3 x T3	-16.31**	4.60**	-1.48	-2.38**	-	0.88	-	-	-	-	-	-
24.	L4 x T3	2.46	-15.71**	-20.92**	-19.28**	-	-	-	-	-	-	-	-
25.	L5 x T3	-8.92**	-18.67**	-22.63**	-22.68**	-	-	-	-	-	-	-	-
26.	L6 x T3	-9.94**	-6.84**	-12.39**	-11.11**	-	-	-	-	-	-	-	-
27.	L7 x T3	2.85	-15.78**	-19.57**	-18.98**	-	-	-	-	-	-	-	-
28.	L8 x T3	-9.18**	-26.88**	-13.76**	-10.88**	-	-	-	-	-	-	-	-
29.	L9 x T3	-11.69**	-22.25**	-22.18**	-19.75**	-	-	-	-	-	-	-	-
30.	L10 x T3	-8.42**	-14.04**	-13.05**	-15.01**	-	-	-	-	-	-	-	-

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

Table.13 Heterosis for protein content in fodder

S. No.	Crosses	Heterosis				Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
1.	L1 x T1	-0.12	6.00**	5.43**	5.23**	-	3.03**	4.23**	3.69**	-	-	-	-
2.	L2 x T1	-7.23**	1.01	1.94*	3.87**	-	0.97	1.73	1.77*	-	-	-	-
3.	L3 x T1	-1.18	2.65**	3.56**	4.39**	-	-	1.53	3.91**	-	-	-	-
4.	L4 x T1	-25.26**	-5.59**	-1.86	-0.79	-	-	-	-	-	-	-	-
5.	L5 x T1	2.72	-6.18**	-6.14**	-4.20**	-	-	-	-	-	-	-	-
6.	L6 x T1	-10.00**	-37.27**	-32.69**	-35.73**	-	-	-	-	-	-	-	-
7.	L7 x T1	20.82**	26.32**	27.76**	31.55**	10.73**	7.22**	9.21**	13.96**	-	-	-	-
8.	L8 x T1	14.31**	3.87**	7.01**	9.75**	13.05**	3.23**	5.72**	7.04**	-	-	-	-
9.	L9 x T1	-17.30**	-10.87**	-10.21**	-9.04**	-	-	-	-	-	-	-	-
10.	L10 x T1	21.44**	-9.15**	-8.07**	-6.66**	20.65**	-	-	-	1.76	-	-	-
11.	L1 x T2	-0.66	-0.60	-1.95	-2.57**	-	-	-	-	-	-	-	-
12.	L2 x T2	-19.76**	-4.76**	-2.98**	-3.37**	-	-	-	-	-	-	-	-
13.	L3 x T2	11.97**	4.96**	5.17**	4.81**	7.97**	0.60	0.00	-	-	-	-	-
14.	L4 x T2	-2.00	14.09**	14.68**	9.83**	-	6.98**	7.36**	2.67**	-	-	-	-
15.	L5 x T2	-23.98**	-7.28**	-6.31**	-7.46**	-	-	-	-	-	-	-	-
16.	L6 x T2	4.71**	-16.21**	-16.51**	-15.39**	1.18	-	-	-	-	-	-	-
17.	L7 x T2	-8.64**	27.33**	27.78**	28.47**	-	15.13**	16.23**	16.52**	-	-	-	-
18.	L8 x T2	13.41**	9.30**	8.60**	8.09**	11.01**	1.24	0.20	0.29	-	-	-	-
19.	L9 x T2	22.85**	-26.40**	-25.00**	-25.12**	21.61**	-	-	-	-	-	-	-
20.	L10 x T2	-0.05	3.55**	6.12**	5.08**	-	-	0.38	-	-	-	-	-
21.	L1 x T3	-23.83**	-28.11**	-28.03**	-29.45**	-	-	-	-	-	-	-	-
22.	L2 x T3	25.12**	9.37**	10.55**	9.02**	14.10**	5.04**	6.62**	5.20**	8.34**	-	-	-
23.	L3 x T3	-27.59**	10.23**	8.72**	7.73**	-	9.00**	7.13**	5.58**	-	-	-	-
24.	L4 x T3	26.38**	-30.62**	-28.49**	-29.69**	17.78**	-	-	-	6.66**	-	-	-
25.	L5 x T3	-10.61**	-11.12**	-10.65**	-12.15**	-	-	-	-	-	-	-	-
26.	L6 x T3	-20.19**	-34.27**	-33.33**	-33.86**	-	-	-	-	-	-	-	-
27.	L7 x T3	28.79**	30.93**	31.61**	31.26**	21.47**	15.10**	15.87**	15.26**	-	-	-	-
28.	L8 x T3	-18.95**	-26.12**	-23.62**	-24.56**	-	-	-	-	-	-	-	-
29.	L9 x T3	-7.81**	0.26	0.86	-0.38	-	-	-	-	-	-	-	-
30.	L10 x T3	-3.89*	-9.92**	-9.79**	-10.49**	-	-	-	-	-	-	-	-

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

The positive heterosis was significant for 15, 10, 19 and 9 crosses in E_1, E_2, E_3 and E_4, respectively. The expression of grain yield depends upon the contribution of component traits and extent of their mutual cancellations. The crosses exhibited significant positive heterosis for grain yield in different environment, also exhibited significant heterosis for one or other characters like dry fodder yield, harvest index, number of primaries per plant, number of seeds per primary, protein content in grain and protein content in fodder. This indicates that component traits made significant contribution in expression of high heterosis for grain yield. Heterosis for grain yield along with heterosis for one or more yield component was also reported by EI-Shouny *et al.,* (1990), Manikam and Das (1994), Ganesh *et al.,* (1996), Ghorade *et al.,* (1997), Navapour and Rezaie (1998), Salunke and Deore (1998), Swami (2000), Acharya (2000), Sharma (2002), Deora (2000) and Khandelwal (2003).

Out of these crosses, which exhibited significant positive heterosis for grain yield, heterobeltiosis was significant for 7, 8, 14 and 7 crosses in E_1, E_2, E_3 and E_4 respectively. The maximum value of heterobeltiosis was 73.40 (L_2 x T_2), 158.54 (L_1 x T_3), 73.15 (L_2 x T_1) and 111.36 per cent (L_6 x T_1) in E_1, E_2, E_3 and E_4, respectively. The crosses exhibited heterobeltiosis in more than one environment for grain yield were L_5 x T_1, L_6 x T_1, L_7 x T_1 and L_9 x T_1 in E_3 and E_4. Apart from these heterobeltiosis for other economically important characters in more than one environment were also observed *i.e.*, for dry fodder yield in L_5 x T_1, L_2 x T_2, L_3 x T_2, L_2 x T_3 and L_3 x T_3 in E_1 and E_3; for protein content in fodder in L_7 x T_1, L_2 x T_3 and L_7 x T_3 in all the four environments and L_1 x T_1, L_8 x T_1, L_4 x T_2, L_7 x T_2 and L_3 x T_3 in E_1, E_2 and E_3; for days to maturity L_1 x T_1, L_6 x T_1, L_7 x T_1, L_8 x T_1, L_{10} x T_2, L_1 x T_3, L_4 x T_3, L_5 x T_3, L_6 x T_3 and L_6 x T_3 in all the four environments and for early flowering L_4 x T_1, L_6 x T_1, L_7 x T_1, L_9 x T_1, L_6 x T_2, L_8 x T_1, L_4 x T_2, L_6 x T_2, L_8 x T_2, L_4 x T_2, L_7 x T_3 and L_8 x T_3 in E_3.

In above heterobeltiotic crosses the 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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