HETEROSIS AND GENE ACTION IN BAJRA-NAPIER HYBRIDS

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DECLARATION

I hereby declare that this thesis entitled "**Heterosis and gene action in bajra-napier hybrids**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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LIST OF ABBREVIATIONS

%	per cent
σ^2A	Additive variance
σ^2D	Dominance variance
µm	Micro metre
^0C	Degree Celsius
ANOVA	Analysis of variance
cm	Centimetre(s)
et al.	And others
F.I.B.	Farm Information Bureau
F_1	First filial generation
Fig.	Figure
g	Gram(s)
GCA	General combining ability variance
gca	General combining ability effect
ha	Hectare
i.e.	That is
KAU	Kerala Agricultural University
kg	Kilogram
ml	Millilitre
MSE	Error mean square
SCA	Specific combining ability variance
sca	Specific combining ability effect
SS	Sum of squares
t	Tonne(s)
viz.	Namely

Introduction

1. INTRODUCTION

In world food production and rural economy, the role and importance of forages for feeding domestic herbivores is not so small that it needs greater attention and research. The soaring prices of dairy products and sometimes their non-availability in sufficient quantities are often attributed to the increasing price of cattle feeds. Therefore large scale production of green fodder will help bring down the prices of concentrates and rear healthy milch animals. In dairy production, the cost of feed constitutes about 60-65 per cent of total cost of milk production. Year round supply of forage is very important in order to stabilize animal production especially in the milk shed areas and also for farmers who maintain dairy animals as a source of income. The green nutritious fodder paves the way not only for augmenting the economic production of animal products, but also for the availability of draught power in the era of energy crisis.

Kerala, today accounts for about 1.18 per cent of the total livestock population in India, with only 1.18 per cent of India's total geographical area. Our cattle and buffalo population are 3.39 million and 1.65 million respectively (F.I.B., 2002). But only 2024 ha (0.07 per cent) of the state's cropped area is under forage crops and there is hardly any scope for expansion because of pressure on agricultural lands for food and cash crops.

The only solution for bridging the gap between the demand and supply of green fodder lies in maximizing the fodder production in space and time, by identifying new forage resources and increasing the fodder production within the existing farming system. This calls for the need to rejuvenate and also to increase the productivity of fodder crops by developing new varieties.

Grasses and legumes are the cheapest source of feeds for ruminants and among these grasses have priority due to their high yield and perenniality. Stebbins (1974) was of the view that interspecific hybridization could be of value in the arid and semi arid regions where suitably adapted species are rare. Interspecific hybridization between genetically divergent species of bajra (*Pennisetum americanum*) and napier grass (*Pennisetum purpureum*) has been attempted to evolve hybrids by combining the superior quality attributes of bajra and high yielding ability of napier grass.

Owing to paucity of information on the genetics of various yield and quality attributes in bajra-napier hybrids, only few studies have been carried out in this field. An attempt has been made here to study "Heterosis and gene action in bajra-napier hybrids" with the objective of developing hybrids with high fodder yield and quality.

Review of Literature

2. REVIEW OF LITERATURE

A review of research work on different aspects like heterosis, combining ability and gene action is presented here.

Interspecific hybrids between *Pennisetum americanum*, 2n = 14 (diploid) and *Pennisetum purpureum*, 2n = 4x = 48 (tetraploid) are the most widely studied in the genus *Pennisetum*. Several hybrids have been produced between these two species by many workers. The first interspecific hybrid between *P. purpureum* (napier grass) and *Pennisetum glaucum* (pearl millet) was produced by Burton in 1941 (Burton, 1944). He reported that the hybrids resembled napier grass, out yielded both the parents, were triploid and highly sterile.

Later, interspecific hybrids were produced in India (Krishnaswamy and Raman, 1949, 1951 and 1953), South Africa (Gildenhuys, 1950; Gildenhuys and Brix, 1964), Pakistan (Khan and Rahman, 1963), Australia (Pritchard, 1971; Muldoon and Pearson, 1977), Sri Lanka (Dhanapala *et al.*, 1972), Nigeria (Aken 'Ova and Chheda, 1973) and in other countries.

The interspecific hybrids between bajra and napier grass were allotriploid and sterile. These sterile hybrids were amenable for easy vegetative propagation through root slips and stem cuttings. The hybrids were highly vigorous and produced quality forage which excelled both the parents in many respects (Patil and Gosh, 1962; Khan, 1962; Powell and Burton, 1966; Gupta, 1969; Jauhar, 1981).

The hybrids are produced using either pearl millet or napier grass as the female parent. However, using pearl millet as the female parent has several advantages. The protogynous nature of pearl millet eliminates the need for emasculation. Also identification of hybrids is easier at seedling stage and seed shattering is absent or minimal (Jauhar, 1981).

2.1 HETEROSIS

2.1.1 Biometrical Traits

In interspecific hybrids between pearl millet and napier grass, considerable heterosis for plant height, stem thickness, tillering, leaf size and fodder yield has been reported by many workers (Burton, 1944; Krishnaswamy and Raman, 1949; Khan and Rahman, 1963; Patil, 1963; Hussain *et al.*, 1968; Aken 'Ova *et al.*, 1974; Gupta, 1974; Muldoon and Pearson, 1977).

Sterile hybrid produced from a cross between *Pennisetum typhoides* and *P. purpureum* was propagated by cuttings and some of the clones gave very high fodder yield. They were capable of yielding four or five cuts per year and performed well in rainfed areas (Khan, 1960).

Patil and Joshi (1962) produced a hybrid 'Giant Napier' by crossing *P. purpureum* and cultivated *P. typhoides*. The hybrid recorded a total annual production of 1,15,203 kg per acre as compared to 55,792 kg by napier grass.

Powell and Burton (1966) crossed Merkerson type of *P. purpureum* with male sterile Tift 23A of *P. typhoides* and obtained a high yielding hybrid.

In a cross between the diploid *P. typhoides* and tetraploid *P. purpureum*, Aken'Ova and Chheda (1973) reported that forage yield of hybrids varied from 0.84 to 250 kg per plant. Leaf length, leaf width and number of tillers were also closer to *P. purpureum* than to *P. typhoides*.

It has been reported by Chheda *et al.* (1973) that dry matter yield of hybrids from the cross between *P. typhoides* cv. Maiwa and *P. purpureum* were comparable with those of *P. purpureum* and superior to those of *P. typhoides* Tift 23A x *P. purpureum* hybrids.

Veerappa *et al.* (1976) reported that BH 18, an interspecific hybrid between *P. typhoides* male sterile Tift 23A and *P. purpureum* produced an average of 100 tillers per plant and 15.5 kg of fodder as compared to 65 tillers and 11.5 kg in Kamadhenu.

Hanna and Monson (1980) reported that in most of the pearl millet x napier grass hybrids, green fodder yield was equal to the best of pearl millet hybrids. They also reported significant heterosis for dry fodder yield.

Three promising hybrids CN 1, CN 2 and CN 3 identified at Coimbatore was derived from crosses between ICRISAT pearl millet lines 2787 and 1697 and napier grass (Chandrasekaran, 1982).

In their study on heterosis in pearl millet x napier grass hybrids, Natarajaratnam and Chandrasekharan (1983) reported that heterosis for yield was due to simultaneous heterosis for leaf number, tiller number and leaf area.

Katoch *et al.* (1987) evaluated fourteen genetically diverse napier-bajra hybrids from different sources viz., Jhansi, Ludhiana and Coimbatore along with NB-21 as check. They observed that three hybrids out yielded the check by 97, 38 and 39 per cent for green fodder yield and 65, 16 ad 18 per cent for dry matter yield.

Thirumeni (1992) obtained a hybrid between *P. americanum* and *P. purpureum* which was found to be superior based on *per se* performance and heterosis values for four of the thirteen traits studied. The heterotic expression for the four traits were 29.30 per cent for green fodder yield, 43.29 per cent for dry fodder yield, 4.26 per cent for leaf : stem ratio and 39.57 per cent for leaf area per clump.

Thirumeni and Das (1994) studied heterosis for eight quantitative characters in interspecific hybrids of pearl millet and napier grass. Among the fifteen genotypes studied, IP 7460 x FD 444 exhibited high positive standard heterosis for traits associated with biomass production.

Amirthadevarathinam (1995) reported high heterosis for various forage yield characters in bajra-napier hybrids.

In a cross involving seven *P. americanum* lines and five *P. purpureum* testers, Amirthadevarathinam and Dorairaj (1995) obtained a most promising hybrid, showing higher heterosis for all the seven forage yield components studied.

Thirumeni and Das (1997), in a study involving fifteen forage pearl millet genotypes, five napier grass genotypes and their fifteen hybrids, found that the hybrid IP 15507 x FD 429 was superior based on *per se* performance and heterosis values for four of the thirteen traits studied. The heterotic expression of this cross was found to be optimum for three important characters viz., green fodder yield, dry fodder yield and leaf : stem ratio.

2.1.2 Qualitative Traits

In pearl millet x napier grass hybrids considerable heterosis for qualitative traits was observed by many workers (Burton, 1944; Krishnaswamy and Raman, 1949; Khan and Rahman, 1963; Patil,1963; Hussain *et al.*, 1968; Aken'Ova *et al.*, 1974; Gupta, 1974 and Muldoon and Pearson,1977).

The interspecific hybrid, 'Giant Napier' produced by crossing *P. purpureum* and cultivated *P. typhoides* recorded 25 per cent more protein and 12 per cent more sugar than napier grass and was considered more nutritious and palatable than napier grass (Patil and Joshi, 1962).

Powell and Burton (1966) reported that a cross between Merkerson type of *P. purpureum* and male sterile Tift 23A of *P. typhoides* was of high quality, juicy with low fibre content.

In a comparative study involving fourteen interspecific hybrids and their parents for qualitative characters like crude fat, crude fibre, total digestible nutrients etc, Hussain *et al.* (1968) reported an average increase of four times over *P. typhoides* and two and a half times over *P. purpureum* of total digestible nutrients per acre from hybrids. Five hybrids had low crude fibre content.

Aken'Ova and Chheda (1973) reported that crude protein content of hybrids ranged from 23.7 per cent to 28.7 per cent of total dry weight.

Studies conducted by Hanna and Monson (1980) revealed that crude protein in pearl millet x napier grass hybrids was equal to that of best pearl millet hybrids.

Chandrasekaran (1982) reported that the three promising hybrids CN1, CN2 and CN3 were more superior to their parents in macro and micro nutrient content as well as palatability.

Natarajaratnam and Chandrasekharan (1983) while studying heterosis in the hybrid TNAU CN2 observed a higher photosynthetic rate, phosphoenol pyruvate carboxylase activity and nitrate reductase activity than its parents.

Katoch *et al.* (1987) evaluated fourteen genetically diverse napier – bajra hybrids from different sources along with a check (NB21) and found that three hybrids out yielded the check by 80, 38 and 9 per cent for crude protein and 69, 33 and 14 per cent for digestible dry matter production besides possessing low oxalate content.

Thirumeni and Das (1994) reported that there were different responses among the interspecific hybrids for qualitative traits. For oxalic acid content, negative heterosis was considered advantageous. All the hybrids showed significant negative heterobeltiosis but only one hybrid showed significant negative standard heterosis.

2.2 COMBINING ABILITY AND GENE ACTION

Based on diallel analysis in pearl millet Mahadevappa (1968a) reported that straw yield was governed by over dominance and epistasis whereas tillering was controlled by dominant and complementary genes and plant height by complementary and over dominance genes.

Mahadevappa (1968b) in a diallel cross study with ten pearl millet inbreds reported that general combining effects were lower than specific combining effects for peduncle diameter and plant height. Tillering was influenced by additive genes whereas plant height and straw yield were not much under the influence of additive gene action.

In a cross involving twenty five lines of *P. typhoides* and two male sterile lines, Gupta and Sidhu (1970) reported that general and specific combining effects of yield were related to that of yield components of male parents. The variance component due to specific combining ability was high for all the characters except for leaf number and leaf size.

Gupta and Gupta (1971) in a study involving eighteen lines of pearl millet, three male sterile lines and F_1s, reported that the component of specific combining ability variance was high for leaf size and leaf number along with green fodder yield, stem thickness, plant height and days to flowering. The general combining ability effects were also found to be important for leaf size, stem thickness and leaf number. Eight crosses were found to have high specific combining ability and these crosses involved high x high or high x average combining parents.

In a study involving 18 inbreds and three male sterile lines of pearl millet in a line x tester analysis, Tyagi *et al.* (1974) reported that component of specific combining ability was higher than general combining ability for plant height, tiller number, leaf number, stem thickness and fodder weight, indicating the prevalence of non-additive gene action. The magnitude of heterosis was high when parents having high x high or high x medium combining ability was involved. They also reported that lines with good combining ability might necessarily not be better in all cross combinations.

From a combining ability analysis for eleven characters in diallel set of nineteen fodder lines of pearl millet, Ramanujam and Verma (1976) reported that variances due to general and specific combining abilities were significant for green and dry fodder yield, plant height, leaf number, leaf length and leaf breadth and variances due to specific combining ability were higher than that of general combining ability.

Jacob (1977) reported that pearl millet lines 126 D2A, 8369 A, MS 6316A and MS 6713 A had highest general combining effects for most of the characters studied. Variance due to general combining ability was high for plant height, stem thickness, leaf length and leaf breadth whereas high specific combining ability variances were observed for tiller number, leaf number and green fodder yield. Parents involved in three high yielding crosses showed high general combining ability indicating the partial contribution of general combining ability effects for high specific combining ability effects in these crosses.

In a diallel analysis in fodder pearl millet Hooda *et al.* (1978) reported that green fodder yield, dry matter yield, stem girth, leaf length, leaf breadth, protein content and *in vitro* drymatter digestibility were governed by non-additive genetic variance and to certain extent, additive genetic variance also governed green fodder yield, drymatter yield, stem girth and leaf length.

In a study involving six inbreds of pearl millet and their hybrids Hooda and Solanki (1979) reported high variance due to specific combining ability for protein content indicating non-additive gene action for this character. They also reported significant positive correlation between specific combining ability effects and the F_1 mean.

Sidhu *et al.* (1980) in a 13 x 13 diallel cross of pearl millet reported both additive and non-additive gene action for green fodder yield, leaf number, leaf size, tiller number and plant height.

In a diallel analysis involving twelve *P. typhoides* lines, Chawla and Gupta (1982) reported that non-additive gene effects were more important for characters like green fodder yield, oxalic acid, calcium, sodium and potassium contents.

Dass *et al.* (1982) in a 12 x 12 diallel analysis reported that mostly dominant genes were responsible for high dry fodder yield in pearl millet.

In a 13 x 13 diallel cross of pearl millet, Gupta and Sidhu (1984) reported that non-additive component was important for oxalic acid while for protein content both additive and non-additive components were equally important.

In a study involving twelve inbred lines, three male sterile lines of pearl millet and their hybrids, Gupta and Choubey (1988) reported that general combining ability of females was significant for all characters except stem thickness and of males was significant for leaf length and leaf width. The specific combining ability was significant for plant height, stem thickness and leaf width.

Ashwanikumar and Dahiya (1989) in an analysis of nine parent diallel of pearl millet reported that general combining ability mean squares were significant for stover yield and tillering whereas specific combining ability mean squares were significant for stover yield and plant height. They also reported that additive component was predominant for tillering and non-additive component for plant height and stover yield.

In a line x tester analysis involving 25 inbred lines and three male sterile lines of pearl millet along with their 75 hybrids, Gopalan and Sreerangasamy (1989) reported that the variance due to specific combining ability was greater than the variance due to general combining ability for characters like plant height, tiller number, leaf number, stem thickness, stem weight, green fodder yield, dry matter yield and crude protein content. The general combining ability variance was higher than specific combining ability variance for leaf length, leaf breadth and leaf weight.

In a diallel analysis using 36 F_1s of pearl millet, Vedprakash and Sastry (1989) reported that there was predominance of non-additive genetic effects in the inheritance of green fodder yield and its components, *viz.*, number of tillers per plant, number of leaves per plant and leaf area. The crosses exhibiting positive and desirable specific combining ability effects had either both or one of the parents as a poor general combiner.

On a combining ability analysis involving nine parent diallel crosses of pearl millet for dry fodder yield, biological yield, plant height and number of tillers, Ashwanikumar and Dahiya (1991) reported highly significant mean squares for general combining ability and specific combining ability.

In a diallel cross involving twelve parental populations of pearl millet, Mani and Phatadi (1992) reported that additive gene action was predominant for various traits studied.

In a line x tester study involving eighteen genotypes of pearl millet, five napier grass genotypes and their hybrids, Thirumeni (1992) reported that, among female parents RCB IC-9 and APFB-3 recorded high general combining ability effects as well as *per se* performance for green fodder yield and its component traits besides a few quality attributes. Among the male parents FD 464, which recorded high cumulative green fodder yield, showed high *gca* effect for green fodder yield and its component characters besides quality traits. The hybrids of RCB IC-9 x FD 464 and ICMV-86104 x FD 429 were found to be outstanding in their *per se* performance and specific combining ability effects for green fodder yield and its component traits.

Amirthadevarathinam (1995) while studying combining ability in interspecific hybrids between bajra and napier grass, reported that the magnitude of specific combining ability variance was greater than that of general combining ability for various characters suggesting the predominance of non-additive gene action.

Sukanya (1997) in a line x tester analysis involving three bajra lines and ten napier grass genotypes as testers, observed that specific combining ability was high for all the characters studied. Bajra line IP 6426 and napier lines FD 434 and FD 439 were best general combiners for fodder yield. Pb 405 A x AD 680, Giant bajra x FD 449 and IP 6426 x FD 469 were superior for both green and dry fodder yield. IP 6426 x FD 469 was also good for leaf/stem ratio indicating superior quality.

Materials and Methods

3. MATERIALS AND METHODS

The present study on "Heterosis and gene action in bajra-napier hybrids" was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during March 2001 to August 2002. The details of the materials used as well as the methods adopted are discussed in this chapter.

3.1 MATERIALS

The experimental material consisted of seven accessions of bajra (*Pennisetum americanum* (L.) Leeke), three accessions of napier grass (*Pennisetum purpureum* (K.) Schum) and 21 hybrid combinations. The seven superior female parents (bajra) based on their characteristics of economic importance and also quality attributes, *viz.*, APFB-2, Composite 9, DRSB-3, FD 1917, HES-4, IP 15814 and TNSC-4 and three male parents (napier grass) with high yield *viz.*, FD 431, FD 467 and FD 471 were selected using selection index based on discriminant function from the germplasm collection maintained under the All India Coordinated Research Project on Forage Crops, College of Agriculture, Vellayani. Twenty one hybrids were produced by crossing these seven lines and three testers. The details of the parents and hybrids produced are presented in Tables 1 and 2 respectively.

3.2 METHODS

3.2.1 Line x Tester Hybridization Programme

The bajra accessions used as female parents were sown twice, during June 2001 at an interval of ten days to ensure synchrony in flowering with napier grass accessions, which were used as male parents. The napier grass accessions were raised using rooted slips during February 2001.

The protogynous nature of bajra facilitated artificial pollination without emasculation. The spikes of both the lines and testers were

Table 1 Details of parents studied

Sl. No.	Treatments	Parents	Characters
	LINES		
1	L_1	APFB-2	Good quality
2	L_2	Composite 9	Good quality
3	L_3	DRSB-3	Good quality
4	L_4	FD 1917	Good quality
5	L_5	HES-4	Good quality
6	L_6	IP 15814	Good quality
7	L_7	TNSC-4	Good quality
	TESTERS		
8	T_1	FD 431	High yielding
9	T_2	FD 467	High yielding
10	T_3	FD 471	High yielding

Table 2 Details of hybrids obtained

Sl. No.	Treatments	Hybrids
1	$L_1 \times T_1$	APFB-2 x FD 431
2	$L_1 \times T_2$	APFB-2 x FD 467
3	$L_1 \times T_3$	APFB-2 x FD 471
4	$L_2 \times T_1$	Composite 9 x FD 431
5	$L_2 \times T_2$	Composite 9 x FD 467
6	$L_2 \times T_3$	Composite 9 x FD 471
7	$L_3 \times T_1$	DRSB-3 x FD 431
8	$L_3 \times T_2$	DRSB-3 x FD 467
9	$L_3 \times T_3$	DRSB-3 x FD 471
10	$L_4 \times T_1$	FD 1917 x FD 431
11	$L_4 \times T_2$	FD 1917 x FD 467
12	$L_4 \times T_3$	FD 1917 x FD 471
13	$L_5 \times T_1$	HES-4 x FD 431
14	$L_5 \times T_2$	HES-4 x FD 467
15	$L_5 \times T_3$	HES-4 x FD 471
16	$L_6 \times T_1$	IP 15814 x FD 431
17	$L_6 \times T_2$	IP 15814 x FD 467
18	$L_6 \times T_3$	IP 15814 x FD 471
19	$L_7 \times T_1$	TNSC-4 x FD 431
20	$L_7 \times T_2$	TNSC-4 x FD 467
21	$L_7 \times T_3$	TNSC-4 x FD 471

bagged separately with butterpaper bags immediately after the emergence of the spike from the flag leaf, in order to avoid contamination from foreign pollen. In case of long panicles, bagging and crossing were restricted to top 20-25 cm portion to avoid overlapping of stigma receptivity and anthesis. The pollen grains were collected in butterpaper bags from the bagged spike of the male parent and dusted on to the receptive stigmas of the previously bagged spike of the female parent. This was carried out for three consecutive days. The crossed ear heads were covered with butterpaper bags and labelled properly (Plate 1). The crossed bajra spikes were harvested at maturity for evaluation of hybrids. Selfed spikes from female parents were also harvested separately.

3.2.2 Identification of Hybrids

The seeds from the crossed ear heads which contained both selfed and crossed seeds were sown during October 2001 to identify the hybrids. The seeds were sown in rows of two metre length spaced 50 cms apart (Plate 2). Selfed plants were removed based on their earliness in flowering and pollen fertility. Plants with panicles resembling napier grass were considered as hybrids (Plates 3 and 4) and hybridity was confirmed based on pollen study. The plants producing sterile pollen were identified as hybrids.

3.2.3 Evaluation of Hybrids

The seven lines (female parents), three testers (male parents) and their 21 hybrids were evaluated along with a check Co-2, in a randomised block design with two replications during March to August, 2002. The slips of each treatment were planted in a single row at a spacing of 50 cm (Plate 5). The cultural and management practices were followed as per Package of Practices Recommendations (KAU, 1996).

Three cuts were taken from napier grass and hybrids. The first cut was taken 60 days after planting and subsequent cuts at 45 days interval. In bajra, only one cut was taken, at 50 per cent flowering stage. Data on

Plate 1 Crossing block

Plate 2 Population of bajra and bajra x napier hybrids

Plate 3 Panicles of bajra and napier grass

Plate 4 Panicle of bajra x napier hybrid

Plate 5 Field view of bajra x napier hybrids

various characters were recorded at each harvest, replication wise from a random sample of five plants each with respect to treatments and the mean values were used for statistical analysis.

3.2.4 Observations Recorded

3.2.4.1 Plant Height, cm

The height of the plant from the ground level to the tip of the main tiller at the time of harvest was measured and expressed in centimeters.

3.2.4.2 Tiller Number per Plant

The total number of tillers per plant including the main shoot were counted and recorded.

3.2.4.3 Leaf Number per Plant

The total number of leaves from the observational plants were counted and the mean number recorded.

3.2.4.4 Internode Length, cm

The length of the fourth internode from the top was measured in centimeters.

3.2.4.5 Stem Girth, cm

The girth at the middle of the fourth internode from the top was measured and expressed in centimeters.

3.2.4.6 Leaf Weight per Plant, g

The three crops were harvested at appropriate stage of harvest. The leaves were separated from the observational plants and the mean weight recorded in grams.

3.2.4.7 Leaf/Stem Ratio

After harvest of each clump, the weight of the leaves and stems were taken separately. From these weights, the leaf/stem ratio was worked out for the observational plants.

3.2.4.8 Crude Protein Content, %

The total nitrogen content of the oven dried samples of the observational plants was estimated by modified Microkjeldhal method (Jackson, 1967). The nitrogen value was multiplied by the factor 6.25 to obtain the protein content expressed as percentage of dry weight of leaves (Simpson *et al.*, 1965).

3.2.4.9 Crude Fibre Content, %

The crude fibre content of the leaves of the observational plants was estimated by acid and alkali digestion method (Sadasivam and Manickam, 1992). From the representative sample of the dried plant material, two grams was taken and boiled with 200 ml of sulphuric acid for 30 minutes. Then it was filtered through a muslin cloth and the filtrate washed with boiling water until the washings were no longer acidic. Residue obtained was again boiled with 200 ml sodium hydroxide solution for 30 minutes. It was again filtered through muslin cloth and washed with 25 ml of 1.25 per cent boiling sulphuric acid, three 50 ml portions of water and 25 ml alcohol. The residue was transferred to ashing dish which was pre-weighed (W_1). The residue was then dried for two hours at 130 ± 2°C. The dish was cooled and weighed (W_2). Then the residue was ignited for 30 minutes at 600 ± 15°C, cooled in a dessicator and weighed (W_3). The percentage crude fibre in the sample was estimated as :

$$= \frac{\text{Loss in weight on ignition}}{\text{Weight of sample}} \times 100$$

$$= \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Weight of sample}} \times 100$$

3.2.4.10 Green Fodder Yield, t ha^{-1}

The total weight of the observational plants were taken at the time of harvest and mean weight calculated and multiplied with the number of plants in one hectare and expressed in tonnes per hectare.

3.2.4.11 Dry Fodder Yield, t ha^{-1}

One hundred grams of the fresh sample from the observational plants were taken and dried under normal conditions for 10 days. This was then dried in an electric oven at 60°C for 24 hours. The dried samples were weighed and the dry matter content was calculated in percentage. The green fodder yield was multiplied with dry matter content to get the dry fodder yield per hectare in tonnes.

3.2.4.12 Pollen Sterility, %

Pollen sterility of the observational plants was estimated by staining pollen grains from freshly prepared anthers on a glass slide with glycerine : acetocarmine (1 : 1). The partly and poorly stained, shrivelled and empty pollen grains were considered as sterile while pollen grains that were full and well stained were considered as fertile. Pollen sterility was expressed in percentage. Size of both fertile and sterile pollen grains was measured using ocular micrometer which was calibrated with stage micrometer.

3.2.4.13 Palatability

Equal quantity of napier grass, bajra and hybrids was fed to the cattle and it was found that hybrids had been completely consumed.

3.3 STATISTICAL ANALYSIS

Analysis of variance was done for all the characters under study and significant differences among parents and crosses were tested (Singh and Choudhary, 1985).

3.3.1 Combining Ability Analysis

Combining ability analysis of the line x tester was done through ANOVA technique (Dabholkar, 1992) as follows (Table 3).

Table 3 Analysis of variance for Line x Tester design

Source	df	MS	Expected mean square
Replication	r – 1		
Treatments	n – 1		
Parents	l + t – 1		
Parents vs crosses	1		
Crosses	l x t – 1		
a. Lines	l – 1	M_L	$\sigma^2_e + r\sigma^2_{SCA} + rt\ \sigma^2_{GCA}$ (l)
b. Testers	t – 1	M_T	$\sigma^2_e + r\sigma^2_{SCA} + rl\ \sigma^2_{GCA}$ (t)
c. Line x Tester	(l – 1) (t – 1)	M_{LT}	$\sigma^2_e + r\ \sigma^2_{SCA}$
Error	(n – 1) (r – 1)	M_e	σ^2_e
Total	nr – 1		

where, n = number of treatment materials (l + t + lt)

r = number of replications

l = number of lines

t = number of testers

3.3.1.1 Estimation of General and Specific Combining Ability Effects

General combining ability effect (*gca*) of parents and specific combining ability effect (*sca*) of hybrids were estimated using the following model.

$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$

where,

μ = Population mean

g_i = *gca* effect of i^{th} line

g_j = *gca* effect of j^{th} tester

s_{ij} = *sca* effect of ij^{th} hybrid

e_{ijk} = error associated with ijk^{th} observation

i = 1, 2, ..., l

j = 1, 2, ..., t

k = 1, 2, ..., r

The individual effects were estimated as follows :

(i) Mean $= \dfrac{x_{...}}{rlt}$

(ii) *gca* effect of lines

$$g_i = \frac{x_{i..}}{rt} - \frac{x_{...}}{rlt}$$

(iii) *gca* effect of testers

$$g_j = \frac{x_{.j.}}{rl} - \frac{x_{...}}{rlt}$$

(iv) *sca* effect of hybrids

$$s_{ij} = \frac{x_{ij}}{r} - \frac{x_{i..}}{rt} - \frac{x_{.j.}}{rl} + \frac{x_{...}}{rlt}$$

where,

$x_{...}$ = Totality of observations on all hybrids over 'r' number of replications.

$x_{i..}$ = Totality of observations on i^{th} line over 't' testers and 'r' replications

$x_{.j.}$ = Totality of observations on j^{th} tester over 'l' lines and 'r' replications

Significance of combining ability effects was tested as: $t = \frac{\text{(Effect)}}{\text{SE (effect)}}$

where,

$$\text{SE of } gca \text{ (lines)} = \sqrt{\frac{M_e}{rt}}$$

$$\text{SE of } gca \text{ (testers)} = \sqrt{\frac{M_e}{rl}}$$

$$\text{SE of } sca \text{ (hybrids)} = \sqrt{\frac{M_e}{r}}$$

3.3.1.2 Combining Ability Variance

The GCA variance for lines and testers and SCA variance for the hybrids were calculated as follows :

$$\sigma^2_{GCA} \text{ (lines)} = \frac{M_L - M_{LT}}{rt} = \text{Cov. H.S. (lines)}$$

$$\sigma^2_{GCA}\ \text{(testers)} = \frac{M_T - M_{LT}}{rl} = \text{Cov. H.S. (testers)}$$

$$\sigma^2_{SCA}\ \text{(hybrids)} = \frac{M_{LT} - M_e}{r}$$

3.3.1.3 Gene Action

After estimating the variances due to general combining ability (σ^2_{GCA}) and specific combining ability (σ^2_{SCA}) the gene action was worked out as :

$$\sigma^2_{GCA} = \left[\frac{1 + F}{4}\right] \sigma^2_A$$

$$\sigma^2_{SCA} = \left[\frac{1 + F}{2}\right]^2 \sigma^2_D$$

where, F = inbreeding coefficient

If inbreeding is absent (F = 0)

$$\sigma^2_{GCA} = \tfrac{1}{4}\, \sigma^2_A$$

$$\sigma^2_{SCA} = \tfrac{1}{4}\, \sigma^2_D$$

$$\text{So, } \sigma^2_A = 4\, \sigma^2_{GCA}$$

$$\sigma^2_A = 4\, \sigma^2_{SCA}$$

The significance of σ^2_A is tested respectively for lines and testers as

$$F_{[(l-1),\ (l-1)(t-1)]} = M_L / M_{LT}$$

$$F_{[(t-1),\ (l-1)(t-1)]} = M_T / M_{LT}$$

and that of σ^2_D from

$$F_{[(l-1)(t-1),\ (n-1)(r-1)]} = M_{LT} / M_e$$

3.3.1.4 Proportional Contribution of Lines, Testers and Line x Tester to the Total Sum of Squares of the Hybrids

$$\text{Contribution of lines} = \frac{\text{S.S. (lines)}}{\text{S.S. (hybrids)}} \times 100$$

$$\text{Contribution of testers} = \frac{\text{S.S. (testers)}}{\text{S.S. (hybrids)}} \times 100$$

$$\text{Contribution of lines x testers} = \frac{\text{S.S. (line x tester)}}{\text{S.S. (hybrids)}} \times 100$$

3.3.2 Estimation of Heterosis

Heterosis (expressed in percentage) was estimated for all the characters over mid-parent (relative heterosis), better parent (heterobeltiosis) and standard variety (standard heterosis) as suggested by Rai (1979).

3.3.2.1 Relative Heterosis

Relative heterosis was estimated as the percentage deviation of the mean performance of F_1 ($\overline{F_1}$) over the mean performance of the parents ($\overline{MP}$).

$$\text{Relative heterosis (RH)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

where $\overline{MP}$ = mid parental mean value

$\overline{F_1}$ = average performance of F_1

3.3.2.2 Heterobeltiosis

Heterobeltiosis was estimated in comparison to the better parent as

$$\text{Heterobeltiosis (HB)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where $\overline{BP}$ = better parental mean of a particular cross

3.3.2.3 Standard Heterosis

Standard heterosis was estimated in comparison to the standard variety as

$$\text{Standard heterosis (SH)} = \frac{\overline{F_1} - \overline{SP}}{\overline{SP}} \times 100$$

where $\overline{SP}$ = mean of the standard variety.

The significance of different types of heterosis was tested by 't' test with (n-1) (r-1) degrees of freedom. The critical difference (CD) for comparison of

$\overline{F_1}$ with $\overline{MP}$ is $t\sqrt{\dfrac{3\ M_e}{2r}}$

$\overline{F_1}$ with $\overline{BP}$ is $t\sqrt{\dfrac{2\ M_e}{r}}$

$\overline{F_1}$ with $\overline{SP}$ is $t\sqrt{\dfrac{2\ M_e}{r}}$

Results

4. RESULTS

The performance of 21 bajra-napier hybrids was evaluated for heterosis and combining ability, along with their parents for eleven characters namely, plant height, tiller number per plant, leaf number per plant, internode length, stem girth, leaf weight per plant, leaf/stem ratio, crude protein content, crude fibre content, green fodder yield and dry fodder yield. Apart from these, palatability and pollen sterility was also studied.

The mean data were subjected to Line x Tester analysis and the results are presented below.

4.1 MEAN PERFORMANCE

Significant genotypic differences were observed for all the characters. The mean performance of lines, testers and hybrids for different characters are presented in Table 4a and 4b.

4.1.1 Plant Height, cm

The mean plant height of lines ranged form 153.25 cm in TNSC-4 to 193.55 cm in Composite 9. The plant height was maximum for FD 467 (212.52 cm) and minimum for FD 431 (198.34 cm) among testers. The maximum plant height among crosses was recorded by DRSB-3 x FD 467 (270.71 cm) and the minimum height was shown by FD 1917 x FD 467 (140.32 cm). All the hybrids differed significantly in their height from DRSB-3 x FD 467.

4.1.2 Tiller Number per Plant

The maximum number of tillers per plant was 6.49 in DRSB-3 among lines and 16.87 in FD 471 among testers. The minimum number was recorded in IP 15814 (4.48) among lines and FD 431 (12.33) among testers. The testers differed significantly from each other. The cross

Table 4a Mean performance of lines and testers for various characters

Characters / Treatments	Plant height, cm	Tiller number per plant	Leaf number per plant	Inter node length, cm	Stem girth, cm	Leaf weight per plant, g	Leaf/stem ratio	Crude protein content, %	Crude fibre content, %	Green fodder yield, t ha^{-1}	Dry fodder yield, t ha^{-1}
L_1	167.50	5.25	44.62	20.85	3.11	55.29	0.43	11.75	28.03	30.51	5.43
L_2	193.55	5.90	46.32	23.00	3.20	69.92	0.46	9.52	24.04	37.10	6.31
L_3	179.81	6.49	54.09	21.70	2.72	80.82	0.47	9.99	20.99	41.96	7.72
L_4	191.83	4.95	42.22	23.66	3.11	67.06	0.40	8.70	19.22	39.10	7.92
L_5	165.24	6.02	50.90	22.83	2.64	79.65	0.47	10.08	25.96	41.55	7.06
L_6	164.12	4.48	38.38	19.58	2.82	57.91	0.40	11.02	18.21	33.98	5.93
L_7	153.25	5.52	47.64	24.22	2.25	76.62	0.44	9.44	24.91	41.30	6.84
T_1	198.34	12.33	120.23	13.25	5.74	190.99	0.45	9.12	25.66	51.72	9.17
T_2	212.52	14.90	146.45	12.19	6.61	233.95	0.53	8.64	29.87	57.42	9.74
T_3	208.69	16.87	160.12	10.51	6.15	212.77	0.50	8.01	28.80	53.62	9.88

Table 4b Mean performance of hybrids for various characters

Characters / Treatments	Plant height, cm	Tiller number per plant	Leaf number per plant	Inter node length, cm	Stem girth, cm	Leaf weight per plant, g	Leaf/stem ratio	Crude protein content, %	Crude fibre content, %	Green fodder yield, t ha^{-1}	Dry fodder yield, t ha^{-1}
L_1 x T_1	153.17	11.69	111.71	11.04	2.87	174.99	0.64	8.32	25.05	37.67	7.17
L_1 x T_2	207.39	15.88	140.79	14.37	4.00	227.79	0.74	7.61	23.11	45.17	8.36
L_1 x T_3	173.10	20.98	235.87	13.24	3.36	448.96	0.90	7.99	22.02	79.86	13.75
L_2 x T_1	206.67	20.14	187.21	16.99	3.29	319.26	0.94	8.98	24.05	55.35	9.85
L_2 x T_2	259.49	12.03	112.33	17.61	4.48	197.18	0.87	8.88	21.04	35.72	7.49
L_2 x T_3	236.44	12.31	126.56	18.92	4.07	227.10	0.77	7.32	24.93	44.02	8.66
L_3 x T_1	246.50	16.48	156.34	19.90	4.35	255.60	0.63	7.61	24.03	55.55	10.41
L_3 x T_2	270.71	14.06	150.76	18.02	3.61	239.48	0.62	8.87	24.39	53.10	9.32
L_3 x T_3	211.76	14.25	141.28	13.42	3.50	230.09	0.83	8.06	20.94	42.62	8.05
L_4 x T_1	199.74	14.16	125.75	16.42	4.39	213.89	0.78	8.21	25.00	41.16	8.26
L_4 x T_2	140.32	22.92	239.19	9.75	3.36	491.11	0.95	7.78	23.81	84.68	16.62
L_4 x T_3	220.61	14.66	136.63	14.41	4.21	244.72	0.73	8.07	22.07	48.91	8.65
L_5 x T_1	232.26	13.15	129.60	17.75	4.08	232.63	0.63	8.71	22.83	50.57	11.11
L_5 x T_2	200.15	25.70	308.77	15.23	4.11	572.87	0.97	9.36	23.98	97.99	16.92
L_5 x T_3	229.22	13.99	136.19	18.61	4.30	220.02	0.77	8.07	23.19	42.48	7.22
L_6 x T_1	200.61	26.14	272.60	13.89	3.26	510.92	0.94	9.24	21.96	88.54	15.19
L_6 x T_2	226.71	15.67	155.61	19.26	4.16	287.54	0.92	8.80	23.75	50.55	10.24
L_6 x T_3	248.18	12.21	123.35	20.00	4.41	226.94	0.64	8.19	22.05	49.09	8.78
L_7 x T_1	241.35	15.16	151.99	18.78	4.17	269.30	0.88	7.63	20.27	48.33	8.53
L_7 x T_2	229.84	11.02	105.33	18.73	4.48	199.07	0.67	8.43	21.70	41.89	7.97
L_7 x T_3	152.80	29.95	325.01	12.85	3.19	650.56	0.94	9.10	23.01	113.12	20.73
M_e	23.142	0.309	10.100	0.547	0.024	10.408	0.0002	0.018	0.097	0.460	0.031
CD (0.05)	9.823	1.135	6.489	1.510	0.316	6.588	0.029	0.274	0.636	1.385	0.359
CD (0.01)	13.229	1.528	8.739	2.033	0.426	8.872	0.039	0.368	0.856	1.865	0.484

TNSC-4 x FD 471 recorded the maximum number of tillers per plant (29.95) while TNSC-4 x FD 467 recorded the least number (11.02). The hybrids differed significantly from TNSC-4 x FD 471.

4.1.3 Leaf Number per Plant

DRSB-3 recorded the maximum number of leaves per plant (54.09) and IP 15814 had the least number (38.38) among lines. TNSC-4 (47.64) was found to be on par with DRSB-3. Among testers, the highest number was recorded by FD 471 (160.12) and the least by FD 431 (120.23). All the testers differed significantly from each other. Among hybrids, the number of leaves ranged from 105.53 in Composite 9 x FD 467 to 325.01 in TNSC-4 x FD 471. All the hybrids differed significantly from TNSC-4 x FD 471.

4.1.4 Internode Length, cm

Among lines, the internode length ranged from 19.58 cm in IP 15814 to 24.22 cm in TNSC-4 and among testers, the shortest internode length was recorded by FD 471 (10.51 cm) and longest by FD 431 (13.25 cm). The cross FD 1917 x FD 467 had the shortest internode length (9.75 cm) while IP 15814 x FD 471 had the longest internode length (20.00 cm). All the hybrids except APFB-2 x FD 431 (11.04 cm) differed significantly from FD 1917 x FD 467.

4.1.5 Stem girth, cm

Stem girth ranged from 2.25 cm in TNSC-4 to 3.20 cm in Composite 9 among lines. The lines APFB-2 and FD 1917 (3.11 cm) were found to be on par with Composite 9 (3.20 cm). Among testers, the range was from 5.74 cm in FD 431 to 6.61 cm in FD 467. The testers differed significantly from each other. Among hybrids, the values ranged from 2.87 cm in APFB-2 x FD 431 to 4.48 cm in Composite 9 x FD 467 and TNSC-4 x FD 467. The hybrids IP 15814 x FD 471 (4.41 cm), FD 1917 x

FD 431 (4.39 cm), DRSB-3 x FD 431 (4.35 cm), HES-4 x FD 471 (4.30 cm) and FD 1917 x FD 471 (4.21 cm) were on par with Composite 9 x FD 467 and TNSC-4 x FD 467.

4.1.6 Leaf Weight per Plant, g

The mean leaf weight per plant ranged form 55.29 g in APFB-2 to 80.82 g in DRSB-3 among lines and 190.99 g in FD 431 to 233.95 g in FD 467 among testers. All the testers differed significantly from each other. Among crosses, the minimum leaf weight was noticed in APFB-2 x FD 431 (174.99 g) and maximum in TNSC-4 x FD 471 (650.56 g). All other hybrids differed significantly from TNSC-4 x FD 471.

4.1.7 Leaf/Stem Ratio

The least leaf/stem ratio was recorded by FD 1917 and IP 15814 (0.40) among lines and by FD 431 (0.45) among testers. The highest ratio was recorded by lines DRSB-3 and HES-4 (0.47) and tester FD 467 (0.53). The testers differed significantly. The range among hybrids was from 0.62 in DRSB-3 x FD 467 to 0.97 in HES-4 x FD 467. The cross FD 1917 x FD 467 (0.95) was on par with HES-4 x FD467.

4.1.8 Crude Protein Content, %

Crude protein content ranged from 8.70 per cent in FD 1917 to 11.75 per cent in APFB-2 among lines and 8.01 per cent in T_3 to 9.12 per cent in T_1 among testers. All the testers differed significantly. The hybrid HES-4 x FD 467 showed the highest crude protein content of 9.36 per cent and the least value of 7.32 per cent was shown by DRSB-3 x FD 467. All the hybrids except IP 15814 x FD 431 (9.24 per cent) and TNSC-4 x FD 471 (9.10 per cent) differed significantly from DRSB-3 x FD 467.

4.1.9 Crude Fibre Content, %

Among lines, IP 15814 (18.21 per cent) and among testers FD 431 (25.66 per cent) recorded the minimum crude fibre content. Among crosses TNSC-4 x FD 431 recorded the minimum crude fibre content

(20.27 per cent). The maximum crude fibre content was recorded by APFB-2 (28.03 per cent) among lines and by FD 467 (29.87 per cent) among testers. The testers differed significantly. The combination APFB-2 x FD 431 recorded the maximum crude fibre content (25.05 per cent). All hybrids differed significantly from TNSC-4 x FD 431.

4.1.10 Green Fodder Yield, t ha^{-1}

The green fodder yield was lowest in APFB-2 (30.51 t/ha) and highest in DRSB-3 (41.96 t/ha) among lines. The lines HES-4 (41.55 t/ha) and TNSC-4 (41.30 t/ha) was on par with DRSB-3. Among testers, the lowest green fodder yield of 51.72 t/ha was recorded by FD 431 and highest yield of 57.42 t/ha by FD 467. The testers differed significantly. Among hybrids the green fodder yield ranged from 35.72 t/ha in Composite 9 x FD 467 to 113.12 t/ha in TNSC-4 x FD 471. TNSC-4 x FD 471 was significantly superior to all other hybrids.

4.1.11 Dry Fodder Yield, t ha^{-1}

Dry fodder yield was maximum (7.92 t/ha) in FD 1917 among lines and in FD 471 (9.88 t/ha) among testers. The minimum dry fodder yield was noticed in APFB-2 (5.43 t/ha) among lines and in FD 431 (9.17 t/ha) among testers. Among hybrids, APFB-2 x FD 431 had the lowest dry fodder yield of 7.17 t/ha and TNSC-4 x FD 471 had the highest yield of 20.73 t/ha. The cross TNSC-4 x FD 471 was significantly superior to all other hybrids for dry fodder yield.

4.2 COMBINING ABILITY AND GENE ACTION

All the characters were subjected to line x tester analysis to study gene action in terms of general combining ability and specific combining ability effects (Table 5). The *gca* effect of lines and also that of testers did not differ significantly but highly significant differences in *sca* effect was observed in hybrids.

Table 5 Abstract of analysis of variance of the characters

Source	Mean sum of squares											
	df	Plant height	Tiller number per plant	Leaf number per plant	Internode length	Stem girth	Leaf weight per plant	Leaf / stem ratio	Crude protein content	Crude fibre content	Green fodder yield	Dry fodder yield
Replication	1	107.50*	0.16	19.38	0.37	0.004	0.25	0.00	0.00	0.05	0.80	0.01
Treatment	30	2329.77**	84.17**	11220.89**	32.32**	1.96**	45675.48**	0.07**	1.98**	13.28**	772.35**	24.61**
Parents	9	834.06**	42.29**	4516.32**	53.77**	5.42**	9881.31**	0.003**	2.57**	31.86**	153.35**	4.97**
Parents Vs Crosses	1	12374.88**	982.90**	122399.90**	124.06**	0.04	510797.30**	1.58**	22.34**	32.98**	2896.31**	124.65**
Crosses	20	2500.58**	58.07**	8678.99**	18.08**	0.51**	38526.76**	0.03**	0.07**	3.94**	944.71**	28.45**
Lines	6	3490.58	13.75	2503.40	25.29	0.33	15161.67	0.02	0.58	2.75	387.98	11.82
Testers	2	329.75	0.16	677.69	0.79	0.24	6278.38	0.005	0.63	1.88	142.12	3.37
Line x Tester	12	2367.39**	89.88**	13100.34**	17.35**	0.64**	55584.05**	0.042**	0.79**	4.87**	1356.83**	40.94**
Error	30	23.14	0.31	10.10	0.55	0.02	10.41	0.0002	0.02	0.10	0.46	0.03

*Significant at 5 per cent level

**Significant at 1 per cent level

4.2.1 General Combining Ability Effects

The general combining ability effects of parents for eleven characters are presented in Table 6 and Fig. 1.

4.2.1.1 Plant Height

The general combining ability effects of lines varied from –35.78 for APFB-2 to 29.32 for DRSB-3. The lines DRSB-3 (29.32), Composite 9 (20.53), IP 15814 (11.49) and HES-4 (6.88) showed significant positive *gca* effects while the remaining three lines had significant but negative *gca* effects. Only two out of three testers had significant *gca* effects for plant height. FD 467 had significant positive *gca* effect (5.56) while FD 471 had significant negative *gca* effect (-3.37).

4.2.1.2 Tiller Number per Plant

Three lines *viz.*, TNSC-4 (1.93), IP 15814 (1.22) and HES-4 (0.83) recorded significant positive *gca* effects for tiller number per plant. Significant but negative *gca* effects were observed for Composite 9 (-1.96), DRSB-3 (-1.86) and APFB-2 (-0.61). None of the testers had significant positive *gca* effects for tiller number per plant. Negative significant *gca* effects were shown by testers FD 431 (-8.48) and FD 467 (-3.48).

4.2.1.3 Leaf Number per Plant

The lines viz., TNSC-4 (24.03), HES-4 (21.38) and IP 15814 (13.71) had significant positive *gca* effects. Among testers, FD 471 (4.84) and FD 467 (3.14) had significant positive *gca* effects while only FD 431 had significant negative *gca* effect (-7.97).

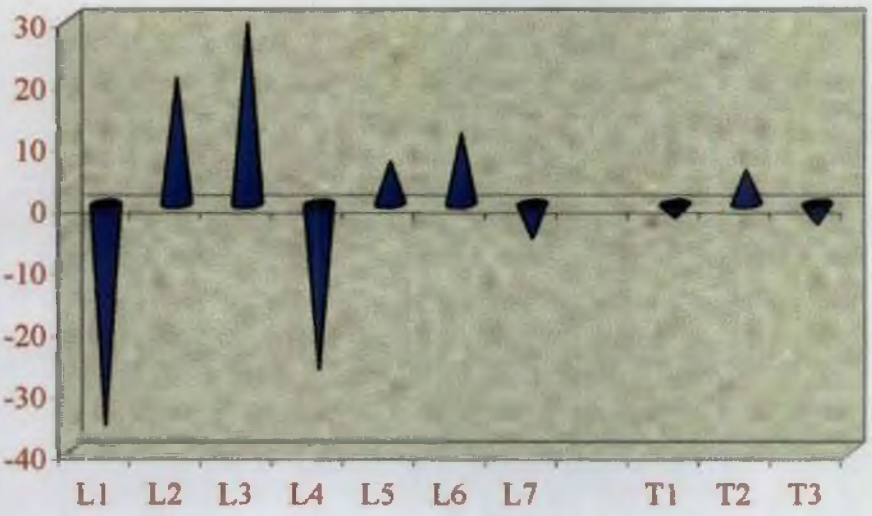
4.2.1.4 Internode Length

Among lines, only APFB-2 (-3.27) and FD 1917 (-2.63) had significant negative *gca* effects. All other lines showed significant positive *gca* effects. None of the testers showed significance for *gca* effects.

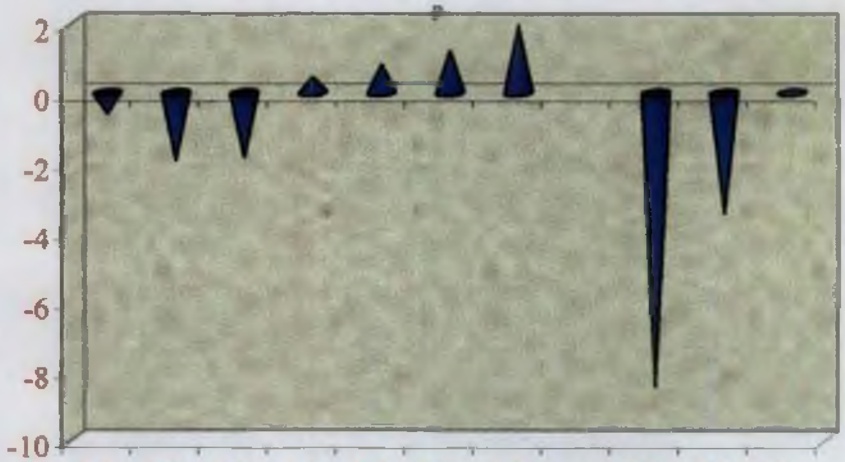
Table 6 General combining ability effects of parents

Characters / Treatments	Plant height	Tiller number per plant	Leaf number per plant	Internode length	Stem girth	Leaf weight per plant	Leaf / stem ratio	Crude protein content	Crude fibre content	Green fodder yield	Dry fodder yield
Lines											
L_1	-35.78**	-0.61*	-7.36**	-3.27**	-0.48**	-22.75**	-0.04**	-0.37**	0.39**	-3.21**	-0.87**
L_2	20.53**	-1.96**	-28.11**	1.69**	0.06 ^{ns}	-58.82**	0.06**	0.05 ^{ns}	0.33**	-12.42**	-1.97**
L_3	29.32**	-1.86**	-20.69**	0.96**	-0.07 ^{ns}	-64.94**	-0.10**	-0.17**	0.11 ^{ns}	-7.02**	-1.38**
L_4	-26.78**	0.46 ^{ns}	-2.96*	-2.63**	0.10 ^{ns}	9.91**	0.02**	-0.33**	0.62**	0.80**	0.55**
L_5	6.88**	0.83**	21.38**	1.04**	0.28**	35.17**	-0.01 ^{ns}	0.37**	0.33*	6.23**	1.12**
L_6	11.50**	1.22**	13.71**	1.56**	0.06 ^{ns}	35.13**	0.04**	0.40**	-0.42**	5.28**	0.77**
L_7	-5.67**	1.93**	24.03**	0.64*	0.06 ^{ns}	66.31**	0.03**	0.04 ^{ns}	-1.35**	10.33**	1.78**
SE	1.964	0.227	1.297	0.302	0.064	1.317	0.006	0.055	0.127	0.277	0.072
Testers											
T_1	-2.20 ^{ns}	-8.48**	-7.97**	0.24 ^{ns}	-0.12**	-24.30**	-0.02**	0.04 ^{ns}	0.31**	-3.57**	-0.56**
T_2	5.56**	-3.48**	3.14**	-0.01 ^{ns}	-0.14**	9.77**	0.02**	0.19**	0.10 ^{ns}	0.99**	0.36**
T_3	-3.37**	0.12 ^{ns}	4.84**	-0.23 ^{ns}	-0.03 ^{ns}	14.53**	-0.00 ^{ns}	-0.23**	-0.41**	2.57**	0.20**
SE	1.286	0.148	0.849	0.198	0.042	0.862	0.004	0.036	0.083	0.181	0.047

*Significant at 5 per cent level
**Significant at 1 per cent level
ns not significant

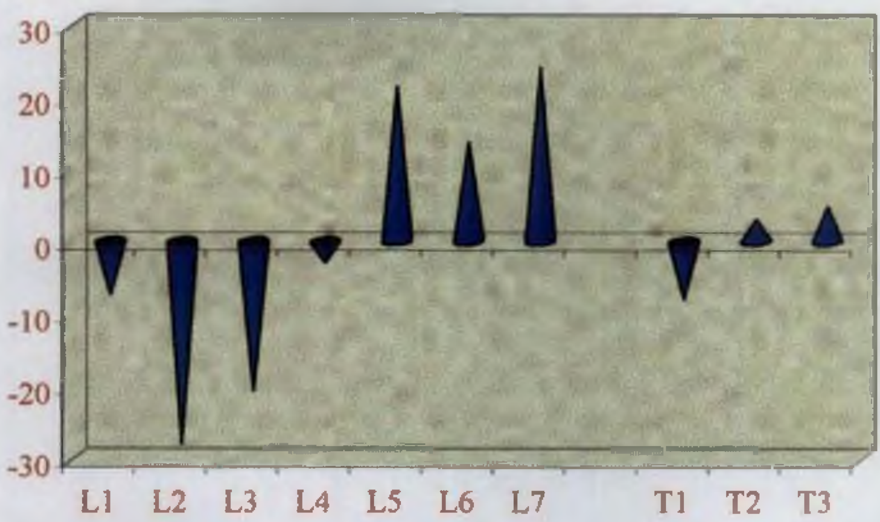


Plant height

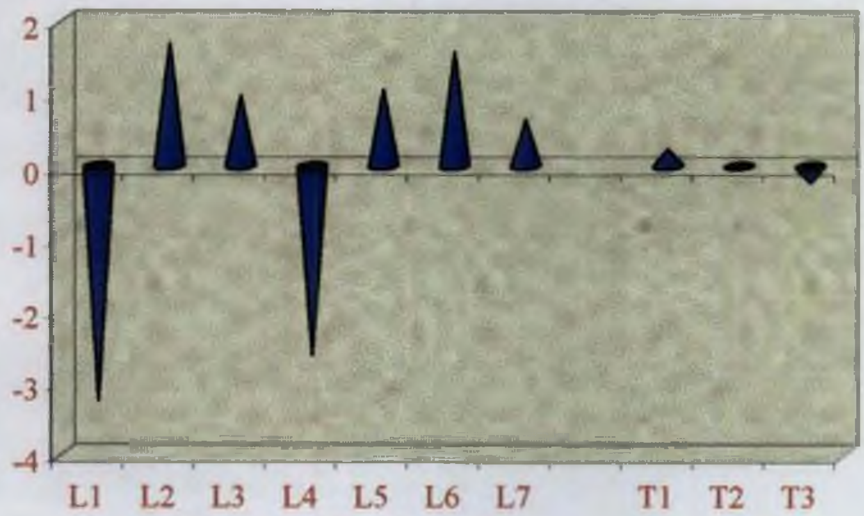


Tiller number per plant

Fig. 1 General combining ability effects

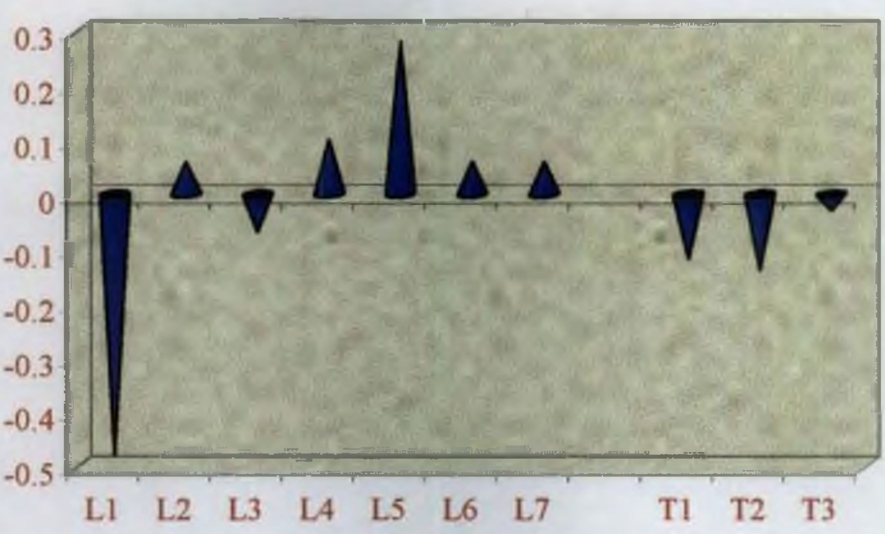


Leaf number per plant

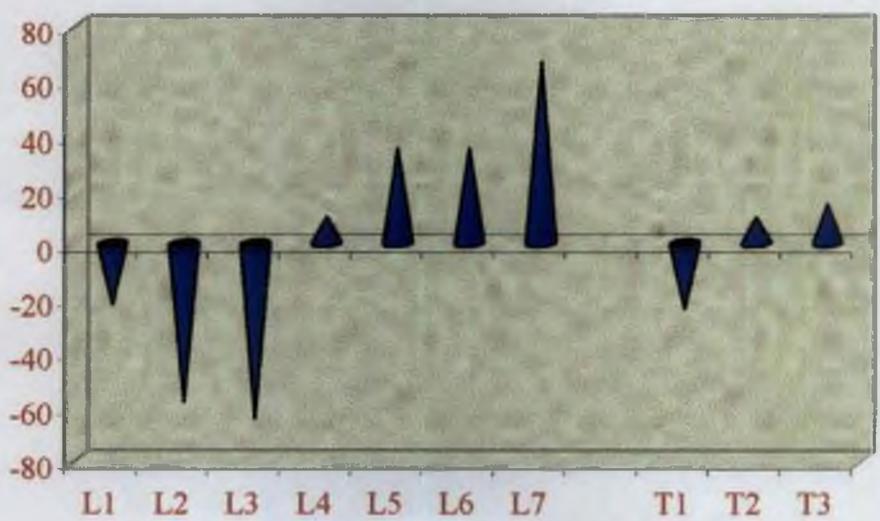


Internode length

Fig. 1 Continued

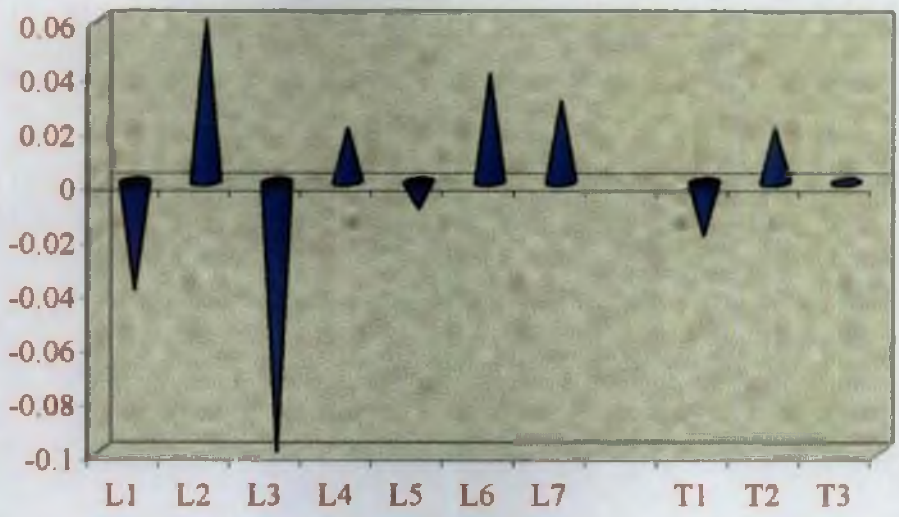


Stem girth

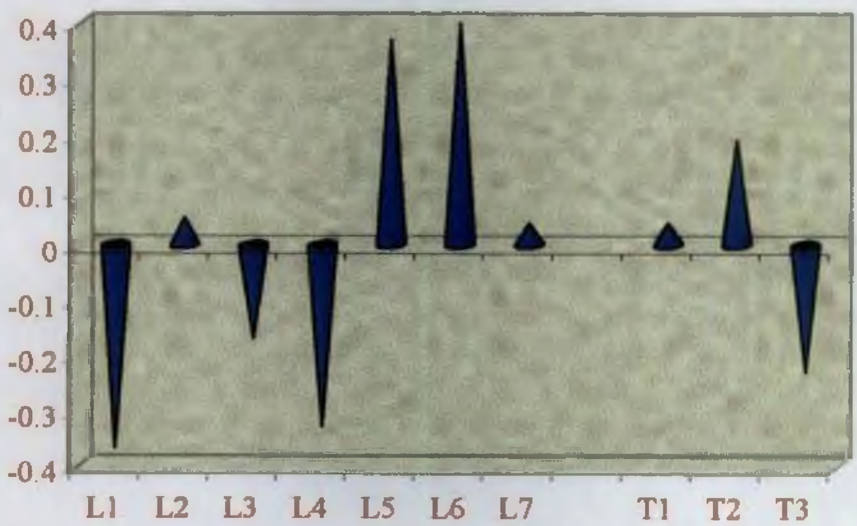


Leaf weight per plant

Fig. 1 Continued



Leaf / stem ratio



Crude protein content

Fig. 1 Continued

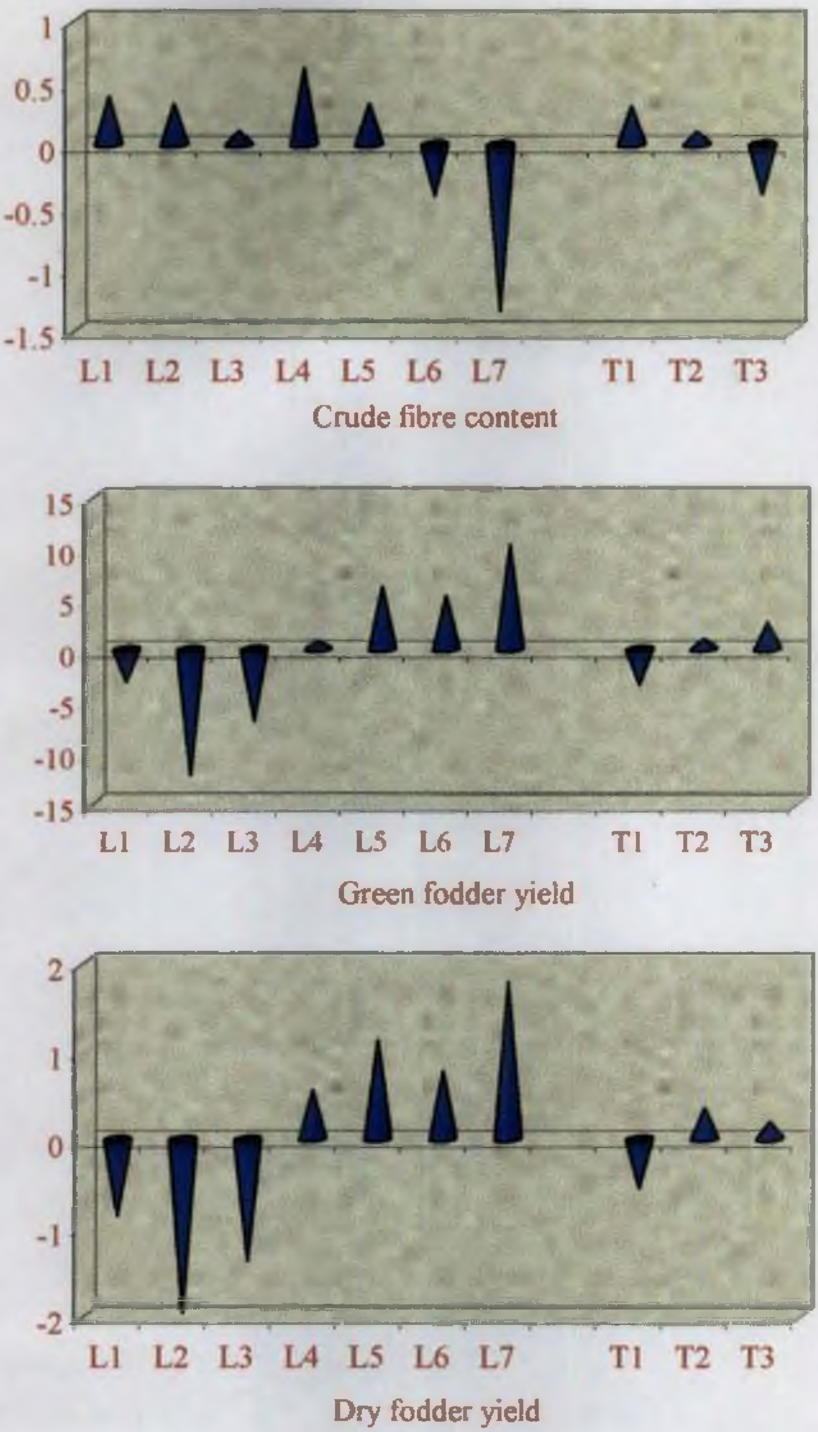


Fig. 1 Continued

4.2.1.5 Stem Girth

Among lines, only HES-4 showed significant positive *gca* effect (0.28) for stem girth. Significant negative *gca* effect was shown by APFB-2 (-0.48). None of the testers had significant positive *gca* effects. Significant negative *gca* effects were shown by FD 431 (-0.12) and FD 467 (-0.14).

4.1.2.6 Leaf Weight per Plant

The general combining ability effects for leaf weight per plant had significant positive values for TNSC-4 (66.31), HES-4 (35.17), IP 15814 (35.13) and FD 1917 (9.91). All the lines differed significantly from TNSC-4. The lines DRSB-3 (-64.94), Composite 9 (-58.82) and APFB-2 (-22.75) had significant negative *gca* effects. Among testers FD 471 and FD 467 showed significant positive *gca* effects of 14.53 and 9.77 respectively while FD 431 had significant negative *gca* effect (-24.30). The testers differed significantly from each other.

4.2.1.7 Leaf/Stem Ratio

All lines except HES-4 had significant *gca* effects for leaf/stem ratio. Lines IP 15814 (0.04), TNSC-4 (0.03) and FD 1917 (0.02) had positive *gca* effects. Among testers, FD 467 showed positive *gca* (0.02) while FD 431 showed negative *gca* effects (-0.02).

4.2.1.8 Crude Protein Content

Among lines, the *gca* for crude protein content had significant positive values for IP 15814 (0.40) and HES-4 (0.37). Significant but negative *gca* effects were shown by lines APFB-2 (-0.37), FD 1917 (-0.33) and DRSB-3 (-0.17). Among testers, only FD 467 had significant positive *gca* effect (0.19) while FD 471 showed significant negative *gca* effect of –0.23.

4.2.1.9 Crude Fibre Content

Regarding the *gca* effects of lines, significantly negative *gca* effects were shown by TNSC-4 (-1.35) and IP 15814 (-0.42) for crude fibre content. Among testers, FD 471 showed significant negative *gca* effect of –0.41 while FD 431 recorded significant positive *gca* effect (0.31).

4.2.1.10 Green Fodder Yield

All the seven lines had significant general combining ability effects for green fodder yield. The lines TNSC-4 (10.33), HES-4 (6.23), IP 15814 (5.28) and FD 1917 (0.80) had significant positive *gca* effects while the remaining lines showed negative *gca* effects. The lines differed significantly from each other. Among testers, FD 471 (2.57) and FD 467 (0.99) had significant positive *gca* effects while FD 431 had negative *gca* effect (-3.57).

4.2.1.11 Dry Fodder Yield

For dry fodder yield, the *gca* effect of lines showed significant values. The lines TNSC-4 (1.78), HES-4 (1.12), IP 15814 (0.77) and FD 1917 (0.55) had positive *gca* effects while others had negative effects. Among testers, FD 467 (0.36) and FD 471 (0.20) showed significant positive *gca* effects while FD 431 had significant negative *gca* effect (-0.56).

4.2.2 Specific Combining Ability Effects

The specific combining ability effects of hybrids for eleven characters studied are given in Table 7.

4.2.2.1 Plant Height

The specific combining ability effects of seventeen out of 21 hybrids were found to be significant for plant height. Ten hybrids had significant positive *sca* effects. The highest positive effect was shown by the cross FD 1917 x FD 471 (37.09). All other crosses except TNSC-4 x FD 431

Table 7 Specific combining ability effects of hybrids

Characters / Treatments	Plant height	Tiller number per plant	Leaf number per plant	Internode length	Stem girth	Leaf weight per plant	Leaf / stem ratio	Crude protein content	Crude fibre content	Green fodder yield	Dry fodder yield
$L_1 \times T_1$	-22.52**	-4.41**	-43.11**	-2.08**	-0.43**	-84.63**	-0.10**	0.31**	1.35**	-12.99**	-2.03**
$L_1 \times T_2$	23.94**	-0.27^{ns}	-25.14**	1.50**	0.45**	-65.89**	-0.04**	-0.55**	-0.39^{ns}	-10.06**	-1.76**
$L_1 \times T_3$	-1.42^{ns}	4.68**	68.24**	0.59^{ns}	-0.02^{ns}	150.52**	0.14**	0.25*	-0.96**	23.06**	3.79**
$L_2 \times T_1$	-25.34**	5.40**	53.15**	-1.09*	-0.54**	95.71**	0.10**	0.55**	0.41^{ns}	13.89**	1.74**
$L_2 \times T_2$	19.73**	-2.77**	-32.84**	-0.22^{ns}	0.39**	-60.43**	-0.01^{ns}	0.29**	-2.40**	-10.31**	-1.53**
$L_2 \times T_3$	5.61^{ns}	-2.64**	-20.31**	1.31*	0.15^{ns}	-35.28**	-0.09**	-0.84**	1.99**	-3.58**	-0.21^{ns}
$L_3 \times T_1$	5.71^{ns}	1.64**	14.86**	2.54**	0.65**	38.17**	-0.04**	-0.61**	0.60*	8.70**	1.71**
$L_3 \times T_2$	22.15**	0.84*	-1.84^{ns}	0.92^{ns}	-0.35**	-12.01**	-0.10**	-0.50**	1.17**	1.68**	-0.30*
$L_3 \times T_3$	-27.86**	-0.80^{ns}	-13.02**	-3.46**	-0.29*	-26.16**	0.14**	0.11^{ns}	-1.77**	-10.37**	-1.41**
$L_4 \times T_1$	15.05**	-3.00**	-33.47**	2.65**	0.52**	-78.38**	-0.02^{ns}	0.15^{ns}	-1.07**	-13.52**	-2.36**
$L_4 \times T_2$	-52.13**	5.71**	68.86**	-3.76**	-0.77**	164.77**	0.11**	-0.43**	0.08^{ns}	25.43**	5.09**
$L_4 \times T_3$	37.09**	-2.71**	-35.40**	1.12*	0.25*	-86.39**	-0.09**	0.28**	-1.15**	-11.91**	-2.73**
$L_5 \times T_1$	13.91**	-4.38**	-53.94**	0.31^{ns}	0.03^{ns}	-84.91**	-0.14**	-0.04^{ns}	-0.81**	-9.55**	-0.08^{ns}
$L_5 \times T_2$	-25.95**	8.12**	114.11**	-1.96**	-0.19^{ns}	221.27**	0.16**	0.46**	0.55*	33.32**	4.82**
$L_5 \times T_3$	12.04**	-3.75**	-60.17**	1.64**	0.16^{ns}	-136.35**	-0.02^{ns}	-0.41**	0.27^{ns}	-23.77	-4.74**
$L_6 \times T_1$	-22.36**	8.22**	96.72**	-4.07**	-0.57**	193.42**	0.13**	0.46**	-0.93**	29.38**	4.34**
$L_6 \times T_2$	-4.02^{ns}	-2.30**	-31.38**	1.56**	0.08^{ns}	-64.03**	0.07**	-0.13^{ns}	1.06**	-13.17**	-1.52**
$L_6 \times T_3$	26.38**	-5.92**	-65.34**	2.52**	0.49**	-129.39**	-0.19**	-0.32**	-0.13^{ns}	-16.20**	-2.82**
$L_7 \times T_1$	35.55**	-3.47**	-34.21**	1.75**	0.34**	-79.38**	0.07**	-0.80**	-1.69**	-15.89**	-3.32**
$L_7 \times T_2$	16.28**	-7.66**	-91.78**	1.96**	0.40**	-183.67**	-0.18**	-0.15^{ns}	-0.07^{ns}	-26.88**	-4.80**
$L_7 \times T_3$	-51.83**	11.12**	125.99**	-3.71**	-0.73**	263.05**	0.11**	0.95**	1.76**	42.77**	8.12**
SE	3.402	0.393	2.247	0.523	0.110	2.281	0.011	0.096	0.225	0.480	0.125
CD (0.05)	9.823	1.134	6.490	1.510	0.319	6.588	0.030	0.277	0.637	1.386	0.360

*Significant at 5 per cent level
**Significant at 1 per cent level
ns not significant

(35.55) differed significantly from FD 1917 x FD 431. The lowest positively significant *sca* effect was shown by HES-4 x FD 471 (12.04). In the case of negatively significant *sca* effects, the highest negative effect was recorded by FD 1917 x FD 467 (-52.13) and the lowest by IP 15814 x FD 431 (-22.36) (Fig. 2).

4.2.2.2 Tiller Number per Plant

All the hybrids except APFB-2 x FD 467 and DRSB-3 x FD 471 had significant *sca* effects for tiller number per plant. Eight out of 21 hybrids showed positive *sca* effects while twelve had negative *sca* effects. The highest positive significant *sca* effect was shown by TNSC-4 x FD 471 (11.12) and lowest positive value by DRSB-3 x FD 467 (0.84). All hybrids differed significantly from TNSC-4 x FD 471. TNSC-4 x FD 467 recorded highest negatively significant *sca* effect (-7.66) while IP 15814 x FD 467 recorded the least negative effect (-2.30) (Fig. 3).

4.2.2.3 Leaf Number per Plant

All the *sca* effects for leaf number per plant were found to be significant except for the cross DRSB-3 x FD 467. Seven out of 21 crosses had positive significant *sca* effects. The cross TNSC-4 x FD 471 had the highest positive significant *sca* effect of 125.99 while DRSB-3 x FD 431 had the lowest value of 14.86. All the hybrids differed significantly from TNSC-4 x FD 471. Thirteen hybrids showed significant negative *sca* effects ranging from –91.78 in TNSC-4 x FD 467 to –13.02 in DRSB-3 x FD 471 (Fig. 4).

4.2.2.4 Internode Length

All hybrids except APFB-2 x FD 471, Composite 9 x FD 467, DRSB-3 x FD 467 and HES-4 x FD 431 had significant *sca* effects for internode length. Out of the 21 crosses, seven had significant negative *sca* effects. Cross IP 15814 x FD 431 had the highest negative effect of –4.07 and Composite 9 x FD 431 had the lowest negative effect of –1.09. The

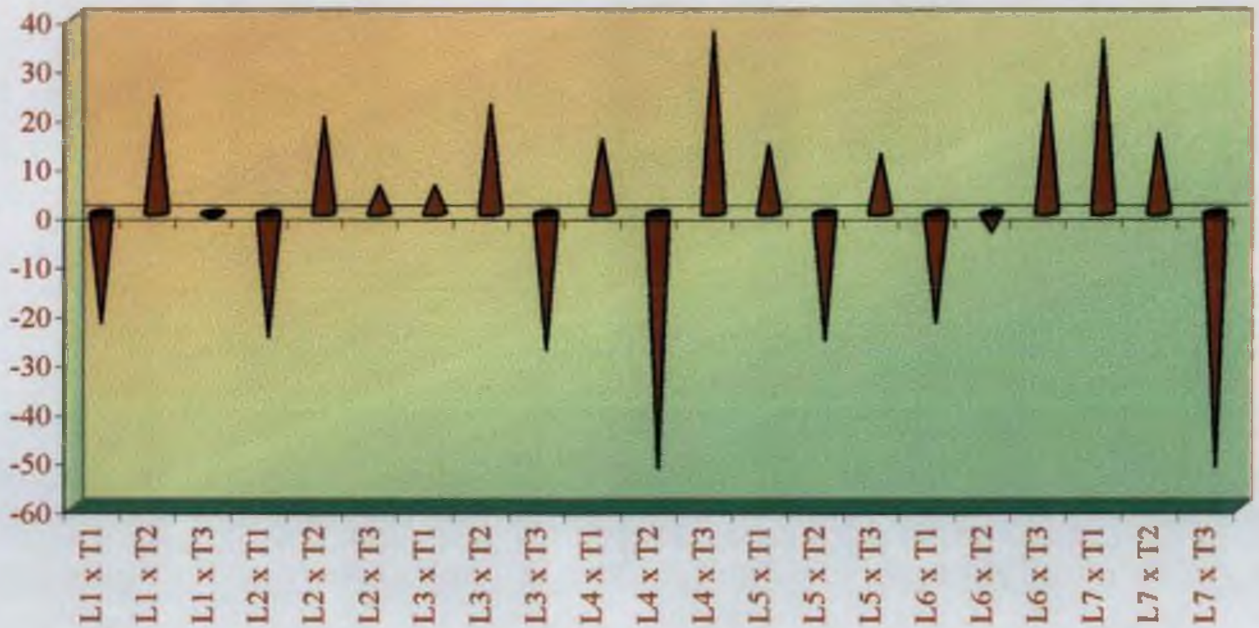


Fig. 2 Specific combining ability effect for plant height

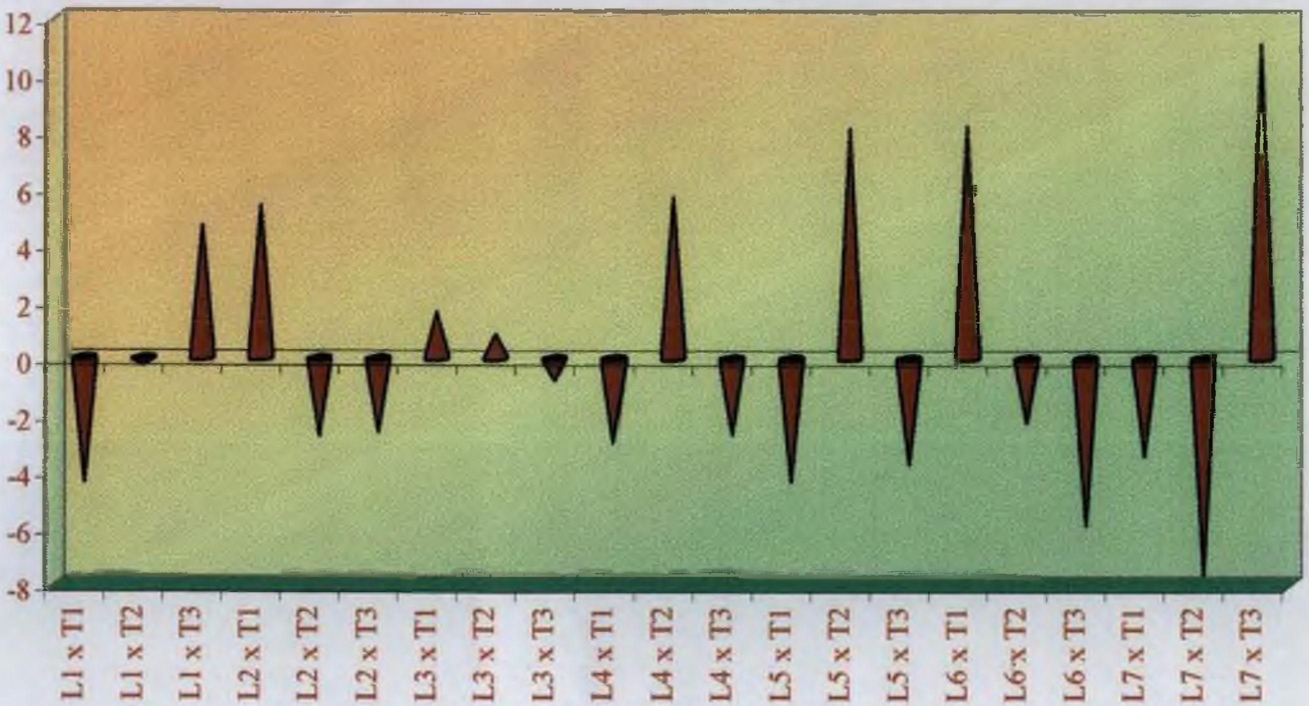


Fig. 3 Specific combining ability effect for tiller number per plant

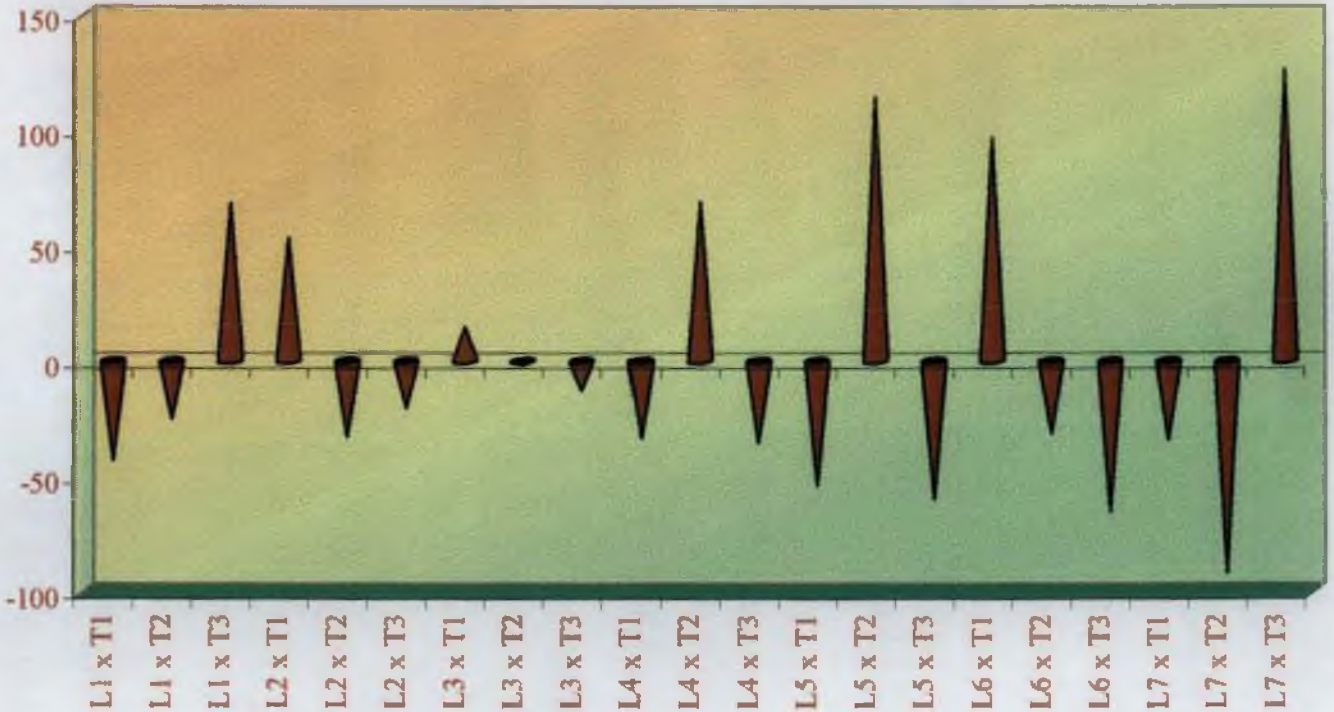


Fig. 4 Specific combining ability effect for leaf number per plant

positively significant *sca* effects ranged from 1.12 (FD 1917 x FD 471) to 2.65 (FD 1917 x FD 431) (Fig. 5).

4.2.2.5 Stem Girth

Fifteen out of 21 hybrids had significant *sca* effects for stem girth. Eight hybrids had significant positive *sca* effects. The highest positive *sca* effect was recorded by DRSB-3 x FD 431 (0.65) and the least by FD 1917 x FD 471 (0.25). All the hybrids with significant positive *sca* effects except FD 1917 x FD 471 were on par with each other. Seven F_1s had significant negative *sca* effects. The cross TNSC-4 x FD 471 had the highest negative value (-0.73) while DRSB-3 x FD 471 had the least negative value (-0.29) (Fig. 6).

4.2.2.6 Leaf Weight per Plant

For leaf weight per plant, all the hybrids had significant *sca* effects. Out of the 21 hybrids only seven showed positive *sca* effects while the remaining fourteen hybrids showed negative *sca* effects. The highest positively significant *sca* effect was shown by the cross TNSC-4 x FD 471 (263.05) and the lowest by DRSB-3 x FD 431 (38.17). The hybrids differed significantly from each other. In the case of negatively significant *sca* effects, the values ranged form –183.67 (TNSC-4 x FD 467) to –12.01 (DRSB-3 x FD 467) (Fig. 7).

4.2.2.7 Leaf/Stem Ratio

Regarding leaf/stem ratio, nine out of 21 hybrids had positive significant *sca* effects while ten hybrids had significant negative *sca* effects. Only two F_1s were found to be non-significant. The highest positively significant *sca* effect was recorded by the cross HES-4 x FD 467 and the lowest by IP 15814 x FD 467 and TNSC-4 x FD 431 (0.07). The crosses APFB-2 x FD 471 and DRSB-3 x FD 471 had significant positive *sca* effect of 0.14 which was on par with HES-4 x FD 467 (0.16).

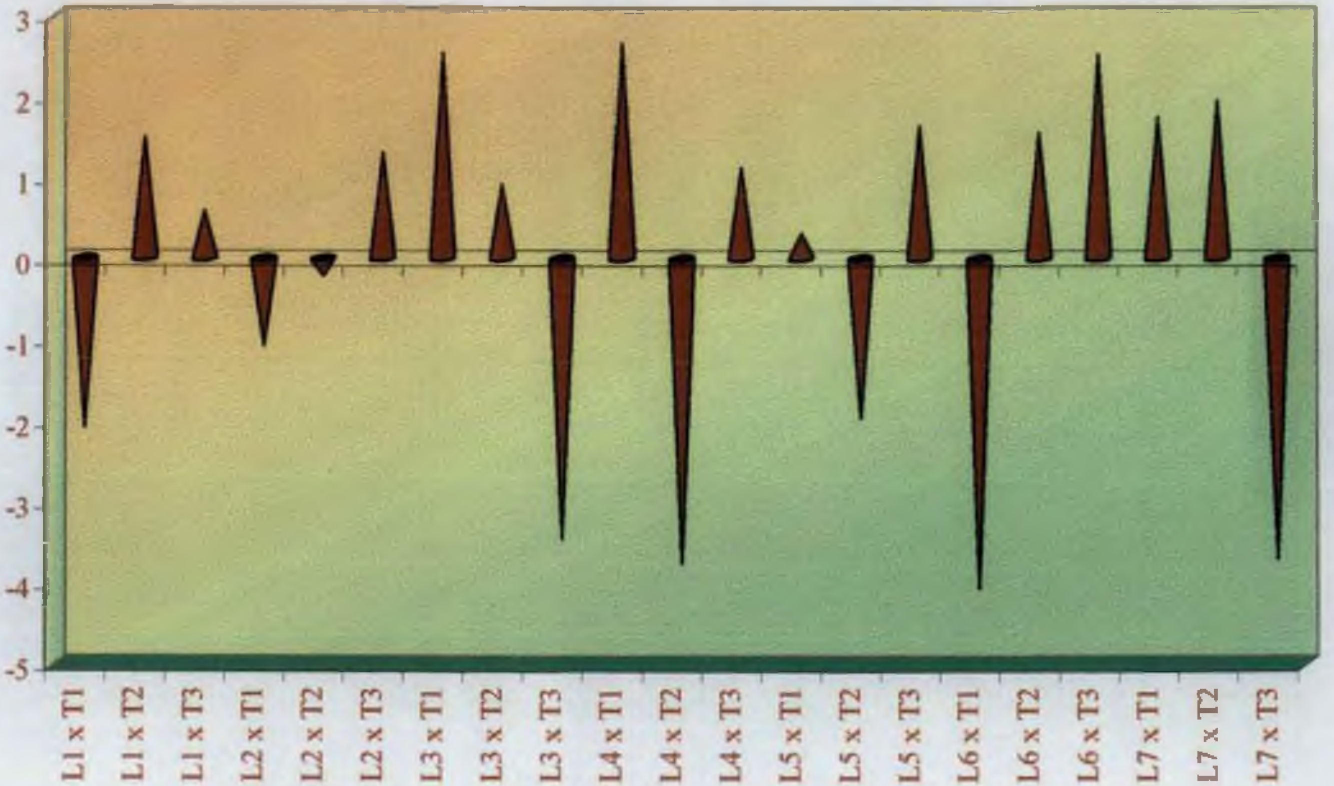


Fig. 5 Specific combining ability effect for internode length

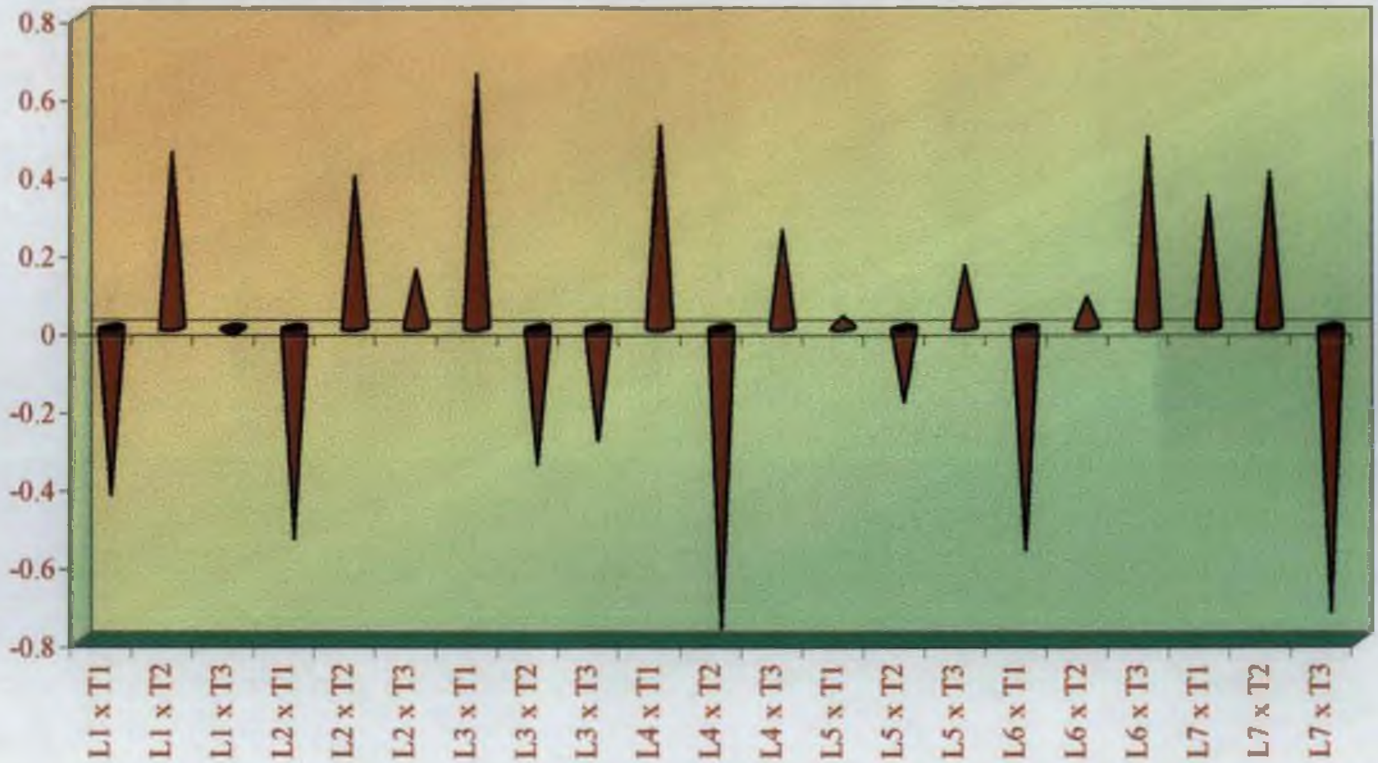


Fig. 6 Specific combining ability effect for stem girth

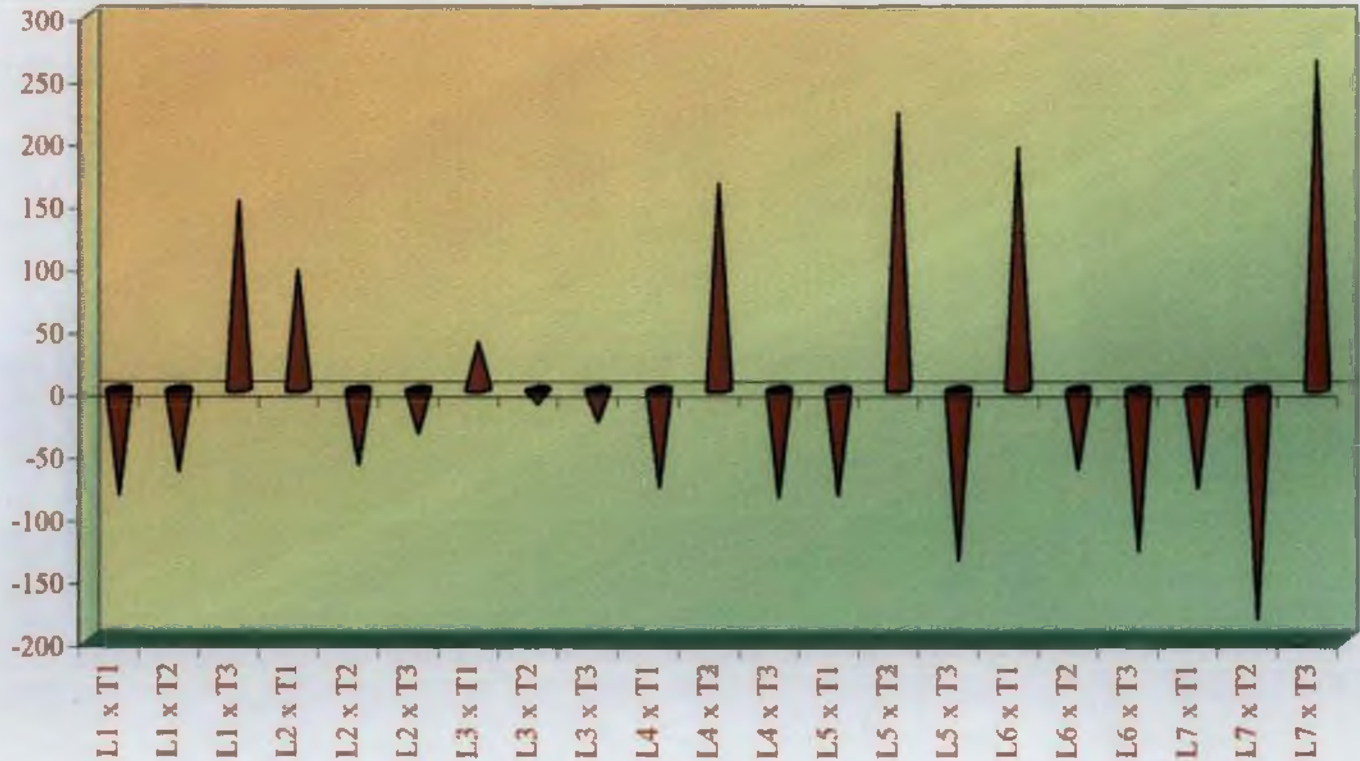


Fig. 7 Specific combining ability effect for leaf weight per plant

The significant negative *sca* effects ranged from –0.19 (IP 15814 x FD 471) to –0.04 (APFB-2 x FD 467 and DRSB-3 x FD 431) (Fig. 8).

4.2.2.8 Crude Protein Content

Eight out of 21 hybrids had significant positive *sca* effects for crude protein content. The highest significant positive *sca* effect was recorded by TNSC-4 x FD 471 (0.95) and the lowest by APFB-2 x FD 471 (0.25). All hybrids differed significantly from TNSC-4 x FD 471. Nine hybrids showed significant negative *sca* effects ranging from –0.84 for Composite 9 x FD 471 to –0.32 for IP 15814 x FD 471 (Fig. 9).

4.2.2.9 Crude Fibre Content

For crude fibre content, fifteen out of 21 hybrids had significant *sca* effects. Seven hybrids had significant negative *sca*. The highest negatively significant *sca* effect was shown by the cross Composite 9 x FD 467 (-2.40). The lowest value was recorded by APFB-2 x FD 467 (-0.81). Eight F_1s showed significant positive *sca* effects. The highest positively significant *sca* effect was shown by Composite 9 x FD 471 (1.99) and lowest by HES-4 x FD 467 0.55) (Fig. 10).

4.2.2.10 Green Fodder Yield

All the specific combining ability effects were found to be significant for green fodder yield. Eight out of 21 hybrids showed significant positive *sca* effects. The highest positive significant *sca* effect was for the cross TNSC-4 x FD 471 (42.77) while the lowest significant positive *sca* effect was four DRSB-3 x FD 467 (1.68). All the eight hybrids differed significantly from each other. Thirteen hybrids had negatively significant *sca* effects ranging from –26.88 to –3.58 in TNSC-4 x FD 467 and Composite 9 x FD 471 respectively (Fig. 11).

4.2.2.11 Dry Fodder Yield

All the crosses except Composite 9 x FD 471 and HES-4 x FD 431 had significant *sca* effects for dry fodder yield. Seven out of 21 hybrids

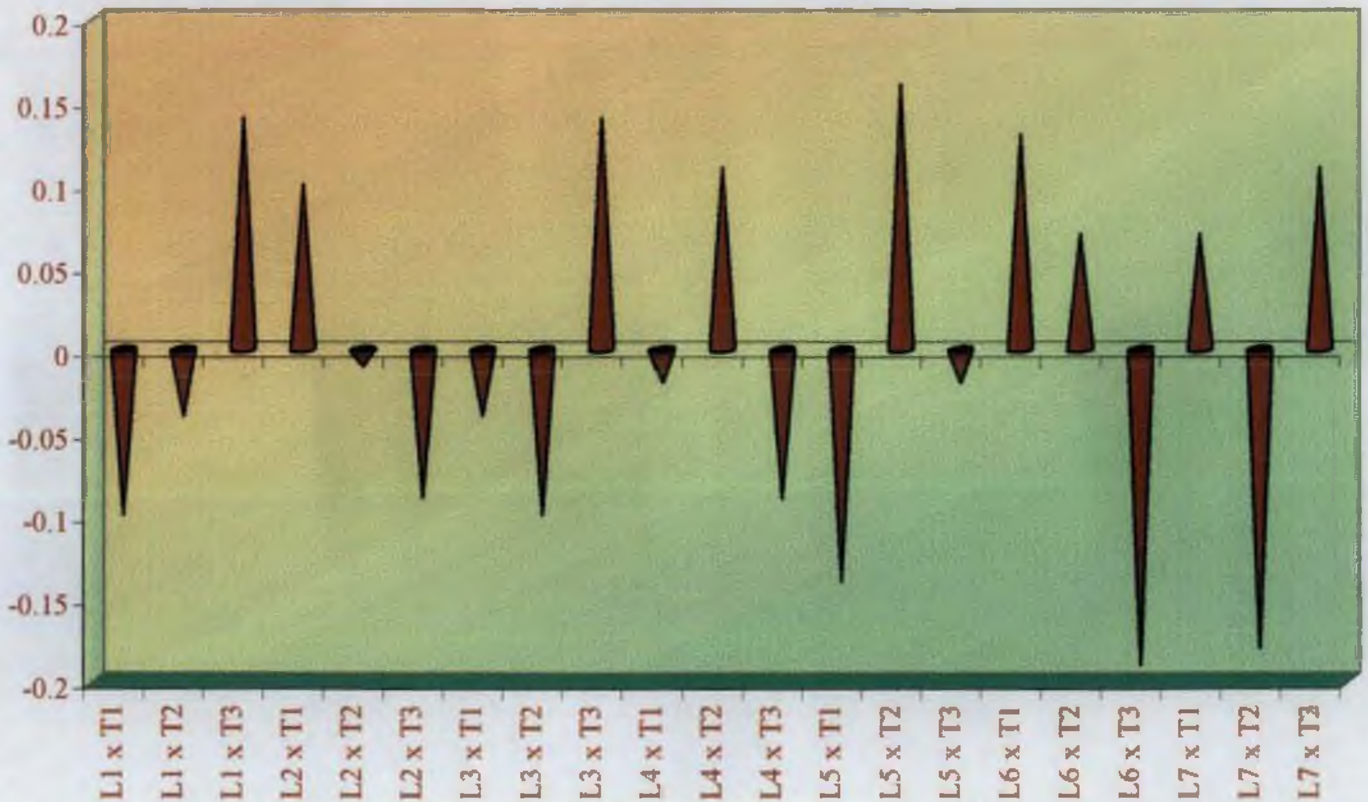


Fig. 8 Specific combining ability effect for leaf / stem ratio

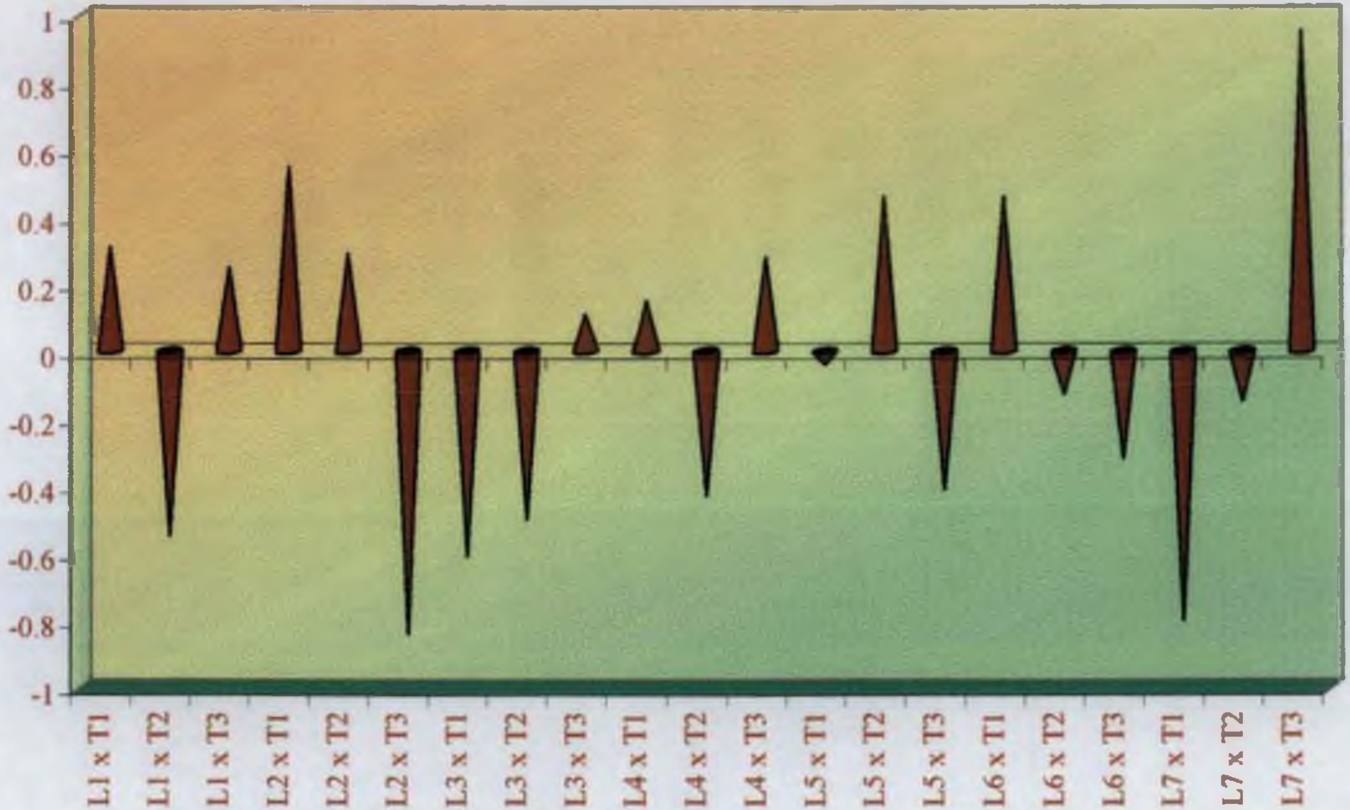


Fig. 9 Specific combining ability effect for crude protein content

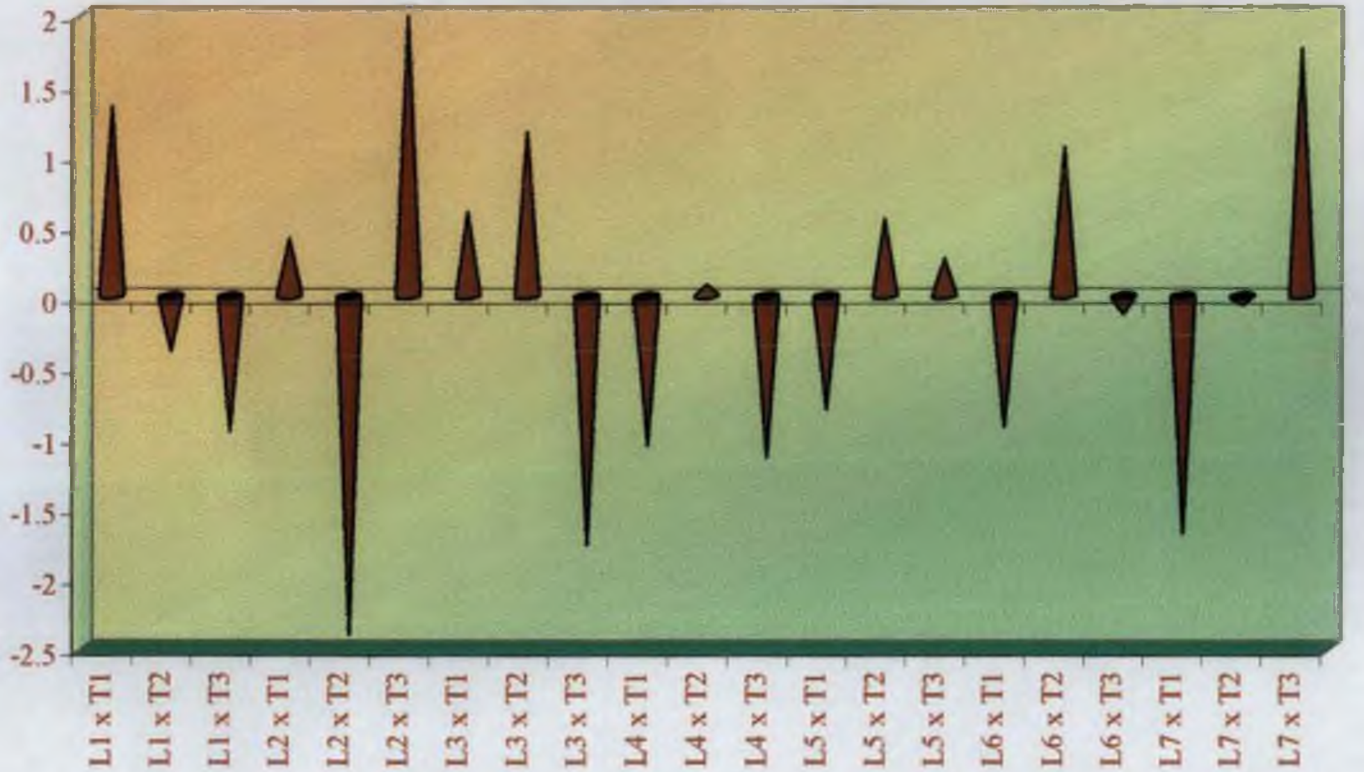


Fig. 10 Specific combining ability effect for crude fibre content

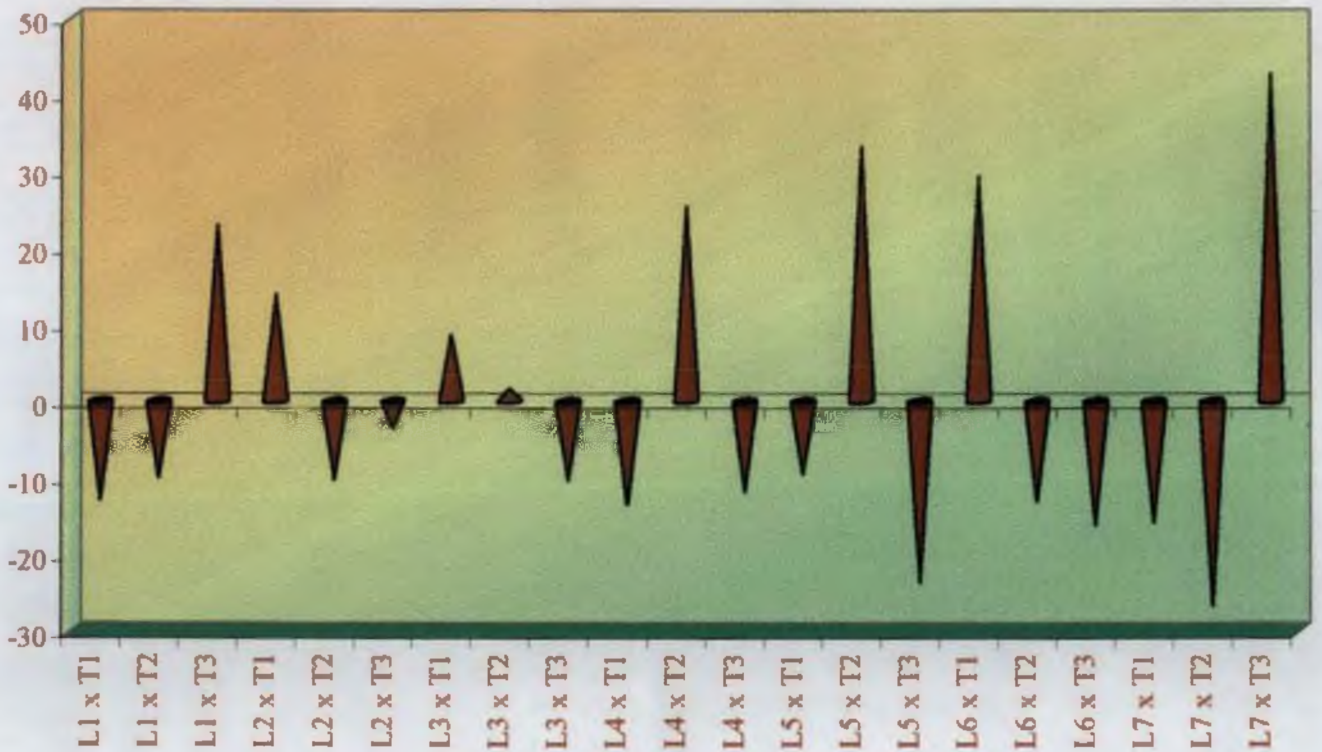


Fig. 11 Specific combining ability effect for green fodder yield

had significant positive *sca* effects. The cross TNSC-4 x FD 471 recorded the highest positive *sca* effect (8.12) while DRSB-3 x FD 431 recorded the lowest value (1.71). TNSC-4 x FD 471 was significantly superior to all other hybrids for dry fodder yield. Twelve hybrids had negative significant *sca* effects which ranged from –4.80 for TNSC-4 x FD 467 to –1.41 for DRSB-3 x FD 471 (Fig. 12).

4.3 COMPONENTS OF GENETIC VARIANCE

The components of genetic variance were calculated and presented in Table 8. Dominance variances were high for all the characters. Additive variance was not estimable for the characters except plant height and internode length. The ratio of additive variance to dominance variance was less than unity for plant height (0.004) and internode length (0.003) while for all other characters the ratio was not estimable.

4.4 PROPORTIONAL CONTRIBUTION

The proportional contribution of lines, testes and crosses to total variance of the characters under study is presented in Table 9 and Fig. 13. The values ranged from 7.11 for tiller number per plant to 41.97 for internode length among lines. Among testers, the values ranged from 0.03 for tiller number per plant to 8.87 for crude protein content. In the case of crosses, the values ranged from 56.80 for plant height to 92.87 for tiller number per plant.

The crosses had contributed maximum to the total variance for all the characters under study and the testers had the least contribution to the total variance with respect to crosses and lines.

4.5 HETEROSIS

The superiority of the hybrids was estimated on the basis of mid parental value (relative heterosis), better parental value (heterobeltiosis) and standard check, Co-2 (standard heterosis) for the eleven characters studied.

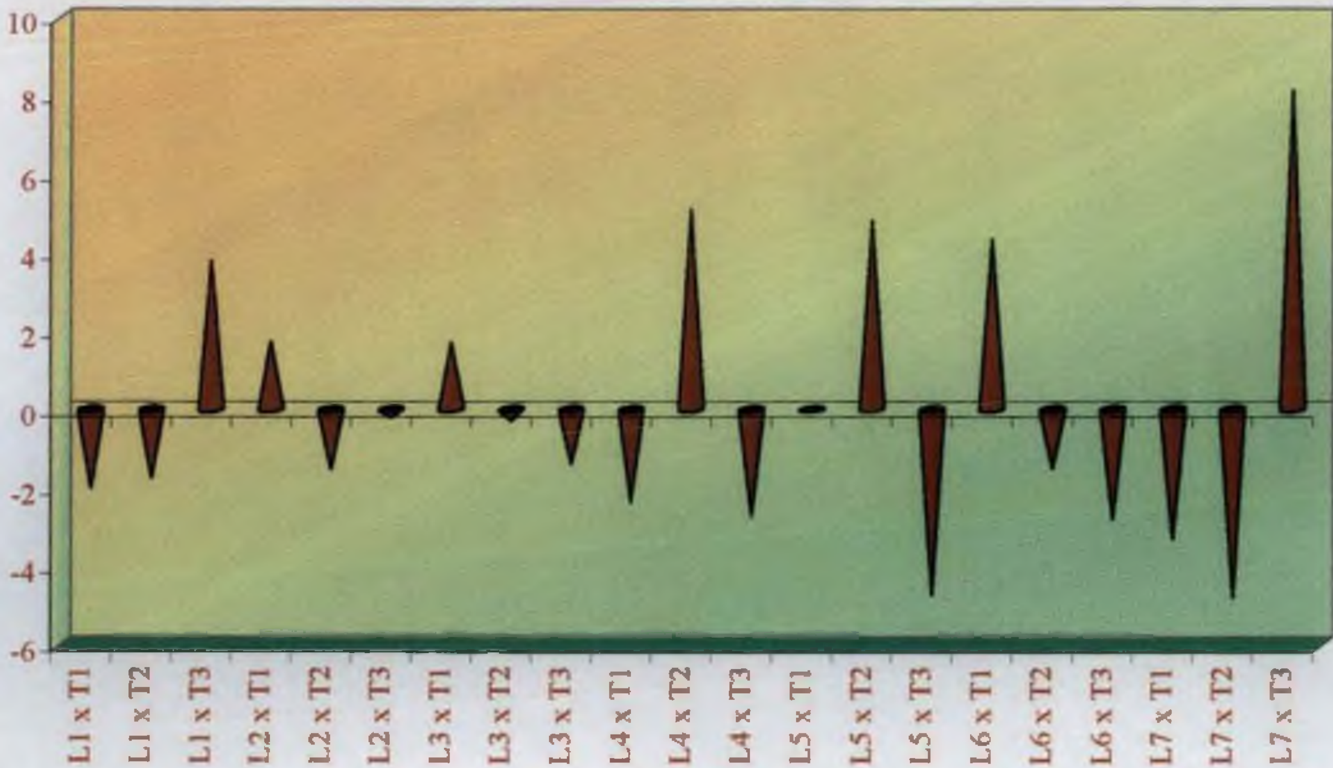


Fig. 12 Specific combining ability effect for dry fodder yield

Table 8 Components of genetic variance for various characters

Sl. No.	Characters	σ^2_A	σ^2_D	σ^2_A / σ_D
1	Plant height, cm	20.811	4688.488	0.004
2	Tiller number per plant	ne	179.152	ne
3	Leaf number per plant	ne	26180.490	ne
4	Internode length, cm	0.113	33.611	0.003
5	Stem girth, cm	ne	1.232	ne
6	Leaf weight per plant, g	ne	111147.300	ne
7	Leaf / stem ratio	ne	0.084	ne
8	Crude protein content, %	ne	1.546	ne
9	Crude fibre content, %	ne	9.546	ne
10	Green fodder yield, t/ha	ne	2712.734	ne
11	Dry fodder yield, t/ha	ne	81.821	ne

ne – not estimable

Table 9 Proportional contribution of lines, testers and line x tester towards total variance

Sl. No.	Characters	Proportional contribution, %		
		Lines	Testers	Line x tester
1.	Plant height, cm	41.88	1.32	56.80
2.	Tiller number per plant	7.11	0.03	92.87
3.	Leaf number per plant	8.65	0.78	90.57
4.	Internode length, cm	41.97	0.43	57.59
5.	Stem girth, cm	19.43	4.65	75.92
6.	Leaf weight per plant, g	11.81	1.63	86.56
7.	Leaf/stem ratio	17.74	1.72	80.54
8.	Crude protein content, %	24.28	8.87	66.85
9.	Crude fibre content, %	20.97	4.79	74.24
10.	Green fodder yield, t ha^{-1}	12.32	1.50	86.17
11.	Dry fodder yield, t ha^{-1}	12.47	1.18	86.35

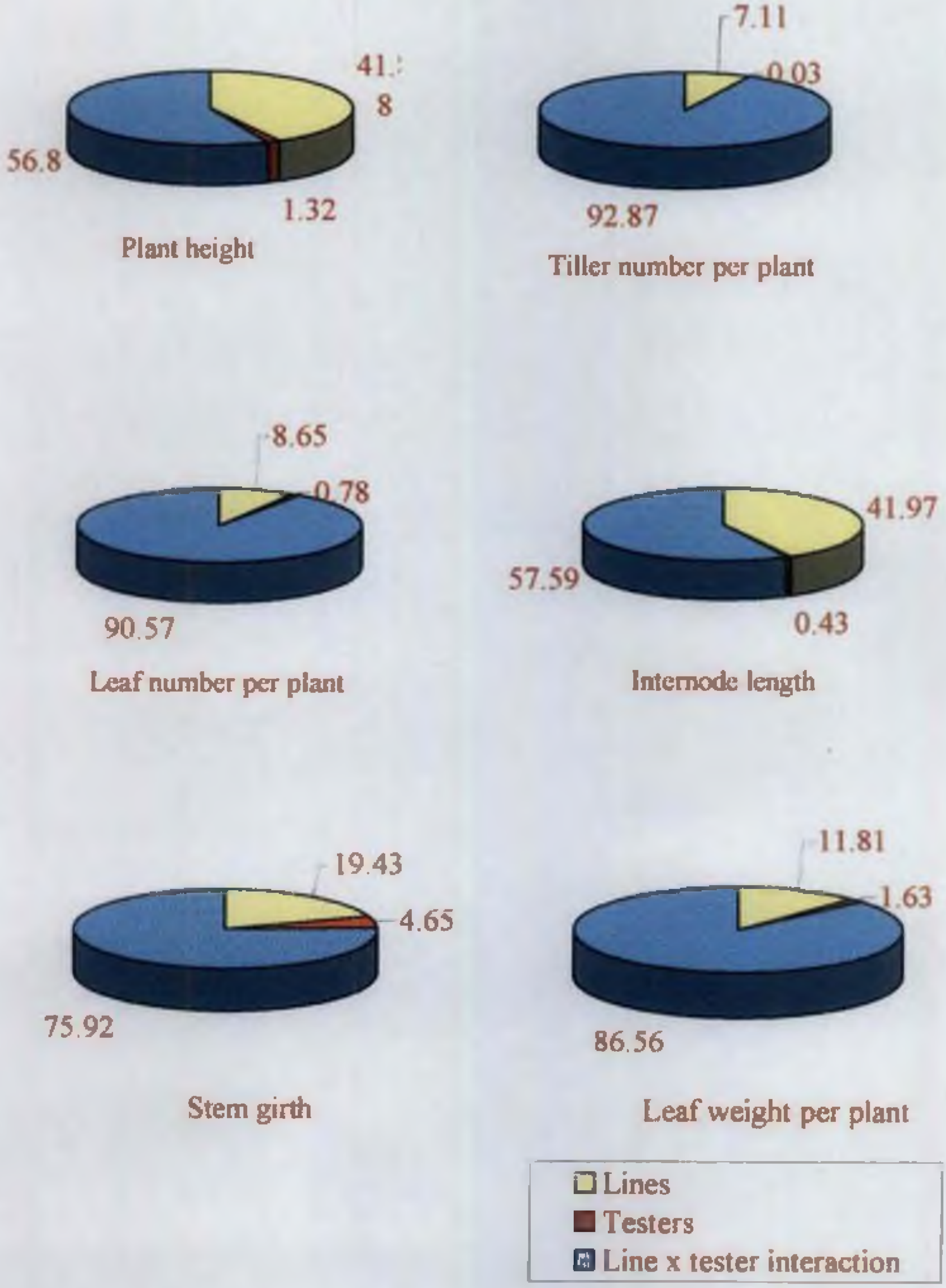


Fig. 13 Proportional contribution (%) of lines, testers and line x tester interaction towards total variance

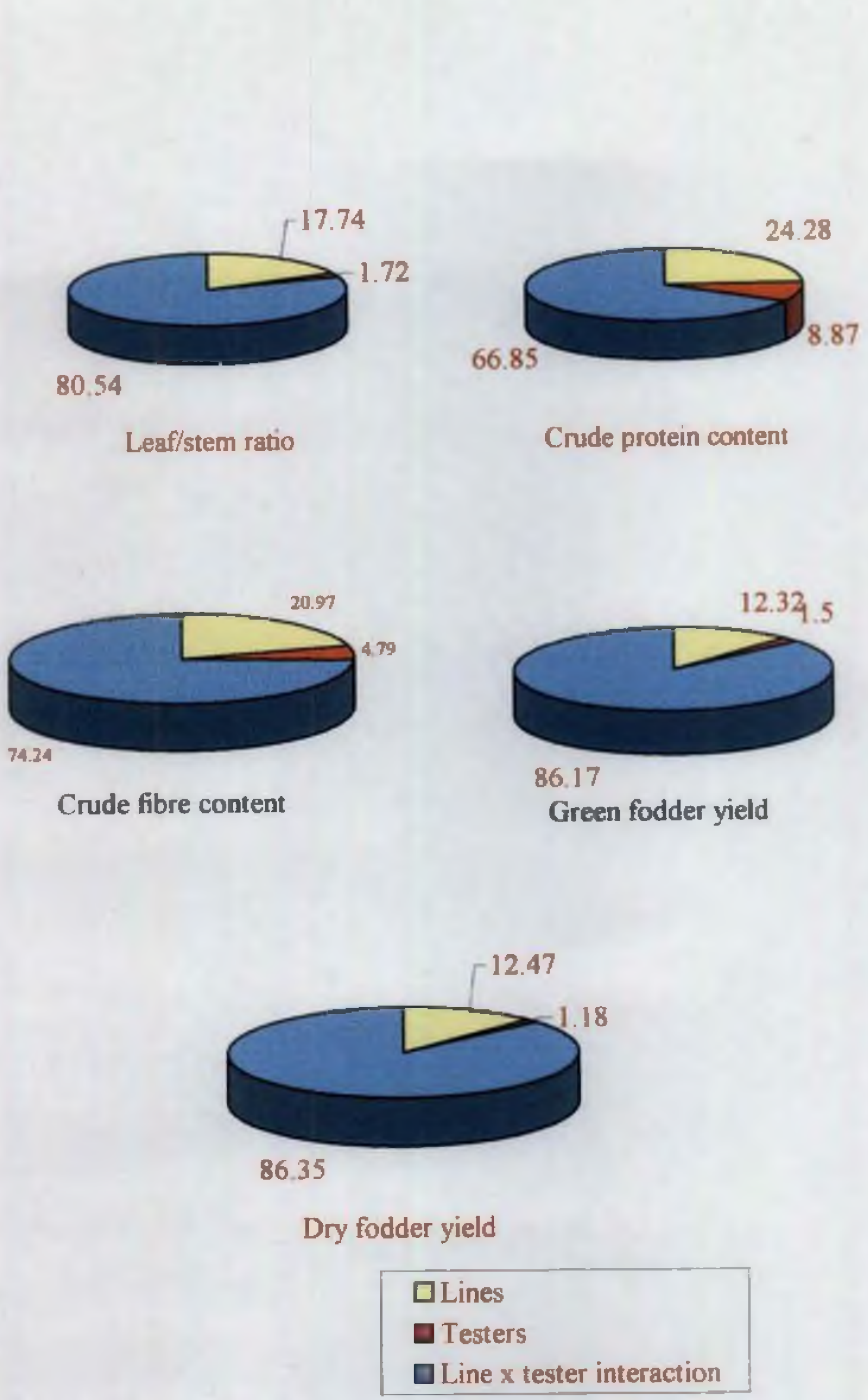


Fig. 13 Continued

The magnitude of relative heterosis, heterobeltiosis and standard heterosis are presented character wise (Tables 10 to 20).

4.5.1 Plant Height

The heterosis per cent for plant height ranged from –30.60 (FD 1917 x FD 467) to 38.00 (DRSB-3 x FD 467) for relative heterosis, from –33.97 (FD 1917 x FD 467) to 27.38 (DRSB-3 x FD 467) for heterobeltiosis and –33.96 (FD 1917 x FD 467) to 27.40 (DRSB-3 x FD 467) for standard heterosis (Table 10). Positive and significant relative heterosis was found for all hybrids except APFB-2 x FD 431, APFB-2 x FD 471, FD 1917 x FD 431, FD 1917 x FD 467 and TNSC-4 x FD 471. Significant negative relative heterosis was shown by hybrids FD 1917 x FD 467 (-30.60 per cent), APFB-2 x FD 431 (-16.27 per cent), TNSC-4 x FD 471 (-15.57 per cent) and APFB-2 x FD 471 (-7.98 per cent). Eleven hybrids showed significant positive heterobeltiosis. Maximum standard heterosis was recorded for DRSB-3 x FD 467 (27.40 per cent) followed by Composite 9 x FD 467 (22.12 per cent) (Fig. 14).

4.5.2 Tiller number per plant

All the hybrids except Composite 9 x FD 471 and TNSC-4 x FD 467 showed significant positive heterotic vigour over the mid parents for this character. Significant positive relative heterosis ranged between 14.38 per cent in IP 15814 x FD 471 and 211.10 per cent in IP 15814 x FD 431. Significant heterobeltiosis ranged from –27.62 per cent (IP 15814 x FD 471) to 77.53 per cent (TNSC-4 x FD 471). Nine hybrids showed significant positive heterosis over better parent. All the hybrids except APFB-2 x FD 467 and DRSB-3 x FD 431 had significant standard heterosis ranging from –7.03 per cent (IP 15814 x FD 467) to 77.69 per cent (TNSC-4 x FD 471). Only six hybrids showed positively significant standard heterosis for this character (Table 11 and Fig. 15).

Table 10 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for plant height

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-16.27**	-22.78**	-27.92**
$L_1 \times T_2$	9.15**	-2.41^{ns}	-2.40^{ns}
$L_1 \times T_3$	-7.98**	-17.06**	-18.54**
$L_2 \times T_1$	5.58*	4.20^{ns}	-2.74^{ns}
$L_2 \times T_2$	27.93**	22.10**	22.12**
$L_2 \times T_3$	17.68**	13.30**	11.28**
$L_3 \times T_1$	30.38**	24.29**	16.01**
$L_3 \times T_2$	38.00**	27.38**	27.40**
$L_3 \times T_3$	9.02**	1.47^{ns}	-0.34^{ns}
$L_4 \times T_1$	2.39^{ns}	0.71^{ns}	-6.00*
$L_4 \times T_2$	-30.60**	-33.97**	-33.96**
$L_4 \times T_3$	10.16**	5.71*	3.82^{ns}
$L_5 \times T_1$	27.76**	17.10**	9.31**
$L_5 \times T_2$	5.97*	-5.82*	-5.80*
$L_5 \times T_3$	22.60**	9.84**	7.88**
$L_6 \times T_1$	10.69**	1.15^{ns}	-5.59*
$L_6 \times T_2$	20.38**	6.68**	6.70**
$L_6 \times T_3$	33.14**	18.92**	16.80**
$L_7 \times T_1$	37.30**	21.69**	13.59**
$L_7 \times T_2$	25.68**	8.15**	8.17**
$L_7 \times T_3$	-15.57**	-26.78**	-28.09**
CD (0.05)	8.507	9.823	9.823

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

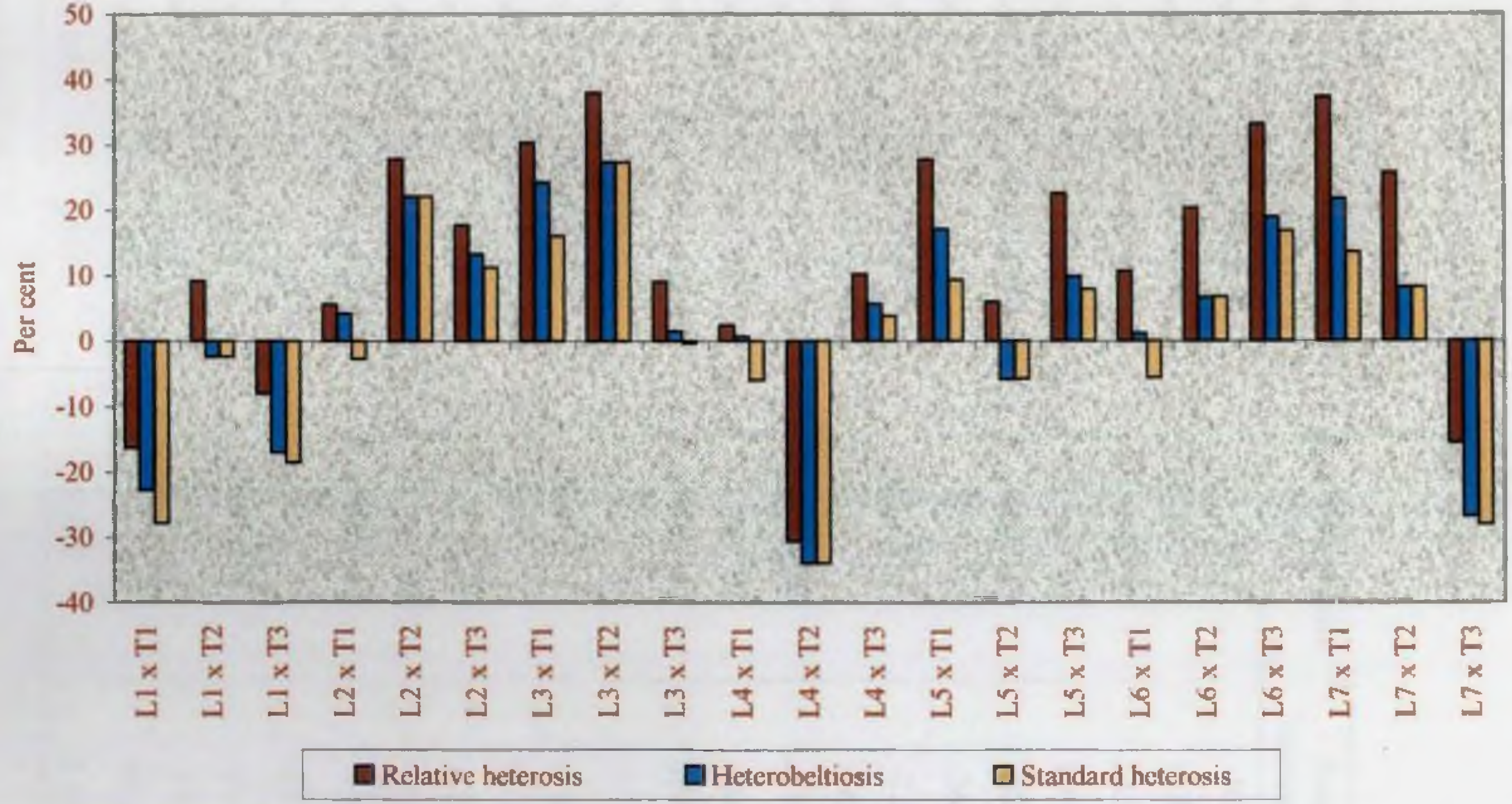


Fig. 14 Heterosis for plant height

Table 11 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for tiller number per plant

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	33.01**	-5.19^{ns}	-30.67**
$L_1 \times T_2$	57.65**	6.58 ^{ns}	-5.81^{ns}
$L_1 \times T_3$	89.74**	24.36**	24.47**
$L_2 \times T_1$	121.02**	63.41**	19.49**
$L_2 \times T_2$	15.65**	-19.27**	-28.66**
$L_2 \times T_3$	8.13^{ns}	-27.03**	-26.97**
$L_3 \times T_1$	75.17**	33.67**	-2.26 ^{ns}
$L_3 \times T_2$	31.48**	-5.64 ^{ns}	-16.61**
$L_3 \times T_3$	21.99**	-15.56**	-15.49**
$L_4 \times T_1$	63.88**	14.85**	-16.02**
$L_4 \times T_2$	130.94**	53.84**	35.95**
$L_4 \times T_3$	34.33**	-13.13**	-13.05**
$L_5 \times T_1$	43.40**	6.69^{ns}	-21.98**
$L_5 \times T_2$	145.77**	72.51**	52.45**
$L_5 \times T_3$	22.22**	-17.10**	-17.03**
$L_6 \times T_1$	211.10**	112.09**	55.09**
$L_6 \times T_2$	61.76**	5.20 ^{ns}	-7.03*
$L_6 \times T_3$	14.38**	-27.62**	-27.56**
$L_7 \times T_1$	69.96**	23.00**	-10.06**
$L_7 \times T_2$	7.99^{ns}	-26.02**	-34.62**
$L_7 \times T_3$	167.59**	77.53**	77.69**
CD (0.05)	0.983	1.135	1.135

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

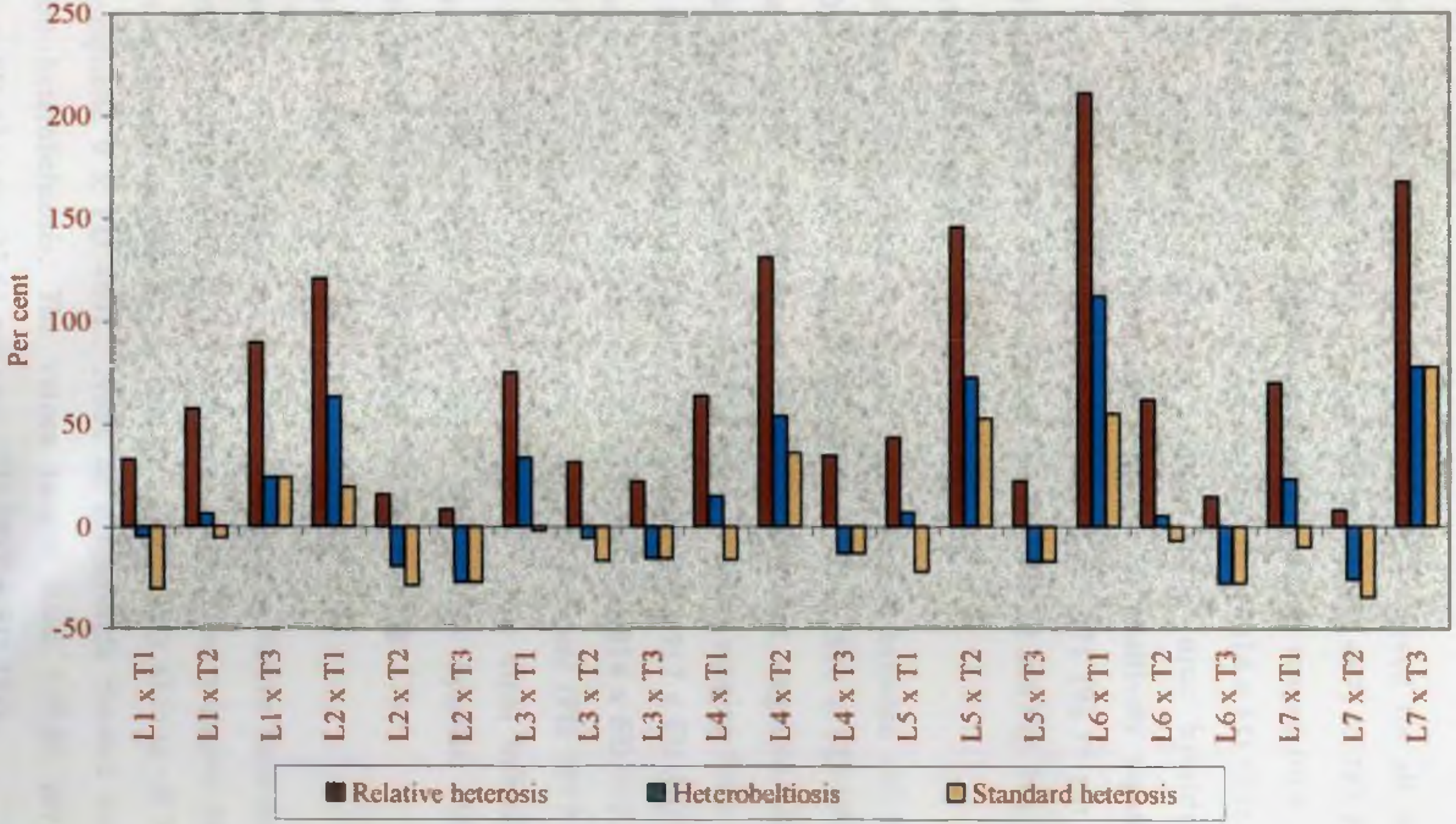


Fig. 15 Heterosis for tiller number per plant

4.5.3 Leaf Number per Plant

Significant positive relative heterosis was observed for all the 21 hybrids, the range being 8.74 per cent (TNSC-4 x FD 467) to 243.76 per cent (IP 15814 x FD 431). Significant heterobeltiosis ranged from –7.09 per cent (APFB-2 x FD 431) to 126.74 per cent (IP 15814 x FD 431). Ten hybrids had positively significant values while nine hybrids had negatively significant heterobeltiosis. Maximum positively significant standard heterosis was recorded for TNSC-4 x FD 471 (92.15 per cent) followed by HES-4 x FD 467 (82.55 per cent) (Table 12 and Fig. 16).

4.5.4 Internode Length

The extent of heterosis over mid parent ranged between –45.59 per cent (FD 1917 x FD 467) and 32.96 per cent (IP 15814 x FD 471) for internode length. Ten hybrids showed significant negative relative heterosis. All hybrids showed negative heterobeltiosis ranging from –8.32 per cent (DRSB-3 x FD 431) to –58.78 per cent (FD 1917 x FD 467) with significance, except for IP 15814 x FD 467 and IP 15814 x FD 471. The value of standard heterosis ranged from –40.78 per cent (FD 1917 x FD 467) to 21.47 per cent (IP 15814 x FD 471). Only eight hybrids had significant negative standard heterosis while nine hybrids recorded significant positive standard heterosis (Table 13 and Fig. 17).

4.5.5 Stem Girth

None of the hybrids had positive significant relative heterosis for stem girth. Fourteen out of 21 hybrids had significant negative relative heterosis ranging from –35.22 per cent (APFB-2 x FD 431) to –8.77 per cent (Composite 9 x FD 467). None of the hybrids showed positive significant heterobeltiosis. The values ranged from –50.09 per cent (APFB-2 x FD 431) to –23.61 per cent (FD 1917 x FD 431). Twelve out of 21 hybrids exhibited significant positive standard heterosis ranging

Table 12 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for leaf number per plant

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	35.53**	-7.09*	-33.96**
$L_1 \times T_2$	47.37**	-3.87^{ns}	-16.74**
$L_1 \times T_3$	130.41**	47.31**	39.45**
$L_2 \times T_1$	124.82**	55.71**	10.68**
$L_2 \times T_2$	16.55**	-23.30**	-33.59**
$L_2 \times T_3$	22.62**	-20.96**	-25.17**
$L_3 \times T_1$	79.38**	30.04**	-7.57**
$L_3 \times T_2$	50.35**	2.94^{ns}	-10.87**
$L_3 \times T_3$	31.91**	-11.77**	-16.48**
$L_4 \times T_1$	54.82**	4.59^{ns}	-25.66**
$L_4 \times T_2$	153.55**	63.32**	41.41**
$L_4 \times T_3$	35.05**	-14.67**	-19.22**
$L_5 \times T_1$	51.47**	7.80**	-23.38**
$L_5 \times T_2$	212.92**	110.84**	82.55**
$L_5 \times T_3$	29.08**	-14.95**	-19.48**
$L_6 \times T_1$	243.76**	126.74**	61.17**
$L_6 \times T_2$	68.39**	6.26**	-7.99**
$L_6 \times T_3$	24.28**	-22.97**	-27.08**
$L_7 \times T_1$	81.09**	26.42**	-10.14**
$L_7 \times T_2$	8.74**	-27.94**	-37.61**
$L_7 \times T_3$	212.87**	102.98**	92.15**
CD (0.05)	5.620	6.489	6.489

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

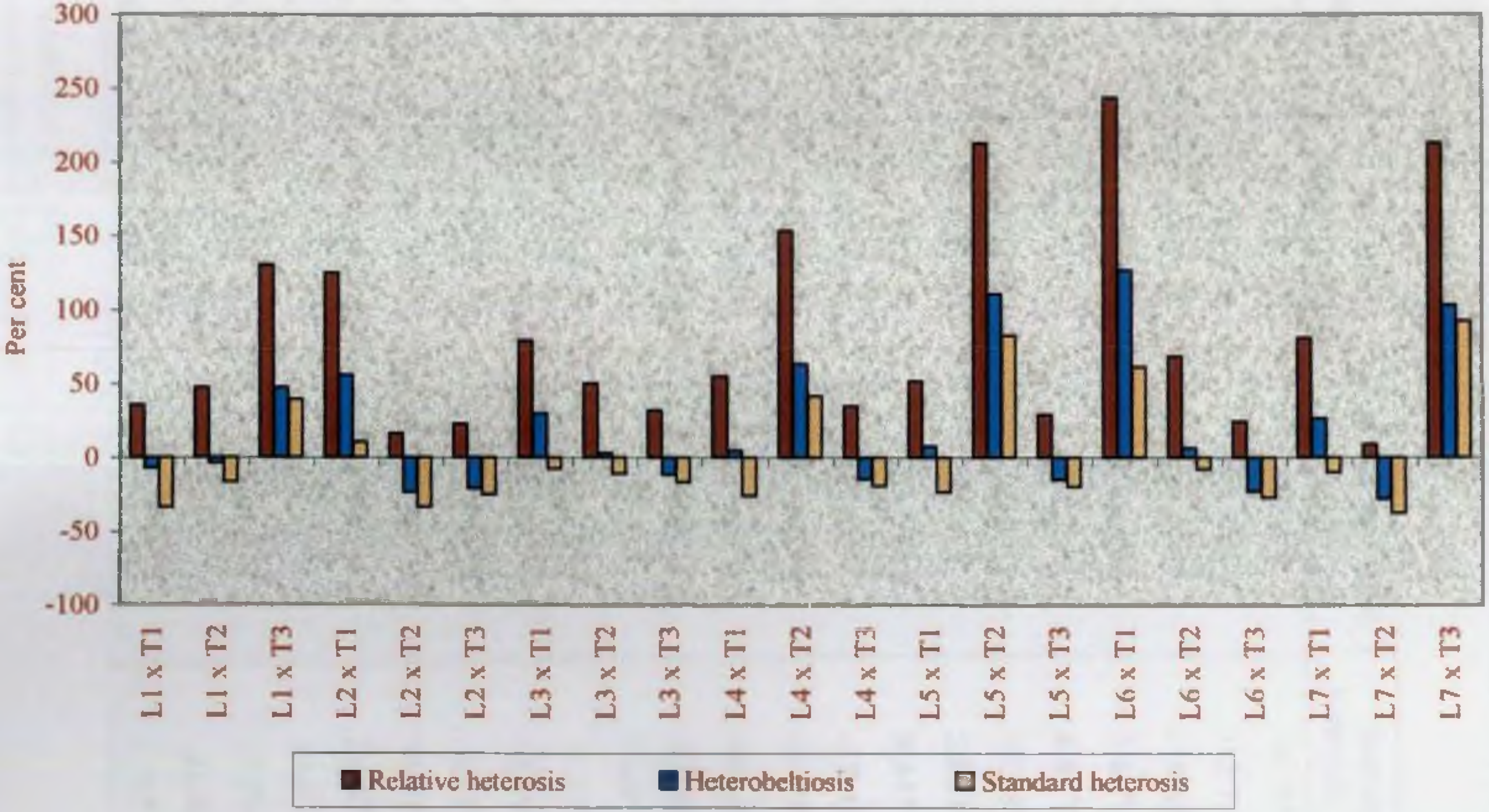


Fig 16 Heterosis for leaf number per plant

Table 13 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for internode length

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-35.20**	-47.04**	-32.95**
$L_1 \times T_2$	-13.02**	-31.09**	-12.75**
$L_1 \times T_3$	-15.57**	-36.51**	-19.62**
$L_2 \times T_1$	-6.24^{ns}	-26.11**	3.19^{ns}
$L_2 \times T_2$	0.11^{ns}	-23.42**	6.95^{ns}
$L_2 \times T_3$	12.93**	-17.43**	14.88**
$L_3 \times T_1$	13.87**	-8.32*	20.83**
$L_3 \times T_2$	6.37^{ns}	-16.96**	9.44**
$L_3 \times T_3$	-16.66*	-38.16**	-18.49**
$L_4 \times T_1$	-11.03**	-30.61**	-0.30^{ns}
$L_4 \times T_2$	-45.59**	-58.78**	-40.78**
$L_4 \times T_3$	-15.63**	-39.08**	-12.48**
$L_5 \times T_1$	-1.59^{ns}	-22.25**	7.80*
$L_5 \times T_2$	-13.04**	-33.31**	-7.53^{ns}
$L_5 \times T_3$	11.62**	-18.50**	12.99**
$L_6 \times T_1$	-15.40**	-29.09**	-15.67**
$L_6 \times T_2$	21.23**	-1.67^{ns}	16.95**
$L_6 \times T_3$	32.96**	2.15^{ns}	21.47**
$L_7 \times T_1$	0.24^{ns}	-22.47**	14.03**
$L_7 \times T_2$	2.91^{ns}	-22.65**	13.76**
$L_7 \times T_3$	-25.98**	-46.93**	-21.96**
CD (0.05)	1.307	1.510	1.510

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

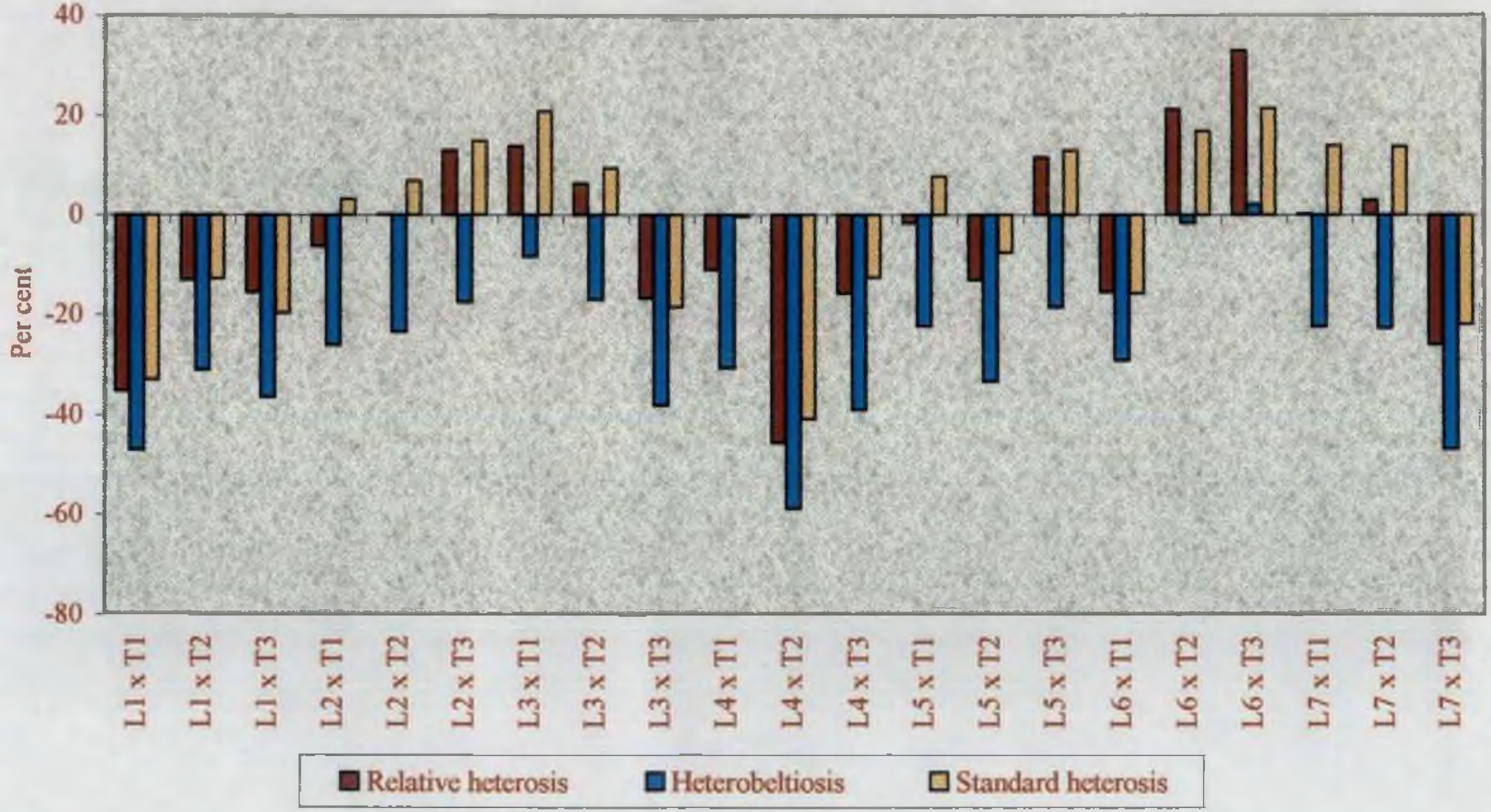


Fig. 17 Heterosis for internode length

from 9.85 per cent (Composite 9 x FD 471) to 20 78 per cent (Composite 9 x FD 467 and TNSC-4 x FD 467) (Table 14 and Fig. 18).

4.5.6 Leaf Weight per Plant

All the 21 hybrids showed significant positive relative heterosis, the range being 28.19 per cent (TNSC-4 x FD 467) to 349.61 per cent (TNSC-4 x FD 471). Heterobeltiosis values ranged from –15.72 per cent (Composite 9 x FD 467) to 205.76 per cent (TNSC-4 x FD 471). Sixteen hybrids showed significant positive heterosis over better parent. Heterosis over standard variety varied from –43.23 per cent (APFB-2 x FD 431) to 110.07 per cent (TNSC-4 x FD 471). Only six crosses showed significant positive standard heterosis while the remaining crosses had significant negative standard heterosis for this character (Table 15 and Fig. 19).

4.5.7 Leaf/Stem Ratio

Significant positive relative heterosis ranging from 23.62 per cent (DRSB-3 x FD 467) to 121.18 per cent (IP 15814 x FD 431) was exhibited by all the 21 hybrids. Similarly, all the hybrids showed significant positive heterobeltiosis ranging from 17.14 per cent (DRSB-3 x FD 467) to 108. 89 per cent (IP 15814 x FD 431). Only two hybrids, FD 1917 x FD 467 (3.83 per cent) and HES-4 x FD 467 (5.46 per cent) showed significant positive standard heterosis (Table 16 and Fig. 20).

4.5.8 Crude Protein Content

Only one hybrid *viz.*, TNSC-4 x FD 471 showed significant positive relative heterosis (4.39 per cent). None of the hybrids showed significant positive values for heterobeltiosis and standard heterosis (Table 17 and Fig. 21).

4.5.9 Crude Fibre Content

The heterosis over mid parental value varied from –22.50 per cent (APFB-2 X FD 471) to 11.41 per cent (FD 1917 x FD 431). Seventeen out

Table 14 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for stem girth

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-35.22**	-50.09**	-22.67**
$L_1 \times T_2$	-17.65**	-39.49**	7.96ns
$L_1 \times T_3$	-27.35**	-45.32**	-9.31*
$L_2 \times T_1$	-26.40**	-42.68**	-11.20*
$L_2 \times T_2$	-8.77**	-32.30**	20.78**
$L_2 \times T_3$	-12.90**	-33.77**	9.85*
$L_3 \times T_1$	2.90ns	-24.22**	17.41**
$L_3 \times T_2$	-22.68**	-45.46**	-2.70ns
$L_3 \times T_3$	-20.99**	-43.04**	-5.53ns
$L_4 \times T_1$	-0.90ns	-23.61**	18.35**
$L_4 \times T_2$	-30.97**	-49.24**	-9.45*
$L_4 \times T_3$	-9.02**	-31.49**	13.63**
$L_5 \times T_1$	-2.57ns	-28.92**	10.12*
$L_5 \times T_2$	-11.09**	-37.82**	10.93*
$L_5 \times T_3$	-2.16ns	-30.11**	15.92**
$L_6 \times T_1$	-23.95**	-43.29**	-12.15**
$L_6 \times T_2$	-11.77**	-37.07**	12.28**
$L_6 \times T_3$	-1.73ns	-28.32**	18.89**
$L_7 \times T_1$	4.32ns	-27.44**	12.42**
$L_7 \times T_2$	1.07ns	-32.30**	20.78**
$L_7 \times T_3$	-24.08**	-48.17**	-14.04**
CD (0.05)	0.274	0.316	0.316

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

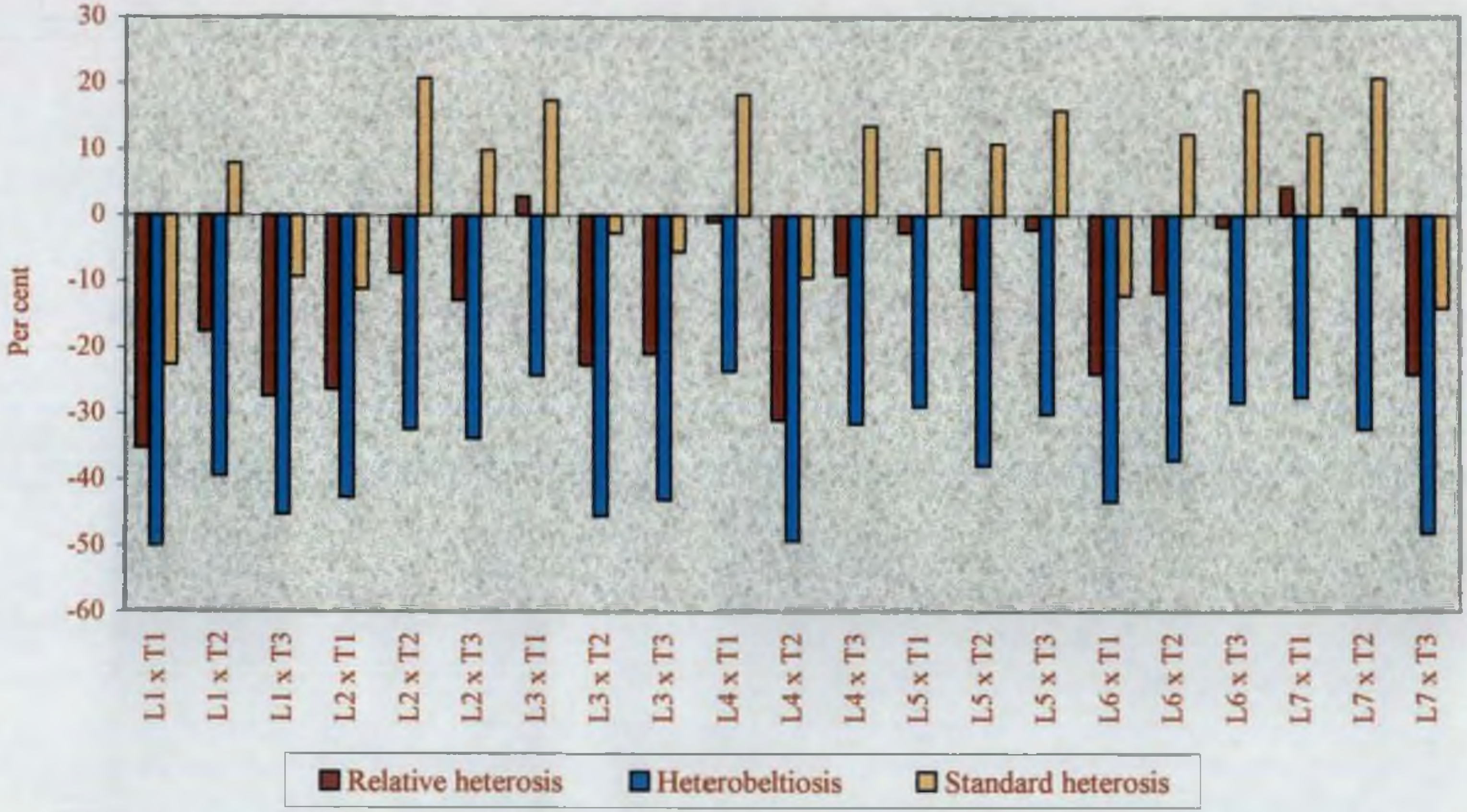


Fig. 18 Heterosis for stem girth

Table 15 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for leaf weight per plant

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	42.11**	-8.38**	-43.23**
$L_1 \times T_2$	57.51**	-2.63^{ns}	-26.10**
$L_1 \times T_3$	234.98**	111.01**	45.66**
$L_2 \times T_1$	144.73**	67.16**	3.58**
$L_2 \times T_2$	29.78**	-15.72**	-36.03**
$L_2 \times T_3$	60.67**	6.74**	-26.32**
$L_3 \times T_1$	88.08**	33.83**	-17.07**
$L_3 \times T_2$	52.16**	2.36^{ns}	-22.30**
$L_3 \times T_3$	56.75**	8.14**	-25.35**
$L_4 \times T_1$	65.78**	11.99**	-30.61**
$L_4 \times T_2$	226.31**	109.92**	59.34**
$L_4 \times T_3$	74.91**	15.02**	-20.60**
$L_5 \times T_1$	71.91**	21.80**	-24.53**
$L_5 \times T_2$	265.35**	144.87**	85.86**
$L_5 \times T_3$	50.48**	3.41*	-28.62**
$L_6 \times T_1$	310.55**	167.52**	65.76**
$L_6 \times T_2$	97.04**	22.91**	-6.71**
$L_6 \times T_3$	67.69**	6.66**	-26.37**
$L_7 \times T_1$	101.26**	41.00**	-12.63**
$L_7 \times T_2$	28.19**	-14.91**	-35.42**
$L_7 \times T_3$	349.61**	205.76**	111.07**
CD (0.05)	5.705	6.588	6.588

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

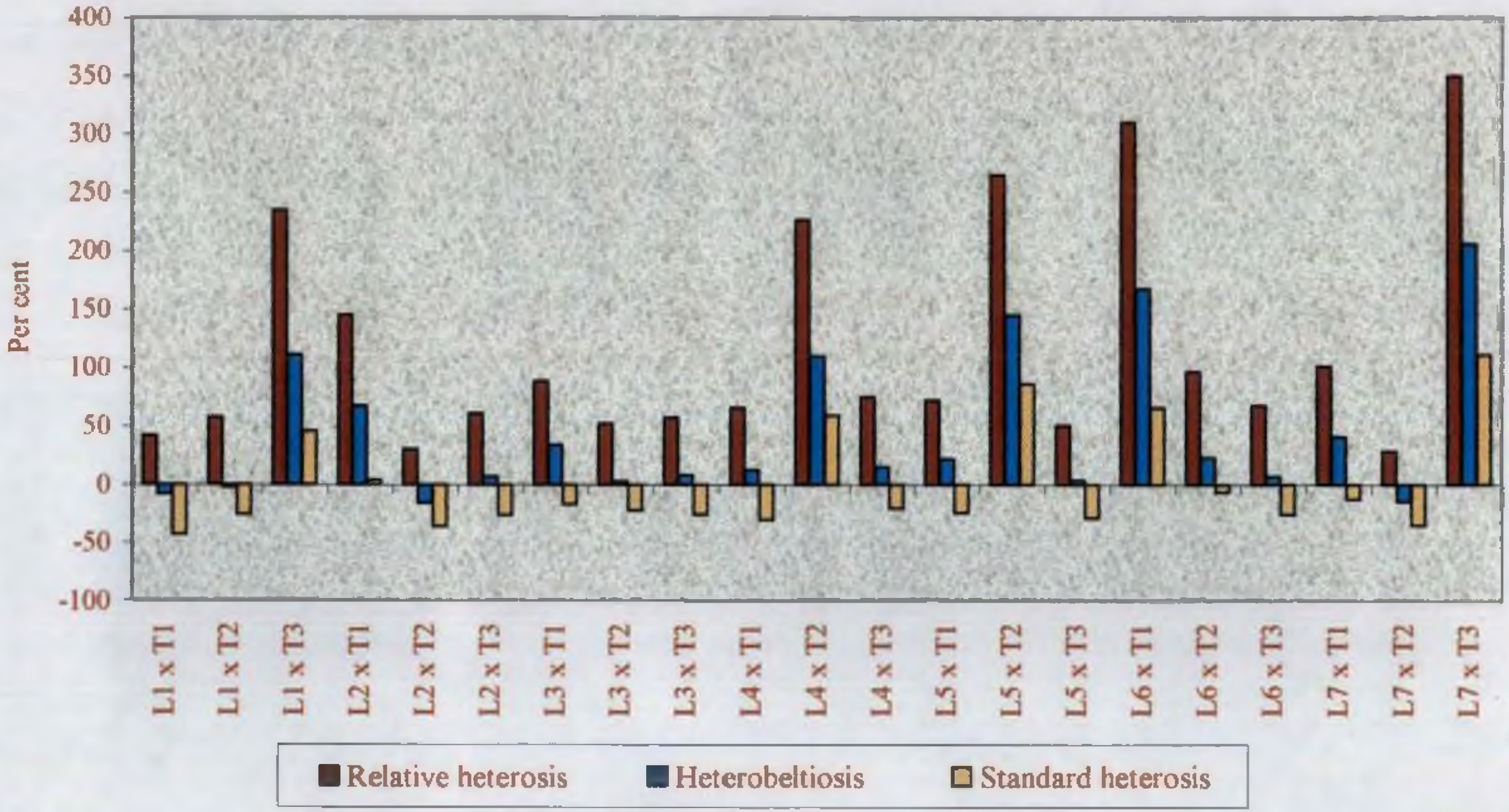


Fig. 19 Heterosis for leaf weight per plant

Table 16 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for leaf/stem ratio

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	45.46**	42.22**	-30.06**
$L_1 \times T_2$	53.95**	40.00**	-19.67**
$L_1 \times T_3$	92.47**	79.00**	-2.19^{ns}
$L_2 \times T_1$	107.74**	106.59**	2.73^{ns}
$L_2 \times T_2$	76.53**	64.76**	-5.46**
$L_2 \times T_3$	60.21**	53.00**	-16.39**
$L_3 \times T_1$	36.96**	34.04**	-31.15**
$L_3 \times T_2$	23.62**	17.14**	-32.79**
$L_3 \times T_3$	71.13**	66.00**	-9.29**
$L_4 \times T_1$	82.35**	72.22**	-15.30**
$L_4 \times T_2$	105.41**	80.95**	3.83**
$L_4 \times T_3$	61.11**	45.00**	-20.77**
$L_5 \times T_1$	36.96**	34.04**	-31.15**
$L_5 \times T_2$	93.97**	83.81**	5.46**
$L_5 \times T_3$	58.76**	54.00**	-15.85**
$L_6 \times T_1$	121.18**	108.89**	2.73^{ns}
$L_6 \times T_2$	97.84**	74.29**	0.00^{ns}
$L_6 \times T_3$	41.11**	27.00**	-30.60**
$L_7 \times T_1$	98.87**	95.56**	-3.83**
$L_7 \times T_2$	38.54**	26.67**	-27.32**
$L_7 \times T_3$	100.00**	87.00**	2.19^{ns}
CD (0.05)	0.025	0.029	0.029

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

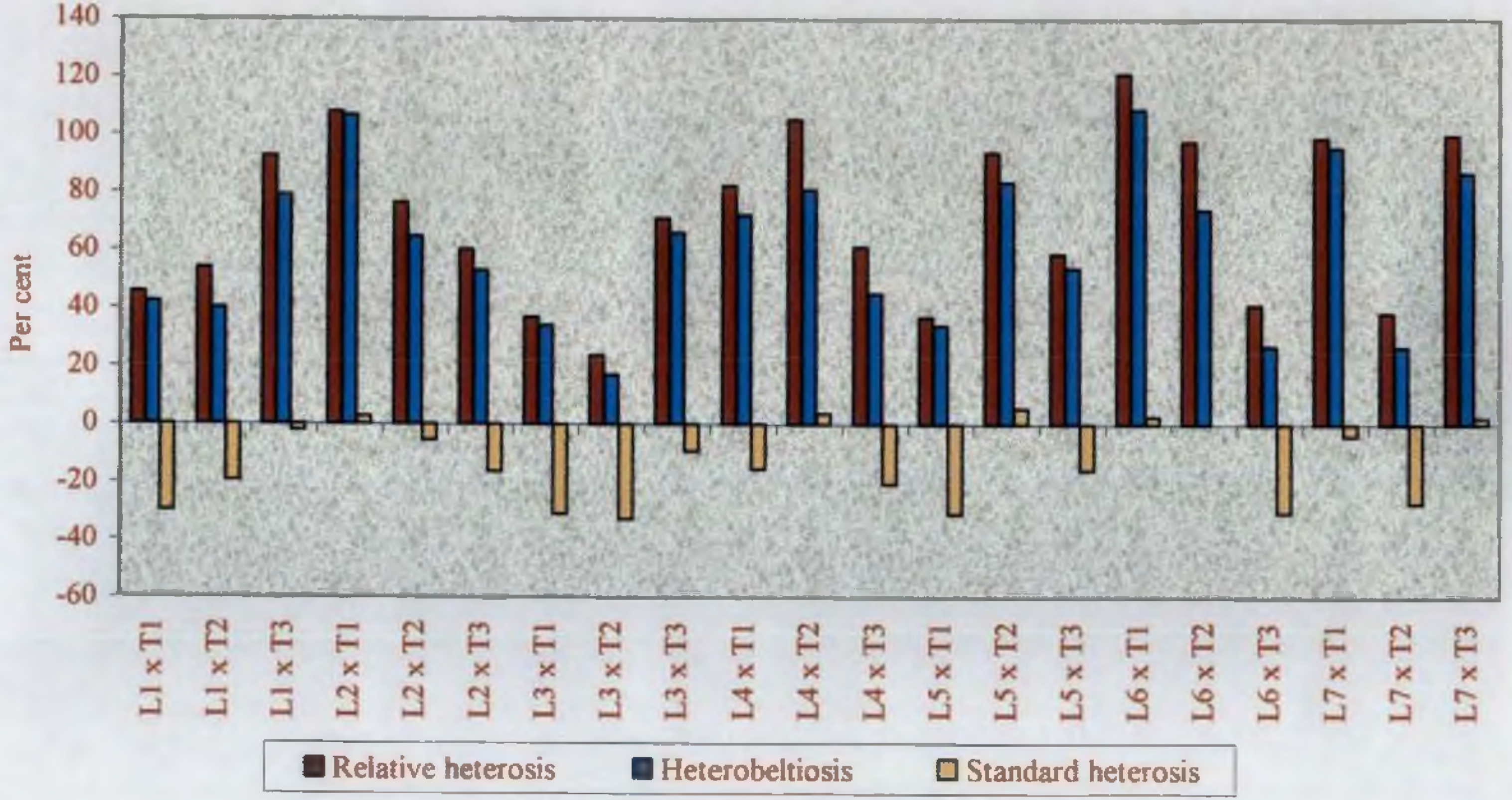


Fig. 20 Heterosis for leaf/stem ratio

Table 17 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for crude protein content

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-20.32**	-29.23**	-10.54**
$L_1 \times T_2$	-25.36**	-35.23**	-18.13**
$L_1 \times T_3$	-19.18**	-32.04**	-14.09**
$L_2 \times T_1$	-3.67**	-5.72**	-3.40*
$L_2 \times T_2$	-2.29^{ns}	-6.82**	-4.52**
$L_2 \times T_3$	-16.51**	-23.15**	-21.25**
$L_3 \times T_1$	-20.41**	-23.87**	-18.18**
$L_3 \times T_2$	-4.78**	-11.21**	-4.57**
$L_3 \times T_3$	-10.50**	-19.37**	-13.34**
$L_4 \times T_1$	-7.89**	-10.03**	-11.73**
$L_4 \times T_2$	-10.24**	-10.52**	-16.30**-
$L_4 \times T_3$	-3.44*	-7.25**	-13.23**
$L_5 \times T_1$	-9.27**	-13.59**	-6.29**
$L_5 \times T_2$	0.00^{ns}	-7.14**	0.70^{ns}
$L_5 \times T_3$	-10.78**	-19.94**	-13.18**
$L_6 \times T_1$	-8.24**	-16.15**	-0.59^{ns}
$L_6 \times T_2$	-10.48**	-20.15**	-5.33*
$L_6 \times T_3$	-13.93**	-25.68**	-11.89**
$L_7 \times T_1$	-17.81**	-19.18**	-17.97**
$L_7 \times T_2$	-6.78**	-10.71**	-9.36**
$L_7 \times T_3$	4.39**	-3.50*	-2.04^{ns}
CD (0.05)	0.237	0.274	0.274

** Significant at 1 per cent level
* Significant at 5 per cent level

ns Not significant

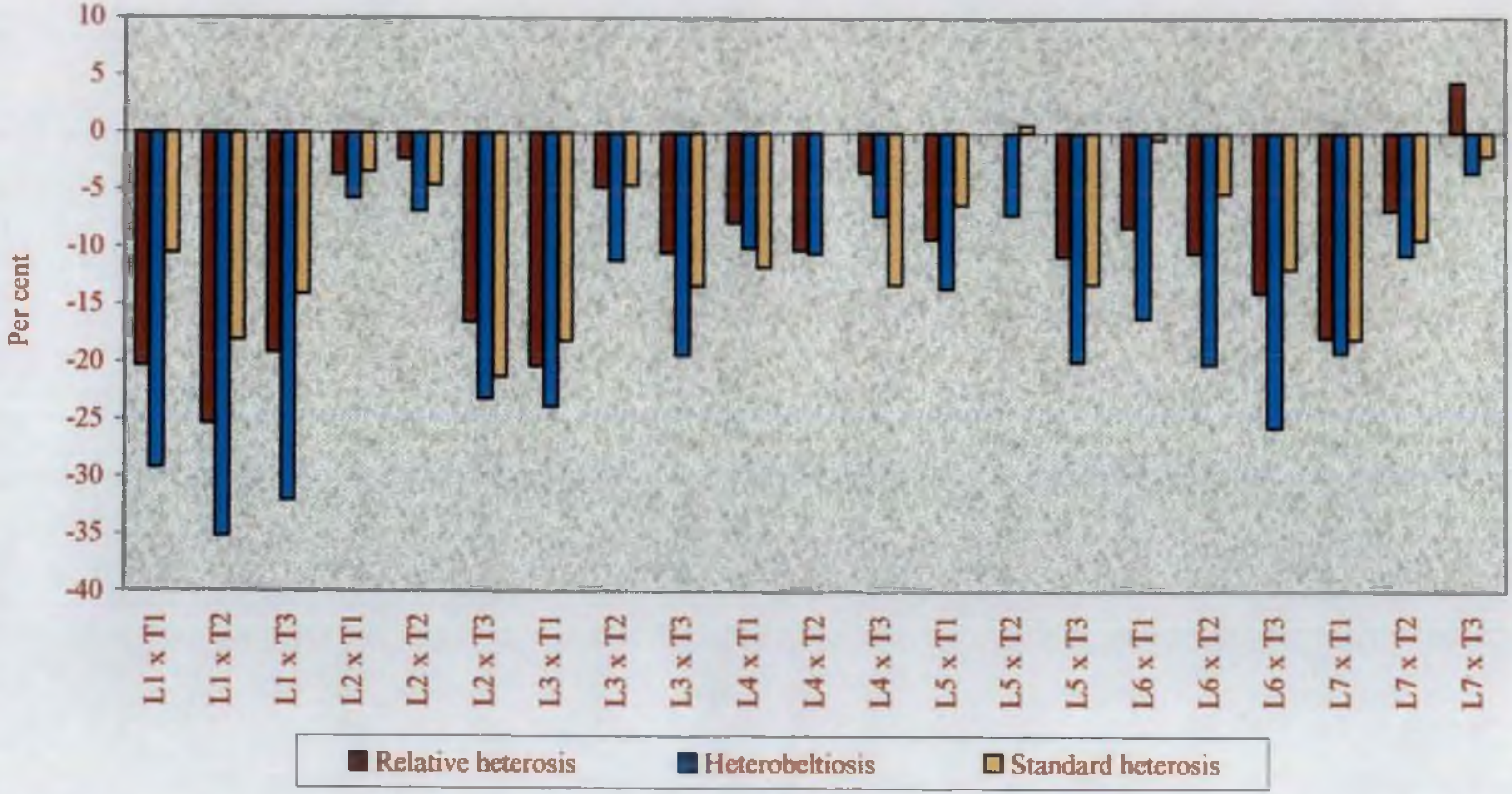


Fig. 21 Heterosis for crude protein content

of 21 hybrids had significant negative relative heterosis. All the 21 hybrids showed significant negative heterobeltiosis for crude fibre content. The highest negative heterobeltiosis value was recorded by Composite 9 x FD 467 (-29.57 per cent) and the lowest negative value by FD 1917 x FD 431 (-2.57 per cent). The standard heterosis values ranged from –4.45 per cent (TNSC-4 x FD 431) to 18.08 per cent (APFB-2 x FD 431). Only one hybrid *viz.*, TNSC-4 x FD 431 had significant negative standard heterosis for crude fibre content (Table 18 and Fig. 22).

4.5.10 Green Fodder Yield

The heterosis values ranged from –24.43 per cent (Composite 9 x FD 467) to 138.36 per cent (TNSC-4 x FD 471) for relative heterosis, from –37.80 per cent (Composite 9 x FD 467) to 110.97 per cent (TNSC-4 x FD 471) for heterobeltiosis and form –34.09 per cent (Composite 9 x FD 467) to 108.77 per cent (TNSC-4 x FD 471) for standard heterosis. Significant positive relative heterosis was exhibited by fourteen hybrids. Seven out of 21 hybrids had significant positive heterobeltiosis. Only five hybrids showed significant standard heterosis (Table 19 and Fig. 23).

4.5.11 Dry Fodder Yield

Significant positive relative heterosis for dry fodder yield was exhibited by thirteen hybrids, of which the maximum value was shown by TNSC-4 x FD 471 (148.08 per cent). All hybrids exhibited significant heterobeltiosis of which only nine hybrids had positive values. The hybrid TNSC-4 x FD 471 had the highest significant positive value (109.82 per cent) for this character. When compared with the mean value of the standard variety, only six hybrids showed significant positive standard heterosis. The hybrid TNSC-4 x FD 471 had the highest value (96.96 per cent) for standard heterosis followed by HES-4 x FD 467 (60.76 per cent) (Table 20 and Fig. 24).

Table 18 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for crude fibre content

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-6.68**	-10.62**	18.08**
$L_1 \times T_2$	-20.18**	-22.64**	8.91**
$L_1 \times T_3$	-22.50**	-23.54**	3.79*
$L_2 \times T_1$	-3.21**	-6.27**	13.36**
$L_2 \times T_2$	-21.95**	-29.57**	-0.85^{ns}
$L_2 \times T_3$	-5.65**	-13.46**	17.49**
$L_3 \times T_1$	3.01*	-6.37**	13.25**
$L_3 \times T_2$	-4.07**	-18.33*	14.97**
$L_3 \times T_3$	-15.90**	-27.31**	-1.32^{ns}
$L_4 \times T_1$	11.41**	-2.57*	17.84**
$L_4 \times T_2$	-3.01*	-20.29**	12.21**
$L_4 \times T_3$	-8.10**	-23.39**	4.01*
$L_5 \times T_1$	-11.56**	-12.06**	7.59**
$L_5 \times T_2$	-14.08**	-19.71**	13.03**
$L_5 \times T_3$	-15.30**	-19.48**	9.31**
$L_6 \times T_1$	0.10^{ns}	-14.44**	3.49*
$L_6 \times T_2$	-1.19^{ns}	-20.48**	11.95**
$L_6 \times T_3$	-6.20**	-23.46**	3.91*
$L_7 \times T_1$	-19.83**	-21.01**	-4.45**
$L_7 \times T_2$	-20.79**	-27.36**	2.26^{ns}
$L_7 \times T_3$	-14.32**	-20.10**	8.46**
CD (0.05)	0.551	0.636	0.636

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

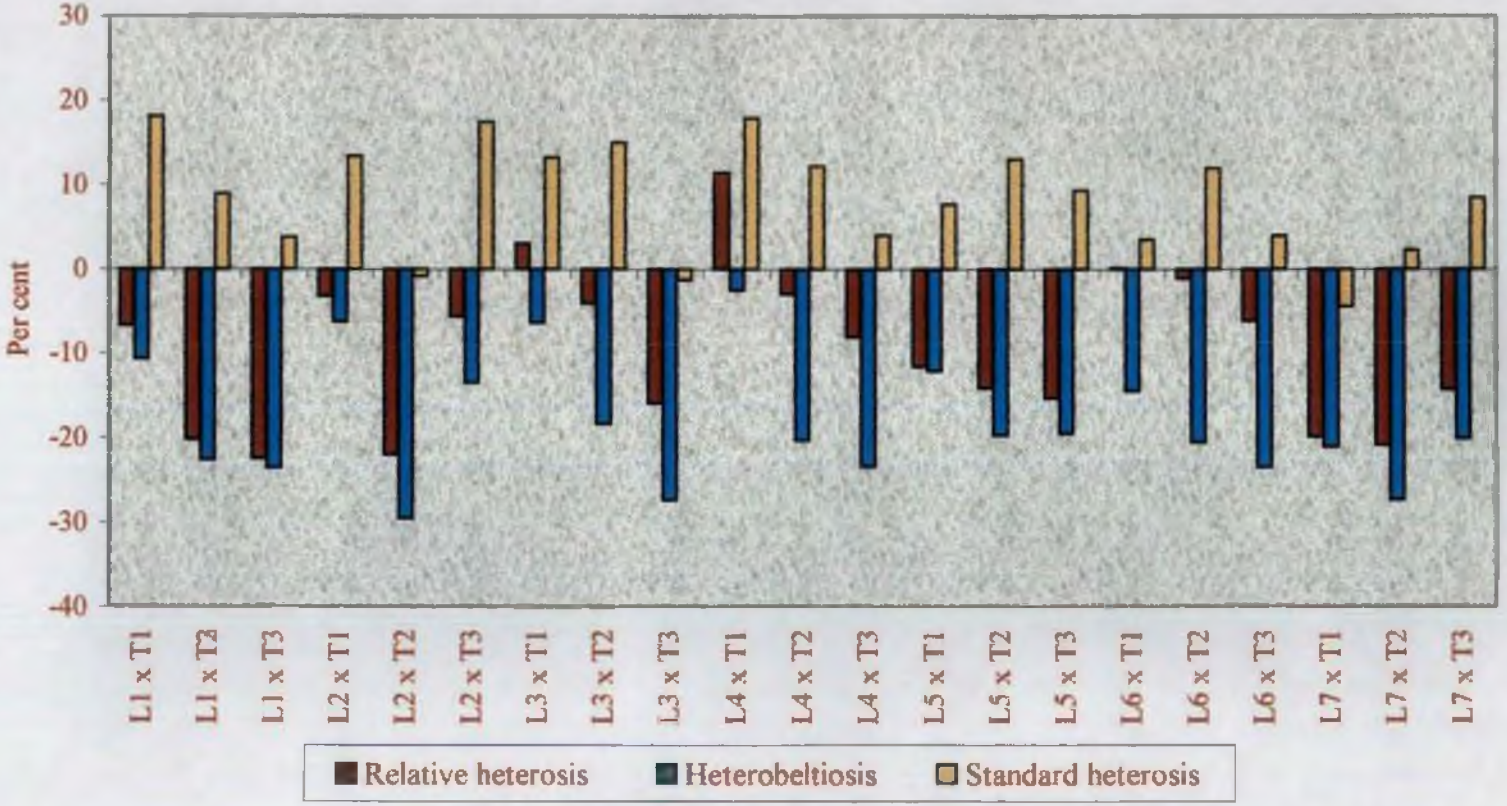


Fig. 22 Heterosis for crude fibre content

Table 19 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for green fodder yield

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-8.37**	-27.16**	-30.48**
$L_1 \times T_2$	2.75*	-21.33**	-16.67**
$L_1 \times T_3$	89.86**	48.94**	47.38**
$L_2 \times T_1$	24.64**	7.03**	2.15^{ns}
$L_2 \times T_2$	-24.43**	-37.80**	-34.09**
$L_2 \times T_3$	-2.95*	-17.90**	-18.76**
$L_3 \times T_1$	18.61**	7.42**	2.52^{ns}
$L_3 \times T_2$	6.86**	-7.53**	-2.01^{ns}
$L_3 \times T_3$	-10.82**	-20.52**	-21.35**
$L_4 \times T_1$	-9.35**	-20.41**	-24.04**
$L_4 \times T_2$	75.46**	47.47**	56.27**
$L_4 \times T_3$	5.49**	-8.79**	-9.74**
$L_5 \times T_1$	8.44**	-2.22^{ns}	-6.68**
$L_5 \times T_2$	98.03**	70.66**	80.84**
$L_5 \times T_3$	-10.72**	-20.78**	-21.60**
$L_6 \times T_1$	106.64**	71.20**	63.39**
$L_6 \times T_2$	10.61**	-11.97**	-6.72**
$L_6 \times T_3$	12.08**	-8.45**	-9.40**
$L_7 \times T_1$	3.91**	-6.56**	-10.82**
$L_7 \times T_2$	-15.13**	-27.05**	-22.69**
$L_7 \times T_3$	138.36**	110.97**	108.77**
CD (0.05)	1.199	1.385	1.385

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

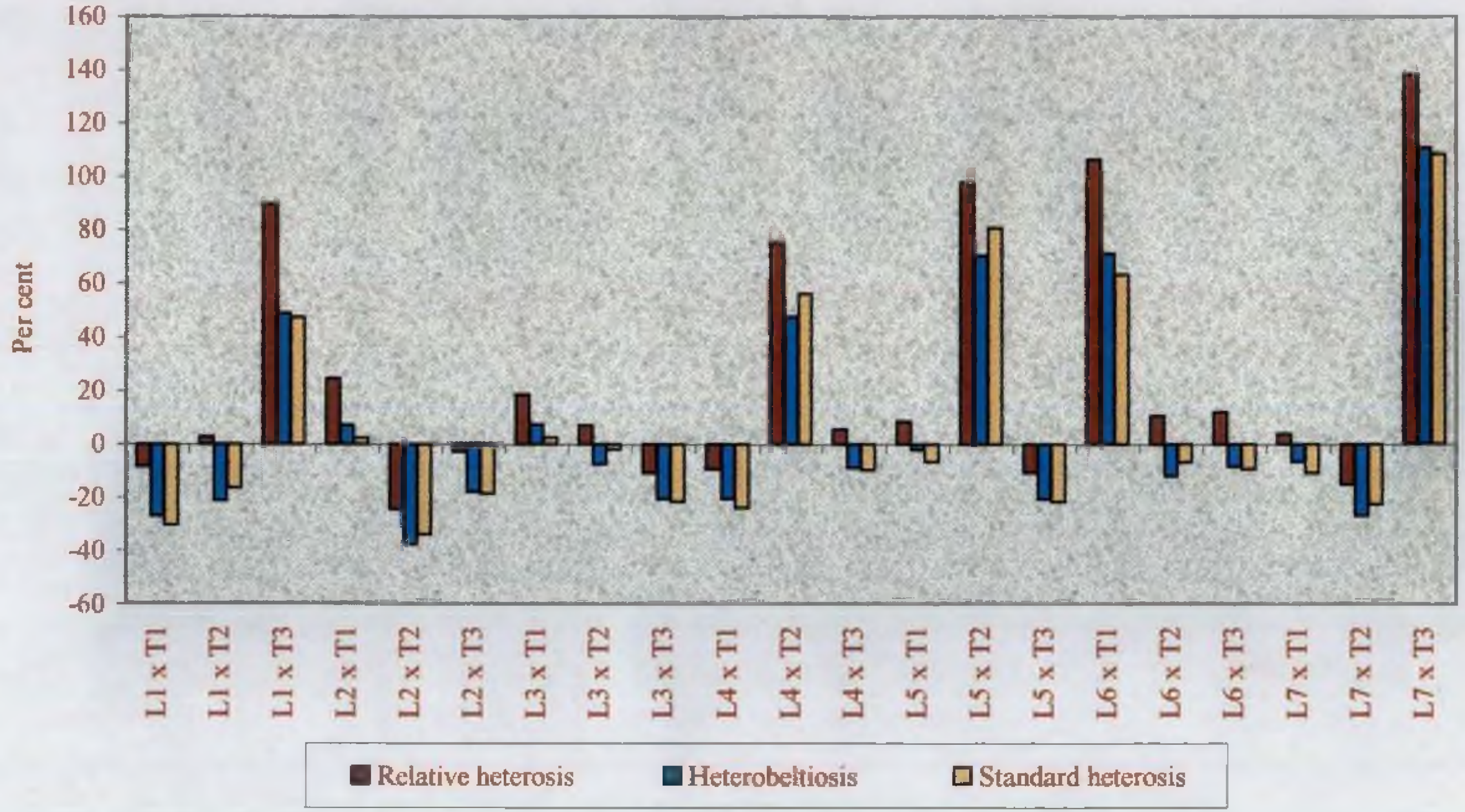


Fig. 23 Heterosis for green fodder yield

Table 20 Magnitude of relative heterosis, heterobeltiosis and standard heterosis for dry fodder yield

Cross	Relative heterosis (RH)	Heterobeltiosis (HB)	Standard heterosis (SH)
$L_1 \times T_1$	-1.78^{ns}	-21.82**	-31.92**
$L_1 \times T_2$	10.29**	-14.12**	-20.57**
$L_1 \times T_3$	79.68**	39.17**	30.61**
$L_2 \times T_1$	27.24**	7.42**	-6.46**
$L_2 \times T_2$	-6.64**	-23.06**	-28.84**
$L_2 \times T_3$	6.92**	-12.40**	-17.77**
$L_3 \times T_1$	23.28**	13.53**	-1.14^{ns}
$L_3 \times T_2$	6.76**	-4.13*	-11.50**
$L_3 \times T_3$	-8.55**	-18.57**	-23.56**
$L_4 \times T_1$	-3.34^{ns}	-9.93**	-21.57**
$L_4 \times T_2$	88.33**	70.72**	57.91**
$L_4 \times T_3$	-2.78^{ns}	-12.45**	-17.82**
$L_5 \times T_1$	36.99**	21.22**	5.56**
$L_5 \times T_2$	101.55**	73.81**	60.76**
$L_5 \times T_3$	-14.79**	-26.97**	-31.45**
$L_6 \times T_1$	101.19**	65.69**	44.28**
$L_6 \times T_2$	30.67**	5.14**	-2.76^{ns}
$L_6 \times T_3$	11.07**	-11.13**	-16.58**
$L_7 \times T_1$	6.63^{ns}	-6.93**	-18.95**
$L_7 \times T_2$	-3.87*	-18.18**	-24.32**
$L_7 \times T_3$	148.04**	109.82**	96.96**
CD (0.05)	0.311	0.359	0.359

** Significant at 1 per cent level
* Significant at 5 per cent level
ns Not significant

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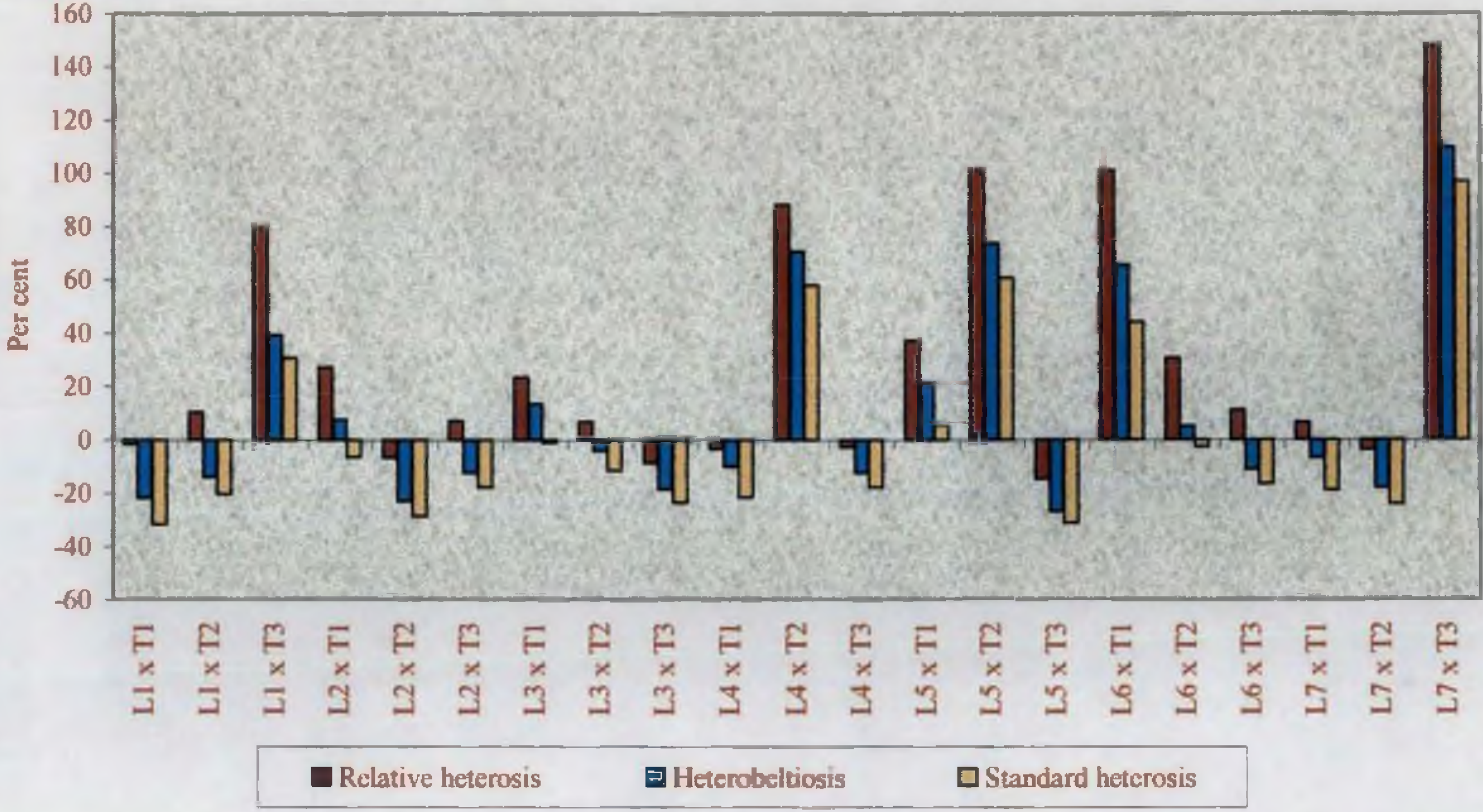

Fig. 24 Heterosis for dry fodder yield

4.6 Pollen Sterility

The pollen grains of lines, testers and hybrids were examined for pollen sterility and pollen diameter estimated.

The pollen grains of lines and testers were found to be fertile (Plate 6 and 7) while that of hybrids were sterile (Plate 8). Among lines, pollen sterility ranged from 2.60 per cent in DRSB-3 to 7.77 per cent in APFB-2 and pollen diameter ranged from 41.11 µm in Composite 9 to 46.36 µm in DRSB-3. Pollen sterility among testers ranged from 6.25 per cent in FD 471 to 7.34 per cent in FD 467. The pollen diameter ranged from 45.47 µm in FD 431 to 48.46 µm in FD 471 (Table 21).

However hundred per cent sterility was observed in all the 21 hybrids and the pollen diameter ranged from 30.00 µm in Composite 9 x FD 467 to 32.50 µm in TNSC-4 x FD 431 (Table 22).

Table 21 Pollen sterility (per cent) and pollen diameter (μm) in parents

Sl. No.	Parents	Pollen sterility, %	Pollen diameter, μm
1	L_1	7.77	42.50
2	L_2	5.38	41.11
3	L_3	2.60	46.36
4	L_4	7.76	43.04
5	L_5	3.57	44.32
6	L_6	6.13	42.00
7	L_7	5.76	42.93
8	T_1	7.16	45.47
9	T_2	7.34	46.76
10	T_3	6.25	48.46

Table 22 Pollen sterility (per cent) and pollen diameter (μm) in hybrids

Sl. No.	Parents	Pollen sterility, %	Pollen diameter, μm
1	L_1 x T_1	100.00	31.58
2	L_1 x T_2	100.00	31.27
3	L_1 x T_3	100.00	30.21
4	L_2 x T_1	100.00	30.78
5	L_2 x T_2	100.00	30.00
6	L_2 x T_3	100.00	31.68
7	L_3 x T_1	100.00	30.94
8	L_3 x T_2	100.00	32.23
9	L_3 x T_3	100.00	31.96
10	L_4 x T_1	100.00	32.17
11	L_4 x T_2	100.00	30.35
12	L_4 x T_3	100.00	30.57
13	L_5 x T_1	100.00	31.67
14	L_5 x T_2	100.00	30.74
15	L_5 x T_3	100.00	31.36
16	L_6 x T_1	100.00	30.90
17	L_6 x T_2	100.00	30.00
18	L_6 x T_3	100.00	31.30
19	L_7 x T_1	100.00	32.50
20	L_7 x T_2	100.00	31.10
21	L_7 x T_3	100.00	31.80

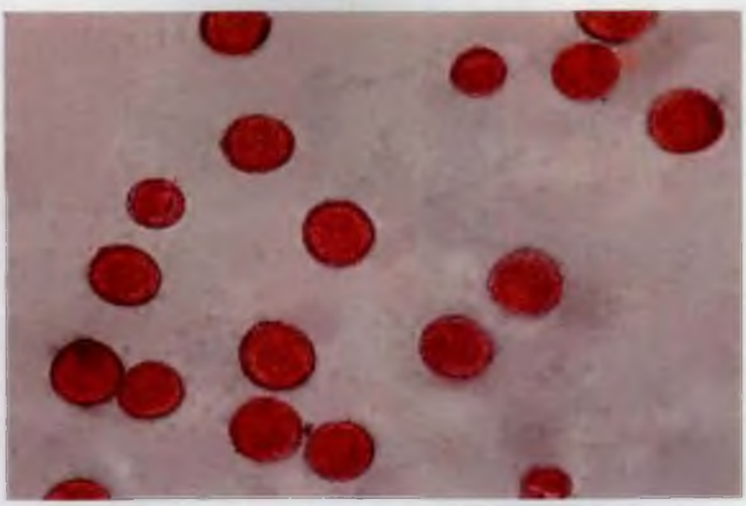

Plate 6 Pollen grains of bajra

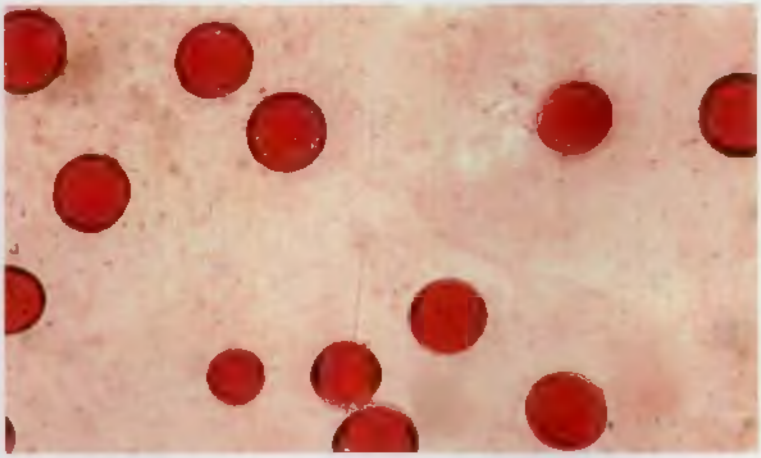

Plate 7 Pollen grains of napier grass

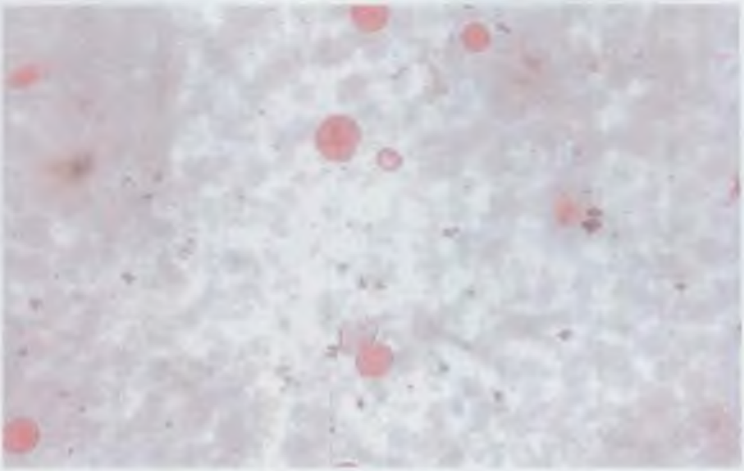

Plate 8 Pollen grains of bajra x napier hybrid

Discussion

5. DISCUSSION

Artificial hybridization has been in use in fodder breeding for breaking yield barriers and developing new varieties. Interspecific hybrids between pearl millet and napier grass have high yield potential and excellent forage quality. In view of this, the present work has been undertaken and the results and findings of the research are discussed in the ensuing pages.

5.1 MEAN PERFORMANCE

Among lines, DRSB-3 was found superior based on mean performance for tiller number per plant, leaf number per plant, leaf weight, leaf/stem ratio and green fodder yield. For plant height and stem girth, Composite 9 had the highest mean performance. Among the other lines, HES-4 was found superior for leaf/stem ratio, FD-1917 for dry fodder yield and APFB-2 for crude protein content. Line IP 15814 recorded the lowest crude fibre content and internode length. The line TNSC-4 did not show superiority for any of the characters.

Testers did not show much variation in mean performance for internode length, stem girth, leaf/stem ratio, crude protein and crude fibre content. FD 467 showed superiority over other testers for traits like plant height, leaf weight per plant and green fodder yield. Highest mean performance for tiller number, leaf number and dry fodder was recorded by FD 471. The lowest crude fibre content was for FD 431.

Among hybrids, mean performance for green fodder yield was high in TNSC-4 x FD 471 followed by HES-4 x FD 467. These hybrids also had high mean performance for tiller number per plant, leaf number per plant, leaf weight and dry fodder yield. One of the two parents of each of the two hybrids were by themselves high green fodder yielders. HES-4 x FD 467 was superior for leaf/stem ratio and crude protein content. The cross TNSC-4 x FD 431 had low crude fibre content. Least internode length was recorded by the cross FD 1917 x FD 431. Superiority for stem girth was shown by Composite 9 x FD 467 and TNSC-4 x FD 467. The highest mean performance for plant height was shown by DRSB-3 x FD 467.

In all the interspecific hybrids that showed high mean performance, one of the parents was a high yielder. This shows that parents with high mean performance would result in hybrids with high mean performance or heterotic effects.

5.2 HETEROSIS AND COMBINING ABILITY ANALYSIS

Analysis of variance revealed that all the treatment mean squares were significant for all the characters, suggesting that there were significant differences among the genotypes. The parents and crosses differed significantly for all the traits. So all the characters were subjected to line x tester analysis to estimate combining ability and gene action.

5.2.1 Plant Height

Analysis of variance for plant height showed that only line x tester mean square was significant. So only SCA variance was found to be significant for this character suggesting non-additive gene action. The importance of non-additive gene action for plant height was reported earlier by Mahadevappa (1968b), Gupta and Sidhu (1970), Gupta and Gupta (1971), Tyagi *et al.* (1974), Ramanujam and Verma (1976), Sidhu *et al.* (1980), Gupta and Choubey (1988), Ashwanikumar and Dahiya (1989) in pearl millet and Amirthadevarathinam (1995) and Sukanya (1997) in pearl millet x napier hybrids. On the other hand, the importance of additive gene action was reported by Jacob (1977) in pearl millet.

Among lines, DRSB-3, Composite 9 and HES-4 and among testers FD 467 had positively significant *gca* effect. The maximum positive *sca* effect was shown by the cross FD 1917 x FD 471. Parents with negative *gca* effects were involved in this cross. The minimum positively significant *sca* effect was shown by HES-4 x FD 471 which had parents with positive x negative *gca* effects. The other good hybrids for plant height were TNSC-4 x FD 431, IP 15814 x FD 471, APFB-2 x FD 467, DRSB-3 x FD 467 and Composite 9 x FD 467. The better combination for plant height, therefore involved parents with negative x negative, positive x negative, negative x positive and positive x positive effects.

Heterosis for all the good performing hybrids except FD 1917 x FD 471 and APFB-2 x FD 467 were positive and high with maximum standard heterosis for DRSB-3 x FD 467 followed by Composite 9 x FD 467. Ten out of 21 hybrids showed significant positive standard heterosis. Similar results were reported by Tewari (1970) and Raveendran and Appadurai (1984) in pearl millet and Thirumeni (1992) in pearl millet x napier hybrids.

5.2.2 Tiller Number per Plant

For tiller number per plant, line x tester interaction alone was found significant, suggesting the importance of *sca* effects for this trait. So the character tiller number per plant is controlled by non-additive gene action. This is in accordance with the findings of Gupta and Sidhu (1970), Tyagi *et al.* (1974), Jacob (1977), Gopalan and Sreerangasamy (1989), Ved Prakash and Sastry (1989) in pearl millet and Amirthadevarathinam (1995) and Sukanya (1997) in pearl millet x napier hybrids. Contrary to this, Mahadevappa (1968b), Ashwanikumar and Dahiya (1989, 1991) and Mani Phatadi (1992) reported the prevalence of additive gene action for this character. In pearl millet, Sidhu *et al.* (1980) found the importance of both additive and non-additive gene action for this character.

Lines, TNSC-4, IP 15814 and HES-4 were found to have positively significant *gca* effects for tiller number per plant. None of the testers showed positive significance for *gca* effects for this character. Eight out of 21 crosses were found to have significant *sca* effects. TNSC-4 x FD 471, which had parents with positive x positive effects showed the maximum *sca* effect. Among the rest, IP 15814 x FD 431 and HES-4 x FD 467 had high *sca* effect and were found to be on par. Apart from them, FD 1917 x FD 467, Composite 9 x FD 431, APFB-2 x FD 471, DRSB-3 x FD 431 and DRSB-3 x FD 467 also had significant *sca* effects. Out of these eight hybrids, three resulted from parents which were good x poor combiners and five of them had both the parents as poor combiners.

All those hybrids found superior based on *sca* effects had significant positive standard heterosis. The cross TNSC-4 x FD 471 had maximum standard heterosis followed by IP 15814 x FD 431. Out of the 21 hybrids, nineteen had significant positive relative heterosis and nine had significant positive heterobeltiosis. Similar results were reported by Veerasekaran and Rao (1971), Singh and Singh (1972), Hapase and Thete (1986), Mangath (1986) and Thete *et al.* (1986) in pearl millet and Thirumeni (1992) in pearl millet x napier hybrids.

5.2.3 Leaf Number per Plant

Significance of only SCA variance was observed for leaf number per plant since line x tester mean square alone was significant. This suggests the importance of non-additive gene action for the expression of the character. Prevalence of non-additive gene action for this character was reported earlier by Gupta and Gupta (1971), Tyagi *et al.* (1974), Ramanujam and Verma (1976), Jacob (1977), Gopalan and Sreerangasamy (1989) and Vedprakash and Sastry (1989) in pearl millet and Amirthadevarathinam (1995) and Sukanya (1997) in pearl millet x napier hybrids. Sidhu *et al.* (1980) reported the presence of both additive and non-additive gene action for leaf number per plant.

Among lines, TNSC-4, HES-4 and IP 15814 and among testers FD 471 and FD 467 were found to be good general combiners for leaf number per plant. Seven crosses had significant positive *sca* effects of which TNSC-4 x FD 471 showed maximum effect. Both the parents involved in the cross had positive *gca* effects. Of the remaining crosses with positive significant *sca* effects, HES-4 x FD 467 had parents with positive x positive effects, IP 15814 x FD 431 with positive x negative effects, FD 1917 x FD 467 and APFB-2 x FD 471 with negative x positive effects and Composite 9 x FD 431 and DRSB-3 x FD 431 with negative x negative effects.

Regarding heterosis, all those hybrids with significant positive *sca* effects, except DRSB-3 x FD 431 had positive and significant standard heterosis. TNSC-4 x FD 471 had the maximum standard heterosis for leaf number per plant followed by HES 4 x FD 467, IP 15814 x FD 431, FD 1917 x FD 467, APFB-2 x FD 471 and Composite 9 x FD 431. All the 21 hybrids showed significant positive relative heterosis while ten hybrids had positively significant values for heterobeltiosis.

Similar results were reported by Burton (1966), Kelkar (1966), Tewari (1970) and Singh (1970) in pearl millet and Thirumeni (1992) in pearl millet x napier hybrids.

5.2.4 Internode Length

For internode length, line x tester interaction alone was found to be significant. So only SCA variance was found to be significant for this trait. Also the ratio of σ^2_A to σ^2_D was less than unity indicating the importance on non-additive gene action. Similar results were earlier reported by Gupta and Sidhu (1970).

Lines APFB-2 and FD 1917 had negatively significant *gca* while all the three testers were insignificant for *gca* effects. The maximum negatively significant *sca* effect was shown by the cross IP 15814 x FD 431. Parents with positive *gca* effects were involved in the cross. The other good hybrids for reduced internode length were FD 1917 x FD 467, TNSC-4 x FD 471 and DRSB-3 x FD 471 which were found to be on par. They had parents with negative x negative and positive x negative combining ability effects.

Eight out of 21 hybrids had significant negative standard heterosis, the maximum negative value being shown by FD 1917 x FD 467 followed by APFB-2 x FD 431. FD 1917 x FD 467 showed the highest negative values for relative heterosis and heterobeltiosis also. All hybrids except IP 15814 x FD 467 and IP 15814 x FD 471 had negatively significant heterobeltiosis while only ten hybrids showed negatively significant relative heterosis. This was in confirmity with the results observed by Burton (1951) in pearl millet and Giriraj and Goud (1981), Kanaka (1982) and Dinakar (1985) in sorghum and Thirumeni (1992) in pearl millet x napier hybrids.

5.2.5 Stem Girth

Only line x tester interaction was found to be significant suggesting the importance of *sca* effects for this trait. This indicates predominance of non-additive gene action. The importance of non-additive gene action for stem girth was earlier reported by Gupta and Gupta (1971), Tyagi *et al.* (1974), Gupta and Choubey (1988) and Gopalan and Sreerangasamy (1989) in pearl millet and Amirthadevarathinam (1995) and Sukanya (1997) in pearl millet x napier hybrids. But the importance of additive gene action was reported by Jacob (1977). However, presence of both additive and non-additive gene action was reported for this character by Hooda *et al.* (1978) in pearl millet.

Among lines, only HES-4 had positively significant *gca* effects while all the testers had negative *gca* effects. Out of the 21 crosses eight had significant positive *sca* effects for stem girth. The maximum positively significant *sca* effect was recorded by DRSB-3 x FD 431 which had both the parents with negative *gca* effects. The minimum positively significant *sca* effect was shown by the cross FD 1917 x FD 471 of which both the parents were poor combiners. Apart from these, the crosses, FD 1917 x FD 431, IP 15814 x FD 471, APFB-2 x FD 467, TNSC-4 x FD 467, Composite 9 x FD 467 and TNSC-4 x FD 431 had significant positive *sca* effects which were found to be on par.

All those hybrids with significant positive *sca* effects had positive standard heterosis, the maximum being shown by TNSC-4 x FD 467 and Composite 9 x FD 467. None of the hybrids had positive significant relative heterosis or heterobeltiosis for stem girth. Burton (1951) in pearl millet and Bhagmal and Mishra (1985) in sorghum and Thirumeni (1992) in pearl millet x napier hybrids reported similar trends. However, in forage sorghum, it was observed by Choudhry *et al.* (1980) that hybrids were generally intermediate between both the parents.

5.2.6 Leaf Weight per Plant

Analysis of variance for leaf weight per plant showed that only line x tester mean square was significant. So only SCA variance was significant for this character, suggesting non-additive gene action. Predominance of non-additive gene action for leaf weight per plant was earlier reported by Gupta and Gupta (1971) and Ramanujam and Verma (1976). However, high general combining ability variance for leaf weight was reported by Gopalan and Sreerangasamy (1989).

Lines TNSC-4, HES-4, IP 15814 and FD 1917 were found to have positively significant *gca* effects for leaf weight per plant and among testers, FD 471 and FD 467 had positively significant *gca* effects. Seven out of 21 crosses had positively significant *sca* effects. The crosses TNSC-4 x FD 471 and HES-4 x FD 467 were found to be better crosses with parents of positive x positive effects. The other crosses which had positively significant *sca* effects were IP 15814 x FD 431, FD 1917 x FD 467, APFB-2 x FD 471, Composite 9 x FD 431 and DRSB-3 x FD 431. These crosses had their parents with positive x negative, positive x positive, negative x positive and negative x negative *gca* effects.

All the 21 crosses had significant and positive relative heterosis for this trait. Sixteen hybrids showed significant positive heterobeltiosis and six hybrids had significant positive standard heterosis. High relative heterosis, heterobeltiosis and standard heterosis was shown by the cross TNSC-4 x FD 471.

5.2.7 Leaf / Stem Ratio

The line x tester interaction alone showed significant variance suggesting the significance of SCA variance for leaf/stem ratio. So it can be concluded that the expression of this character is under the control of non-additive gene action. This is in agreement with the findings of Gupta and Sidhu (1970) in pearl millet and Amirthadevarathinam (1995) and Sukanya (1997) in pearl millet x napier hybrids.

Among lines, Composite 9, TNSC-4 and FD 1917 and among testers, FD 467 had significant positive *gca* effect. Out of 21 hybrids, only nine *sca* effects were found to be positively significant. The maximum *sca* effect was shown by the cross HES-4 x FD 467 i.e., between parents with negative x positive *gca* effects. The crosses, APFB-2 x FD 471, DRSB-3 x FD 471 and IP 15814 x FD 431 were found to be on par with HES-4 x FD 467. The minimum *sca* effect was shown by the crosses IP 15814 x FD 467 and TNSC-4 x FD 431. The remaining three crosses *viz.*, TNSC-4 x FD 471, FD 1917 x FD 467 and Composite 9 x FD 431 were found to be on par.

Relative heterosis and heterobeltiosis were found to be positive and significant for all the 21 hybrids, but only two hybrids *viz.*, HES-4 x FD 467 and FD 1917 x FD 467 showed significant positive standard heterosis. This was in confirmity with the results obtained by Jayamani (1991) in forage sorghum hybrids and Thirumeni (1992) in pearl millet x napier hybrids.

5.2.8 Crude Protein Content

For crude protein content, mean square was significant only for line x tester indicating the presence of non-additive gene action. The predominance of non-additive gene action was earlier reported by Hooda *et al.* (1978), Hooda and Solanki (1979) and Gopalan and Sreerangasamy (1989) in pearl millet while Gupta and Sidhu (1984) reported equal importance of both additive and non-additive components of genetic variance.

IP 15814 and HES-4 among lines and FD 467 among testers showed positively significant *gca* effects for crude protein content. Eight out of 21 hybrids had positively significant *sca* effects. The maximum positively significant *sca* effect was shown by the cross TNSC-4 x FD 471. The *gca* effect of one of the parents involved in the cross was insignificant while the other parent had negatively significant *gca* effect. Other crosses which were found to be better were Composite 9 x FD 431, HES-4 x FD 467 and IP 15814 x FD 431. The remaining crosses had low *sca* effects.

Only one hybrid, TNSC-4 x FD 471 showed significant positive relative heterosis. None of the hybrids showed significant positive values for heterobeltiosis and standard heterosis. Burton (1944), Hussain *et al.* (1968), Gupta (1974) and Thirumeni (1992) obtained similar results in pearl millet x napier grass hybrids.

5.2.9 Crude Fibre Content

Analysis of variance for crude fibre content showed significance only for line x tester mean squares. So only SCA variance was significant indicating the importance of non-additive gene action for the character. Predominance of non-additive gene action for crude fibre content was earlier reported by Suthamathi (1992) in pearl millet x napier hybrids.

Lines TNSC-4 and IP 15814 and tester FD 471 recorded significant negative *gca* effects. Seven *sca* effects were also negatively significant for the trait. The maximum negative *sca* effect was shown by Composite

9 x FD 467 which was evolved from parents with positive *gca* effects. This was followed by DRSB-3 x FD 471 and TNSC-4 x FD 431. The parents involved in these crosses had positive x negative and negative x positive *gca* effects.

Regarding heterotic effects, seventeen out of 21 hybrids showed significant negative relative heterosis and all the hybrids had negatively significant heterobeltiosis. Only one hybrid, TNSC-4 x FD 431 showed significant negative standard heterosis. Powell and Burton (1966) and Hussain *et al.* (1968) obtained similar results in pearl millet x napier hybrids.

5.2.10 Green Fodder Yield

For green fodder yield, line x tester mean square alone was found significant, suggesting the significance of only *sca* effect for this trait. So this character is under the control of non-additive gene action. This is in accordance with Gupta and Sidhu (1970), Gupta and Gupta (1971), Tyagi *et al.* (1974), Ramanujam and Verma (1976), Jacob (1977), Chawla and Gupta (1982), Gopalan and Sreerangasamy (1989), Ved Prakash and Sastry (1989), Ashwanikumar and Dahiya (1991) in pearl millet and Thirumeni (1992), Amirthadevarathinam (1995), and Sukanya (1997) in pearl millet x napier grass hybrids. However, significance of both additive and dominance components for green fodder yield was reported by Hooda *et al.* (1978) and Sidhu *et al.* (1980) in pearl millet.

Four lines and two testers were found to have positively significant *gca* effects for the trait. Among lines, TNSC-4 recorded the maximum positive *gca* effect followed by HES-4, IP 15814 and FD 1917. Among testers, FD 471 showed maximum positive *gca* effect followed by FD 467. Only eight hybrids showed positively significant *sca* effects. TNSC-4 x FD 471 showed the maximum *sca* effect followed by HES-4 x FD 467. The parents involved in both these crosses had positive x positive *gca* effects. The minimum positively significant *sca* effect was shown by

DRSB-3 x FD 467 which had parents with negative x positive effects. The other good hybrids for green fodder yield were IP 15814 x FD 431, FD 1917 x FD 467, APFB-2 x FD 467, Composite 9 x FD 431 and DRSB-3 x FD 431. The combination for good green fodder yield therefore involved parents with positive x negative, positive x positive, negative x positive and negative x negative effects.

The cross, TNSC-4 x FD 471 had the maximum significant positive values for all the three types of heterosis *viz.*, standard heterosis, relative heterosis and heterobeltiosis. This was followed by FD 1917 x FD 467. Only five out of 21 crosses had significant positive standard heterosis. Significant positive relative heterosis and heterobeltiosis was shown by fourteen and seven hybrids respectively. Similar results were observed earlier by Burton (1944), Khan and Rahman (1963), Hussain *et al.* (1968), Gupta (1974) and Muldoon and Pearson (1977) in pearl millet and Natarajaratnam and Chandrasekharan (1983) and Thirumeni (1992) in pearl millet x napier hybrids.

5.2.11 Dry Fodder Yield

Only line x tester mean square was found significant for dry fodder yield suggesting the significance of SCA variance alone. From this, it can be inferred that the expression of the character is under the influence of non-additive gene action. Prevalence of non-additive gene action was reported earlier by Ramanujam and Verma (1976), Dass *et al.* (1982) and Gopalan and Sreerangasamy (1989) while presence of both additive and non-additive gene action was reported by Hooda *et al.* (1978) and Ashwanikumar and Dahiya (1991).

Among lines, TNSC-4, HES-4, IP 15814 and FD 1917 and among testers FD 467 and FD 471 had significant positive *gca* effects for dry fodder yield. Among crosses, TNSC-4 x FD 471 had the maximum positive *sca* effect followed by FD 1917 x FD 467 and HES-4 x FD 467. Both parents involved in all the three crosses had positive x positive *gca* effects. Other good crosses were IP 15814 x FD 431, APFB-2 x FD 471, Composite 9 x FD 431 and DRSB-3 x FD 431 which had parents with positive x negative, negative x positive and negative x negative effects.

Highest significant positive standard heterosis for dry fodder yield was observed for TNSC 4 x FD 471 followed by HES-4 x FD 467. Only six out of 21 hybrids had significant positive standard heterosis. Significant positive relative heterosis and heterobeltiosis was exhibited by thirteen and nine hybrids respectively. Similar results were reported by Verma and Katiyar (1977) in pearl millet, Hanna and Monsoon (1980) and Thirumeni (1992) in pearl millet x napier hybrids.

From the combining ability analysis, four out of seven lines, *viz.*, HES-4, TNSC-4, FD 1917 and IP 15814 were found to have significant *gca* effects for green fodder yield. These general combiners for green fodder yield have proved to be good general combiners for certain other characters as well (Table 23). The line HES-4 is an outstanding general combiner for seven characters besides green fodder yield *viz.*, plant height, tiller number per plant, leaf number per plant, stem girth, leaf weight per plant, crude protein content and dry fodder yield, as the *gca* effects were significant for each of the above characters. TNSC-4 was another good general combiner for tiller number per plant, leaf number per plant, leaf weight per plant, leaf/stem ratio, crude fibre content and dry fodder yield besides green fodder yield. FD 1917 had significant *gca* effects for internode length, leaf weight per plant, leaf/stem ratio, green fodder yield and dry fodder yield. IP 15814 exhibited significant *gca* effects for tiller number per plant, leaf number per plant, crude fibre content, green fodder yield and dry fodder yield. Amnog the other lines, Composite 9 had significant *gca* effects for plant height and leaf/stem ratio while APFB-2 and DRSB-3 had significant *gca* effects for internode length and plant height respectively.

Table 23 Best lines and testers for various characters based on combining ability

Sl. No.	Characters	Best lines	Best testers
1	Plant height	DRSB-3, Composite 9, HES-4	FD 467
2	Tiller number per plant	TNSC-4, IP 15814, HES-4	-
3	Leaf number per plant	TNSC-4, HES-4, IP 15814	FD 471, FD 467
4	Internode length	APFB-2, FD 1917	-
5	Stem girth	HES-4	-
6	Leaf weight per plant	TNSC-4, HES-4, FD 1917	FD 471, FD 467
7	Leaf/stem ratio	Composite 9, TNSC-4, FD 1917	FD 467
8	Crude protein content	IP 15814, HES-4	FD 467
9	Crude fibre content	TNSC-4, IP 15814	FD 471
10	Green fodder yield	TNSC-4, HES-4, IP 15814, FD 1917	FD 471, FD 467
11	Dry fodder yield	TNSC-4, HES-4, IP 15814, FD 1917	FD 467, FD 471

Among the three testers, FD 467 and FD 471 had significant *gca* effects for green fodder yield. FD 467 proved to be an outstanding general combiner as it had significant *gca* effects for plant height, leaf number per plant, leaf weight per plant, leaf /stem ratio, crude protein content, green fodder yield and dry fodder yield. FD 471 exhibited significant *gca* effects for leaf number per plant, leaf weight per plant, crude fibre content, green fodder yield and dry fodder yield (Table 23).

Among the 21 hybrids evaluated, eight combinations had significant *sca* effects for green fodder yield. Most of the crosses exhibited significant *sca* effects for many characters simultaneously (Table 24). Three crosses, TNSC-4 x FD 471, HES-4 x FD 467 and Composite 9 x FD 431 had significant sca effects for tiller number per plant, leaf number per plant, internode length, leaf weight per plant, leaf/stem ratio, crude protein content, green fodder yield and dry fodder yield. Among the other combinations, IP 15814 x FD 431, had significant *sca* effects for ten characters, APFB-2 x FD 471 for eight characters and FD 1917 x FD 467 for seven characters. Also crosses DRSB-3 x FD 431 and DRSB-3 x FD 471 exhibited significant *sca* effects for green fodder yield. It was observed that many of the parents involved in the superior cross combinations were also good general combiners.

The best hybrids, based on mean performance, *sca* effects and standard heterosis for various characters are presented in Table 25.

Among the hybrids, TNSC-4 x FD 471 (Plate 9) recorded high mean performance *sca* effect and standard heterosis for tiller number per plant, leaf number per plant, leaf weight per plant, green fodder yield and dry fodder yield. The hybrid HES 4 x FD 467 (Plate 10), which was next to TNSC-4 x FD 471 in green fodder yield recorded high mean performance, *sca* effect and standard heterosis for leaf number per plant, leaf weight per plant, leaf/stem ratio, green fodder yield and dry fodder yield. The hybrids IP 15814 x FD 431 (Plate 11) and FD 1917 x FD 467 (Plate 12)

Table 24 Combination of parents for various characters based on specific combining ability effects

Lines \ Testers	FD 431	FD 467	FD 471
APFB-2	Internode length Crude protein content	Plant height Stem girth	Tiller number per plant Leaf number per plant Leaf weight per plant Leaf/stem ratio Crude protein content Crude fibre content Green fodder yield Dry fodder yield
Composite 9	Tiller number per plant Leaf number per plant Internode length Leaf weight per plant Leaf/stem ratio Crude protein content Green fodder yield Dry fodder yield	Plant height Stem girth Crude protein content Crude fibre content	-
DRSB-3	Tiller number per plant Leaf number per plant Stem girth Leaf weight per plant Green fodder yield Dry fodder yield	Plant height Tiller number per plant Green fodder yield	Internode length Leaf/stem ratio Crude fibre content
FD 1917	Plant height Stem girth	Tiller number per plant Leaf number per plant Internode length Leaf weight per plant Leaf/stem ratio Green fodder yield Dry fodder yield	Plant height Stem girth Crude protein content Crude fibre content

Table 24 Continued

Testers / Lines	FD 431	FD 467	FD 471
HES-4	Plant height Crude fibre content	Tiller number per plant Leaf number per plant Internode length Leaf weight per plant Leaf/stem ratio Crude protein content Green fodder yield Dry fodder yield	Plant height
IP 15814	Tiller number per plant Leaf number per plant Internode length Stem girth Leaf weight per plant Leaf/stem ratio Crude protein content Crude fibre content Green fodder yield Dry fodder yield	Leaf/stem ratio	Plant height
TNSC-4	Plant height Stem girth Leaf/stem ratio Crude fibre content	Plant height Stem girth	Tiller number per plant Leaf number per plant Internode length Leaf weight per plant Leaf/stem ratio Crude protein content Green fodder yield Dry fodder yield

Table 25 Promising hybrids based on mean performance, *sca* effects and standard heterosis

Characters	Mean performance	*sca* effects	Standard heterosis
Plant height	DRSB –3 X FD 467 Composite 9 x FD 467	FD 1917 x FD 471 TNSC-4 x FD 431	DRSB-3 x FD 467 Composite 9 x FD 467
Tiller number per plant	TNSC-4 x FD 471 IP 15814 x FD 431	TNSC-4 x FD 471 IP 15814 x FD 431	TNSC-4 x FD 471 IP 15814 x FD 431
Leaf number per plant	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467
Internode length	FD 1917 x FD 467 APFB-2 x FD 431	IP 15814 x FD 467 FD 1917 x FD 467	FD 1917 x FD 467 APFB-2 x FD 431
Stem girth	Composite 9 x FD 467 TNSC-4 x FD 467	DRSB-3 x FD 431 FD 1917 x FD 431	Composite 9 x FD 467 TNSC-4 x FD 467
Leaf weight per plant	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467
Leaf/stem ratio	HES-4 x FD 467 FD 1917 x FD 467	HES-4 x FD 467 DRSB-3 x FD 431	HES-4 x FD 467 FD 1917 x FD 467
Crude protein content	HES-4 x FD 467 IP 15814 x FD 431	TNSC-4 x FD 471 Composite 9 x FD 431	-
Crude fibre content	TNSC-4 x FD 431 DRSB-3 x FD 471	Composite 9 x FD 467 DRSB-3 x FD 471	TNSC-4 x FD 431 -
Green fodder yield	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467
Dry fodder yield	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467	TNSC-4 x FD 471 HES-4 x FD 467

Plate 9 TNSC-4 x FD 471

Plate 10 HES-4 x FD 467

Plate 11 IP 15814 x FD 431

Plate 12 FD 1917 x FD 467

registered high mean performance, *sca* effects and standard heterosis for tiller number per plant and reduced internode length respectively.

The other hybrids that recorded high cumulative green fodder yield either did not record high performance for most of the yield components or did not have high *sca* effect for most of the characters studied. Thus among the 21 hybrids evaluated, TNSC-4 x FD 471 and HES4 x FD467 were found to be superior based on mean performance, *sca* effects and standard heterosis. Hence, these hybrids can be advanced for further trials to develop high yielding bajra-napier hybrids.

Summary

6. SUMMARY

The present study on 'Heterosis and gene action in bajra-napier hybrids' was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2001-2002 with the objective of developing bajra-napier hybrids, combining the desirable economic traits and quality attributes of bajra and high yielding character and perenniality of napier grass.

Hybridization was done between seven accessions of bajra (*Pennisetum americanum*) as lines and three accessions of napier grass (*Pennisetum purpureum*) as testers adopting line x tester mating design. The 21 hybrids along with their parents were evaluated for mean performance, combining ability, heterosis and gene action based on eleven characters *viz*., plant height, tiller number per plant, leaf number per plant, internode length, stem girth, leaf weight per plant, leaf/stem ratio, crude protein content, crude fibre content, green fodder yield and dry fodder yield.

Analysis of variance showed significant differences among treatments for all the eleven characters. Also, the parents and crosses differed significantly for all characters indicating high variability among parents and hybrids for these characters.

Studies on combining ability showed higher magnitude of SCA variance for all characters indicating the predominance of non-additive gene action in controlling all the traits.

Based on *gca* effects, the lines HES-4, TNSC-4, IP 15814 and FD 1917 were found to be good general combiners for green fodder yield and other related characters. Among these, HES-4 and TNSC-4 had high *gca* effects along with good mean performance for green fodder yield and its

component traits like tiller number per plant, leaf number per plant, leaf weight per plant and leaf/stem ratio.

Among testers, FD 467 and FD 471 were found to be the best general combiner based on mean performance and *gca* effects. FD 467 had good mean performance and combining ability for seven traits *viz.*, plant height, leaf weight per plant, leaf number per plant, leaf/stem ratio, crude protein content, green fodder yield and dry fodder yield and FD 471 for leaf weight per plant, leaf number per plant, green fodder yield and dry fodder yield.

Among hybrids, TNSC-4 x FD 471, HES-4 x FD 467, IP 15814 x FD 431 and FD 1917 x FD 467 were found to be good specific combiners for green fodder yield and related characters.

Based on mean performance, *sca* effects and standard heterosis, TNSC-4 x FD 471 was found superior for tiller number per plant, leaf number per plant, leaf weight per plant, green fodder yield and dry fodder yield. Also HES-4 x FD 467 was found superior for leaf number per plant, leaf/stem ratio, leaf weight per plant, green fodder yield and dry fodder yield. Hence TNSC-4 x FD 471 and HES-4 x FD 467 can be advanced for further trials to develop bajra-napier hybrids with good quality and high fodder yield.

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HETEROSIS AND GENE ACTION IN BAJRA-NAPIER HYBRIDS

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8. ABSTRACT

A study on 'Heterosis and gene action in bajra-napier hybrids' was carried out with the objective of developing bajra-napier hybrids with high yield potential and good quality. The study was undertaken during the year 2001-2002 in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani.

Seven lines of bajra, *viz.*, APFB-2, Composite 9, DRSB-3, FD 1917, HES-4, IP 15814 and TNSC-4 and three testers of napier grass, FD 431, FD 467 and FD 471 were crossed in a line x tester mating design to obtain 21 cross combinations. The hybrids were evaluated along with their parents for mean performance, combining ability, heterosis and gene action for eleven yield and yield related characters. Significant differences among treatments were observed for all the characters. Also significant differences among parents and crosses were observed for these characters and their general and specific combining ability variances and effects were studied. The magnitude of SCA variances alone was significant suggesting the predominance of non-additive gene action in controlling these traits.

Based on mean performance and *gca* effects, HES-4 was identified as the best general combiner among lines followed by TNSC-4. Among testers, FD 467 can be selected as the best male parent followed by FD 471. The crosses, TNSC-4 x FD 471 and HES-4 x FD 467 were the promising combinations for green fodder yield and its component traits, based on mean performance, *sca* effects and standard heterosis. Hence these crosses can be exploited for developing high yielding hybrids.