GENETIC ANALYSIS OF YIELD AND QUALITY ATTRIBUTES IN FODDER COWPEA [*Vigna unguiculata* (L.) Walp]

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By

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THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF
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VELLAYANI, THIRUVANANTHAPURAM 695 522

2003

Dedicated

to

My Parents

DECLARATION

I hereby declare that this thesis entitled **"Genetic analysis of yield and quality attributes in fodder cowpea [*Vigna unguiculata* (L.) Walp]"** 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.

Vellayani
4-8-2003

Radhika

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CERTIFICATE

Certified that the thesis entitled "**Genetic analysis of yield and quality attributes in fodder cowpea [*Vigna unguiculata* (L.) Walp]**" is a record of research work done independently by **Mrs. Radhika. V.S** (99-21-08) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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RADHIKA. V.S.

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LIST OF ABBREVIATIONS

%	per cent
σ^2A	Additive variance
σ^2D	Dominance variance
µg	Micro gram
^0C	Degree Celsius
ANOVA	Analysis of variance
CD	Critical difference
cm	Centimetre(s)
CV	Coefficient of variation
et al.	And others
F_1	First filial generation
Fig.	Figure
g	Gram(s)
GA	Genetic advance
GCA	General combining ability variance
gca	General combining ability effect
GCV	Genotypic coefficient of variation
h^2	Heritability
KAU	Kerala Agricultural University
L x T	Line x Tester
NS	Non significant
PCV	Phenotypic coefficient of variation
SCA	Specific combining ability variance
sca	Specific combining ability effect
SE	Standard error
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. 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 to 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. 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.

Among the fodder crops, legume fodders are valued for their nutritive quality, especially because of their high crude protein and calcium contents in addition to the green fodder yield. Among these cowpea (*Vigna unguiculata* (L.) Walp) is an important forage legume grown in many regions of India in the summer and rainy seasons. Cowpea as fodder, is sown in mixture with maize, sorghum and pearlmillet or grown as a sole crop.

It is a highly self pollinated annual legume. For formulation of a breeding programme, the knowledge with regard to heterosis, combining ability and gene action is very much needed.

Since the success in any breeding programme mainly depends on the genetic variability available it is essential to assess the genetic variability for important economic characters in the materials available with the breeder. The hertability estimates of different economic traits are of immense value in variety improvement programme. Genetic advance is a measure to evaluate the expected progress under a selection programme. A knowledge on the nature and magnitude of correlation between seed yield and its component traits and also among the component traits pave way for effective selection. In the present study fifty one accessions of diverse origin were taken up for study and assessed for fourteen different characters. A thorough understanding of the gene action involved in yield and components of yield is essential for selecting the parents. Line X Tester analysis has been used to find out the general combining ability and specific combining ability effects for different yield attributes and also the gene action involved. In the present investigation 7 lines and 3 testers identified as superior through selection index were crossed the F_1 hybrids with their parents were evaluated for sixteen fodder attributes. Investigations on the magnitude of heterosis will also help to identify promising hybrid combination for exploitation. The F_2 generation was raised whose mean and variance were also studied.

Keeping in view the above facts, the present study was undertaken with the following objectives.

- To find out the genetic variability in relation to green fodder and dry matter production.
- To study the association between green fodder yield and dry matter yield with other components by estimating genotypic, phenotypic and environmental correlation coefficients.
- To identify promising parents from the germplasm by selection index method.
- To study the type of gene action involved in the inheritance of different characters.
- To study the magnitude of heterosis and combining ability of parents and crosses for fodder yield and other related characters.
- To study the mean and variance of the F_2 generation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cowpea is an old world crop of ancient origin. It is an excellent fodder crop of short duration, high palatability and high protein content. Studies have shown that the crop possesses rich genetic diversity, which provides ample scope for breeding. In this section an attempt has been made to review the up-to-date literature under the following headings.

2.1 Variability studies

2.2 Heritability and genetic advance

2.3 Correlation

2.4 Combining ability and gene action

2.5 Heterosis

2.1 VARIABILITY STUDIES

Das *et al.* (1978) conducted genetic variability and correlation studies in 36 strains of fodder clusterbean and reported that number of branches per plant had highest heritability followed by plant height and dry fodder yield. They also reported that dry fodder yield as well as number of branches had a positive and significant correlation with number of clusters per plant.

Variability studies in 50 diverse genotypes of cowpea conducted by Kumar and Mishra (1981) revealed that for green forage yield, dry matter yield and seed yield environmental coefficient of variation exceeded genotypic variances.

Shanmugam and Balasubramanian (1983) conducted studies on character association in forage clusterbean and reported that the characters leaf weight and stem weight showed high positive association with both green fodder yield and dry matter yield.

Significant differences for plant weight, height, leaf and branch number and dry matter production of 18 cultivars of cowpea grown for forage were reported by Pal (1988).

Genetic variability and correlation in cowpea was studied by Sharma *et al.* (1988) and the maximum genotypic coefficient of variation among 35 genotypes was seen for dry matter yield, plant height, green forage yield and pods per plant. Green forage yield was positively and significantly correlated with days to 50 per cent maturity, days to first flowering, plant height, pods per plant and seeds per pod.

Jindal (1989) studied path coefficient analysis in fodder cowpea and reported that all the characters viz. green fodder yield, leaf weight, stem weight, number of branches, plant height, leaf number and stem girth were positively and significantly correlated among themselves. High significant phenotypic and genotypic variances for plant height and maturity followed by green fodder yield and terminal leaflet area in fodder cowpea was reported by Roquib and Patnaik (1990).

Genetic variability and correlation studies were conducted in fodder lablab by Ushakumari and Chandrasekharan (1991) and reported that green fodder yield had positive and significant genotypic correlation with plant height, dry weight of leaf and stem and dry matter production. They also reported that genetic advance as percentage of mean was maximum for dry matter production. Siddique and Gupta (1991) worked out estimates of variability in cowpea and reported high genotypic and phenotypic coefficient of variation for pods per plant and plant height. In rice bean, Baisakh (1992) reported wide variation in the means of different genotypes for branches per plant, plant height, pod clusters per plant, pods per plant, pod length, yield per plant and days to 50 per cent flowering. Considerable variation for green fodder yield and nutrient composition was reported by Thaware *et al.* (1992) in 30 varieties of fodder cowpea.

Aravindhan and Das (1995) based on correlation and path analysis using 59 genotypes of fodder cowpea reported that fodder yield was significantly and positively correlated with leaf area index, specific leaf yield, number of branches per plant, dry matter yield, leaf/stem ratio and crude protein content.

In fodder cowpea, Aravindhan and Das (1996) studied heterosis and combining ability for fodder and seed yield and reported the predominant effect of sca over gca indicating predominance of non-additive gene action.

Backiyarani and Natarajan (1996) studied the variability on ten yield related characters in thirty four genotypes of cowpea and observed high PCV and GCV for leaf area index. Hazra *et al.* (1996) observed significant variation in the characters, number of primary branches per plant and days to flowering.

Correlation for fodder yield in cowpea was done by Srinivasan and Das (1996) and suggested that a desirable plant type for higher forage yield would be late flowering with a tall plant stature and more number of larger leaves with high protein content.

Vasanthi and Das (1996 a) based on correlation and path analysis studies in 36 hybrid combinations of fodder lablab reported that dry weight of leaf and dry weight of stem were the selection criteria for green fodder yield.

Vasanthi and Das (1996 b) utilized 9 lines and 4 testers to carry a line x tester analysis and their 36 hybrids were evaluated for crude protein, phosphorus and potassium content.

Kumar *et al.* (1997) reported significant variability for all the 9 characters studied in ricebean and high heritability along with high genetic advance for plant height in all locations indicating the predominance of additive gene effects.

In fababean, eleven genotypes were studied by Khabiruddin *et al.* (1998) for various qualitative and quantitative characters at vegetative and maturity stages suggesting that the genotypes HB 207 and BSH-9 were best for quality characters like protein, phosphorus and sugar. High estimates of PCV and GCV were observed for number of branches, number of leaves, dry weight of leaves, dry weight of stem, dry matter yield and green fodder yield by Borah and Fazlullahkhan (2000) in fodder cowpea. Based on variability studies in fodder cowpea, Manonmani *et al.* (2000) reported that green fodder yield recorded the highest PCV and GCV.

2.2 HERITABILITY AND GENETIC ADVANCE

Heritability serves as an useful statistical tool and has been widely exploited in estimating expected progress in determining the degree to which a character may be transmitted from parent to offspring and also helps in indicating the relative importance of heredity and environment on character variation. The characters which exhibit a wide range of expression may be controlled by many genes whose action may be additive and/or geometric. Selection for such characters on a purely phenotypic basis without estimating the magnitude of heritable portion of it will result in a failure.

Heritability in a broad sense concerns the functioning of the genotype as a whole. This would include additive, dominance and epistatic effect of all genes concerned and their interactions with the environment. The heritability in narrow sense is defined as that fraction of the observed variance which is caused by additive genetic variance. Estimation of heritability along with genetic gain is usually more useful in predicting the resultant effect through selection of the best individual (Johnson *et al.*, 1955).

Singh and Mehndiratta (1969) estimated a high heritability for days to flowering in cowpea. But Trehan *et al.* (1970) reported low heritability for the same character. High estimates of heritability and genetic advance were observed for vine length, pod number per plant and plant height in cowpea (Sohoo *et al.*, 1971).

Kohli *et al.* (1971) estimated high heritability and genetic advance for number of leaves per plant and green weight per plant in cowpea. Fifty types of cowpea were studied by Angadi (1976) and reported high broad sense heritability estimates for branches and plant height. High heritability and genetic advance for plant height, number of branches, number of leaves per plant and dry matter production per plant in guar was reported by Solanki *et al.* (1975).

Manoharan (1978) also observed high heritability estimate for number of branches per plant while it was low for dry matter production in fodder cowpea. High heritability and genetic advance for yield per plant and number of days to flowering in lablab was recorded by Singh *et al.* (1979). Kodeeswaran (1980) estimated high heritability for number of leaves, green fodder yield and dry matter production in forage lablab.

Broad sense heritability estimates for dry matter, green forage and seed yields in fodder cowpea was found to be 21.3, 34.6 and 27.2 per cent respectively (Kumar and Mishra, 1981). High heritability was reported for green forage and dry matter yield in cowpea by Singh (1982).

Yadav and Krishna (1985) reported comparatively high estimates of heritability and genetic advance for green fodder yield, leaf number and plant height in lablab bean indicating that mass selection could effectively be used in improving them.

High estimates of broadsense heritability and expected genetic advance, for 100 seed weight and seeds per pod in 50 genotypes of fodder type cowpea was reported by Apte *et al.* (1987).

Roquib and Patnaik (1990) reported high estimates of heritability in broad sense and genetic advance for plant height at maturity, lateral leaflet area and days to 50 per cent flowering in fodder cowpea.

Siddique and Gupta (1991) reported high heritability and genetic advance for plant height in cowpea.

In cowpea high values of heritability and genetic advance for green forage yield, leaf yield, stem yield and leaves per plant was observed by Thaware *et al.*(1991).

Sharma and Singhania (1992) observed high heritability for days to 50 per cent flowering, leaf area, plant height, green fodder yield per plant and dry matter and crude protein contents in cowpea. A range of heritability estimates from 50.2 for branches per plant to 77.9 per cent for stem weight in forage cowpea was obtained by Thaware *et al.* (1992).

Ushakumari and Chandrasekharan (1992) reported that genetic advance as percentage of mean was maximum for dry matter production in fodder lablab.

According to Das and Roquib (1993a) days to 50 per cent flowering, days to forage harvest, green forage yield per plant, dry matter yield per plant, dry leaf weight per plant and plant height showed high values of heritability estimates accompanied by high to moderate values of genetic advance in rice bean.

Rewale *et al.* (1995) studied variability and heritability in seventy diverse genotypes of cowpea on twelve yield related traits and found that the heritability and genetic advance was high for plant height.

Kumar *et al.* (1997) reported significant variability for all the nine characters studied in ricebean and high heritability along with high genetic advance for plant height in all locations indicating the predominance of additive gene effects. Ram and Singh (1997) reported high heritability for days to 50 per cent flowering, days to maturity, plant height and branches per plant in a variability study with thirty four cowpea genotypes. High heritability and genetic advance was observed for number of branches, number of leaves, dry weight of stem and leaves, dry matter yield, green fodder yield and plant height. High heritability with low genetic advance was observed for days to 50 per cent flowering, crude protein content, stem thickness, leaflet length and width (Borah and Fazlullahkhan, 2000).

Kumar and Sangwan (2000) conducted variability studies in cowpea using seventy two genotypes for nine yield related characters and found moderate to high heritability and high genetic advance for plant height and number of branches per plant. Manonmani *et al.* (2000) studied ten diverse genotypes of fodder cowpea and reported that genetic advance was high for green fodder yield and heritability was high for days to 50 per cent flowering.

2.3 CORRELATION

Review of studies made by several workers on correlations between various characters in fodder cowpea and in other legume fodder crops are presented here.

Dangi and Paroda (1974) studied the correlations of different characters in forage cowpea and reported that leaves per plant, leaflet length, leaflet breadth, branches per plant and stem girth were positively correlated to both green fodder yield and dry matter yield. They also reported that green fodder yield was negatively correlated with days to flowering and plant height in highly fertile environment. But in rainfed and low fertility conditions, the characters like leaflet length, leaflet breadth and number of branches showed negative correlation with fodder yield. The associations of leaves per plant with branches and number of branches with stem girth were significant and positive in both the environments. They also reported that stem girth showed positive and significant correlation with length and breadth of central leaflets in both the environments.

Both plant height and number of leaves were positively correlated with dry matter yield in forage cowpea (Katoch and Singh, 1974). Solanki *et al.* (1975) reported that plant height, number of leaves and number of branches in guar had high positive association with green and dry matter yield.

Chopra and Singh (1977) reported that dry matter yield was strongly and positively correlated with plant height, the number of leaves per plant and fresh fodder yield per plant in cowpea. According to Tyagi *et al.* (1978) for fodder yield in cowpea the leaf number, plant height, branch length, stem girth, protein content and digestibility were the potential selection criteria.

Manoharan (1978) studied correlations among different fodder yield components in cowpea and concluded that plant height, number of branches and number of leaves showed positive significant association with both green and dry matter yield at both genotypic and phenotypic levels.

In guar, Shanmugam (1979) reported that plant height, number of branches per plant, leaf weight and stem weight showed significant positive association with dry matter yield.

Kodeeswaran (1980) reported that plant height and number of branches were positively correlated with green and dry fodder yield in forage lablab. Kumar and Mishra (1981) reported highly significant positive correlation between drymatter yield and green forage yield in cowpea. Jain *et al.* (1981) reported that the characters vine length, number of leaves, leaf weight and stem weight were positively correlated with green and dry matter yield per plant in cowpea.

In cowpea correlations of different characters with fodder yield was reported by Singh (1982). According to Yadav and Krishna (1985) plant height, branch length, leaf number and stem thickness were strongly correlated with green and dry matter yield in lablab bean. Highly significant positive correlation between dry matter yield and green fodder yield in two environments indicated positive relationship with these traits.

Significant positive correlation of green forage yield with days to 50 per cent maturity, days to first flowering and plant height in cowpea was reported by Sharma *et al.* (1988).

Jatasra and Dahiya (1988) reported that forage yield in cowpea was significantly and positively correlated with leaf weight, stem weight, plant height and branch number. Biradar *et al.* (1991) also reported similar results in cowpea. Dry matter yield had positive relationship with crude protein content, as observed by Pal (1988) in cowpea. Roquib and Patnaik (1989) observed the positive association between green fodder yield, leaf area index and leaf stem ratio in cowpea. According to Akundabweni *et al.* (1990) there was positive correlation between days to flowering and green fodder yield in cowpea. Significant positive relationship between green fodder yield and plant height, specific leaf weight and number of branches were reported by Thaware *et al.* (1992) in forage cowpea.

Ushakumari and Chandrasekharan (1992) reported that green fodder yield had positive and significant genotypic correlation with plant height and dry weight of leaf, dry weight of stem and dry matter production in fodder lablab.

In cluster bean, the green fodder yield and dry matter yield were significantly and positively correlated with stem weight, leaf weight, leaves per plant, plant height and with each other (Singh *et al.*, 1991).

Deshmukh *et al.* (1993) reported that number of leaves per plant, length of vine and leaf area per plant were positively associated with dry forage yield at both genotypic and phenotypic levels in forage cowpea.

Highly significant positive correlation of green forage yield and dry matter yield with plant height, number of branches per plant, days to 50 per cent flowering, days to forage harvest, leaf/stem ratio and dry leaf weight per plant at genotypic and phenotypic level in rice bean was reported by Das and Roquib (1993b).

Tamilselvam and Das (1994) reported positive correlation of plant height with days to 50 per cent flowering and number of clusters per plant in cowpea.

Aravindhan and Das (1995) reported significant positive correlation of green fodder yield with leaf area index, specific leaf weight, number of branches, dry matter yield, leaf/stem ratio and crude protein content in cowpea.

Ponmariammal and Das (1996) conducted correlation studies using 36 cowpea cultivars and reported significant and positive correlation of green fodder yield with days to flowering, plant height, number of leaves, number of branches and leaf/stem ratio. Correlation and path analysis for fodder yield in cowpea was done by Srinivasan and Das (1996) and suggested that a desirable plant type for higher forage yield would be late flowering with a tall plant stature and more number of larger leaves with high protein content. In fodder cowpea, Manonmani *et al.* (2000) reported positive correlation of green fodder yield with number of branches per plant, leaf length and leaf weight.

2.4 COMBINING ABILITY AND GENE ACTION

Combining ability analysis helps the plant breeder in identifying and selecting potential parents in terms of the performance of the hybrids to be used either for heterosis breeding or for selecting recombinant inbreds by following line selection and progeny testing.

The terms general and specific combining ability were coined by Sprague and Tatum (1942) as a measure of gene action. The procedures usually employed for estimation of the gca and sca are diallel analysis and line x tester analysis. The recent studies on combining ability and gene action in cowpea and other fodder legumes are presented below.

In a 7 x 7 diallel cross in ricebean, Das and Dana (1978) reported that the general and specific combining ability estimates were significant for leaf/stem ratio, green matter and dry matter yield in rice bean. They reported the importance of non additive effects for leaf/stem ratio, green matter and dry matter yield.

From a combining ability analysis of a 8 x 8 diallel set of cowpea for green fodder and dry matter yield, Jatasra (1979)-reported that both additive and non additive type of gene effects were involved in the inheritance of these attributes. The GCA : SCA ratios further indicated preponderance of additive gene action for green fodder yield, whereas non additive type of gene action was more important for dry matter yield. They suggested the use of per se performance instead of sca effects for selecting best specific combinations.

Studies of Jain *et al.* (1980) in forage cowpea hybrids over two environments revealed that estimates of SCA, GCA and their ratios indicated predominantly non-additive type of gene action for both protein and *in vitro* dry matter digestibility (IVDMD) in both the environments. Jatasra (1980) found that among the different yield components of cowpea, grain weight was the most important. The GCA:SCA ratio indicated predominance of additive genetic variance.

The combining ability analysis for fodder yield and related characters in cowpea was carried out in a diallel of 10 lines (Jain *et al.*, 1981). Additive genetic variance was predominant for days to 50 per cent flowering, branches per plant and stem girth whereas non-additive genetic variance was more important for vine length, leaf length, leaf breadth and number of leaves per plant. According to Zaveri *et al.* (1983), both GCA and SCA variances were significant for seed yield and cluster number in cowpea.

Singh *et al.* (1985) performed line X tester analysis with 15 lines and 3 testers in cowpea for 15 morpho agronomical characters and reported that four lines showed significant gca effects for several characters. Twenty eight out of a total 45 F_1s were associated with significant sca effects for one or more characters.

Patil and Shete (1986) emphasized the importance of additive and non-additive genetic variances in the inheritance of the quantitative characters in cowpea. They suggested that parents with high gca effects could be used in component breeding programme, thereby seeking improvement in yield through that component. The sca which represents the predominance of non-additive genetic variance, could not be exploited for improvement in self pollinated crops like cowpea. If crosses with high sca effects involve both the parents having good gca, they could possibly be exploited in practical cowpea breeding programmes. Patil and Bhapkar (1986) reported the predominance of additive effects for days to flowering and days to maturity in cowpea. In the same crop, Singh and Dabas (1986) observed the importance of both additive and non additive effects for all the characters studied..Non-additive effects played a major role for yield and days to maturity.

Mishra *et al.* (1987) observed that both GCA and SCA were important for days to 50 per cent flowering and seed yield in a L x T analysis involving 10 lines and four testers in cowpea.

In a line x tester analysis in forage cowpea, Jhorar and Jatasra (1990) revealed that both additive and non additive gene effects governed the inheritance of green fodder yield, plant height, number of leaves, leaf weight and stem weight. The number of branches was controlled by non additive gene effects.

In cowpea Singh and Dabas (1992) reported significant effects of both additive and non-additive components in the genetic behaviour of days to maturity and grain yield.

Thiyagarajan *et al.* (1990) in a six parent diallel cross in cowpea, the combining ability studies revealed that both the additive and non additive gene effects were important for plant height, branches per plant, clusters and pods per plant and grain yield. As non additive effects were preponderant for most of the characters, biparental mating system was suggested for the improvement of the crop. In fodder lablab, Ushakumari and Chandrasekharan (1992) performed genetic analysis of fodder yield and yield attributes with a 6 x 6 diallel cross and revealed the predominance of dominance genetic component for plant height, total leaf area, dry weight of stem and green fodder yield. Dominant alleles were more frequent than recessive alleles in the parents for plant height, total leaf area, number of leaves, green fodder yield, dry matter production and crude protein content. To exploit both the additive and non additive genetic components in lablab for fodder, the use of biparental mating in early generation among selected crosses was suggested.

The combining ability analysis with ten parents, 45 F_1s and 45 F_2s in pea revealed the importance of both GCA and SCA variances in the F_1 and F_2, though additive gene effects were predominant for the traits studied. Parents with the best *per se* performance were also the best general combiners (Singh *et al.*, 1994b). Combining ability in cowpea for seed yield and 11 yield related traits were studied from a 10 x 10 diallel cross by Sawant (1995) and reported that both GCA and SCA variances were highly significant. Non additive gene effects predominated, except for pod length and 100 seed weight. Golsangi *et al.* (1995) reported the importance of additive component of variance for most of the yield related characters studied in cowpea.

Aravindhan and Das (1996) utilized 42 crosses of cowpea derived from 14 lines and 3 testers for combining ability studies for green fodder yield and other yield components. The sca effects were predominant for all the characters studied which in turn indicated the predominance of non-additive genetic control on all the traits.

Vasanthi and Das (1996 b) utilized 9 lines and 4 testers to carry a line x tester analysis and their 36 hybrids were evaluated for crude protein, phosphorus and potassium content.

2.5 HETEROSIS

Heterosis, conventionally, refers to the increased or decreased vigour of F_1 over its mid parent value. According to Mackey (1976), heterosis is classified as positive or negative, luxuriant, adaptive, selective or reproductive and labile or fixed. The commercial utilization of heterobeltiosis by developing hybrids to increase economic returns is called exploitation of heterosis in crops.

Hybrid vigour can play a great role in boosting yield and improving quality in fodder crops. For developing good hybrids, information regarding the hybrid vigour of the parents and crosses are essential.

Significant heterosis and inbreeding depression in cowpea have been reported for yield and most of the yield components. Singh and Jain (1972) reported from a study of diallel cross that heterosis in yield was influenced by heterosis in pod length in cowpea. Kheradnam *et al.* (1975) reported heterosis for pods per plant.

Premsekar and Raman (1972) found heterosis for length and width of leaf and branch length and earliness in cowpea. Baskaraiah *et al.* (1980) reported hybrid vigour in cowpea.

Chaudhary and Lodhi (1981) from a study involving fifteen F_1s and six parents in cluster bean reported the presence of considerable amount of hybrid vigour over better parent and best check for green fodder yield, dry matter yield, primary branch number, leaf number and leaf weight. The range of heterosis for green fodder yield and dry matter yield was from

8.23 to 86.05 per cent and from 4.18 to 67.09 per cent over best check, respectively.

Venkateswaralu and Singh (1982) from a 10 x 10 diallel cross observed significant heterosis for all yield traits except height in peas. Zaveri *et al.* (1983) reported that heterosis for seed yield could be attributed to heterosis for number of clusters in cowpea.

Ushakumari (1985) in lablab bean observed very high heterosis for green fodder yield in two cross combinations over mid parental value.

Maximum positive heterosis over midparent was observed by Patil and Shete (1987) in cowpea for clusters per plant (158 per cent) followed by seed yield per plant (131 per cent), pods per plant (128 per cent), 100 seed weight (38 per cent) and seed size (34 per cent).

From a study involving sixty three cowpea genotypes, Singh *et al.* (1986) reported the presence of significant desirable heterosis for fifteen characters. Highest degree of heterosis was observed for leaves per plant followed by dry and fresh stem weight and dry and fresh fodder yield. The characters central leaflet length and breath, days to 50 per cent flowering, *in vitro* dry matter digestibility (IVDMD) and protein content were associated with very low heterotic effects. Heterotic vigour for plant height in cowpea was reported by Mylswami (1988).

Lodhi *et al.* (1990) reported that heterosis over the standard parent for green fodder yield per plant ranged from –39.65 to 68.53 per cent in one environment and from –43.82 to 181.48 per cent in another environment in cowpea. For dry matter yield the range was from –51.1 to 132.98 per cent in one environment and from –51.37 to 79.70 per cent in the other environment. High heterosis for protein content was also noted.

Kohli (1990) in cowpea observed maximum, average, mid and better parent heterosis for green fodder yield, dry matter yield and leaf area index. Similar results were also reported by Sohoo *et al.* (1990) and Sanghi and Kandalkar (1991) for the same characters in cowpea.

Singh *et al.* (1994a) showed the presence of positive heterosis for seed yield ranging from 38.6 to 88.0 per cent over the superior parents in peas.

Sawant *et al.* (1994) reported maximum positive heterosis over mid parent for seed yield per plant (140.5 per cent), followed by inflorescences per plant (139.3 per cent), pods per plant (132.5 per cent), branches per plant (85.6 per cent) and plant height (73.4 per cent) in cowpea. A similar trend over better parent was observed except for branches per plant and plant height.

Singh *et al.* (1994b) recorded maximum better parent heterosis of 228 per cent and economic heterosis of 68 per cent for seed yield in a study involving five exotic and seven indigenous pea cultivars. Vasanthi and Das (1995) showed the presence of positive heterosis over better parent for dry weight of leaf, the values ranging from –65.76 to 70.65 per cent in 15 crosses of lablab. Significant positive heterosis was also reported for dry weight of stem and dry matter yield, the values ranging from –61.31 to 57.34 per cent. For crude protein content negative heterosis was predominant.

From a study involving forty two crosses of cowpea derived from 14 lines and 3 testers Aravindhan and Das (1996) recorded maximum, average, mid and better parent heterosis for green fodder yield, dry matter yield and leaf area index (64.09 per cent, 64.08 per cent and 63.34 per cent respectively). Average heterosis for leaf stem ratio over better and standard parents were negative (-11.41 per cent and –16.53 per cent respectively).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1999-2002. In the present study, 51 accessions of fodder cowpea were screened for yield and quality characters using selection index method. Effects of heterosis, gene action and combining ability were estimated through a 7 x 3 Line x Tester cross involving 10 parents. The twenty one combinations were carried forward to the F_2 generation along with the parents to assess the potential of different crosses.

3.1 EXPERIMENT I : GENETIC EVALUATION OF FODDER COWPEA ACCESSIONS

3.1.1 Materials

The basic material for the study consisted of 51 diverse accessions of fodder cowpea collected from different agroclimatic zones.

The details of the materials are presented in Table 3.1.

3.1.2 Method

The fifty one accessions were raised in a randomised block design with two replications during kharif 2000 in the field attached to the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, in plots of size 3 m x 1.5 m at a spacing of 30 cm x 15 cm. The cultural and manurial practices were done as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2002).

3.1.2.1 Observations

Observations were recorded on ten randomly selected plants from each plot.

1. Plant Height (cm)

The height of the plant was measured in centimeters using a meter scale from the base of the plant to the tip of the stem and the mean plant height was estimated.

Table 3.1 Cowpea accessions studied

Sl. No.	Accessions	Source/origin
1.	IFC 9402	IGFRI, Jhansi
2.	EC 241044	NBPGR, New Delhi
3.	IFC 9501	IGFRI, Jhansi
4.	IFC 9304	IC, UP
5.	IFC 9503	IGFRI, Jhansi
6.	UPC 951	Pantnagar, UP
7.	UPC 33 4	Pantnagar, UP
8.	EC 240806	NBPGR, New Delhi
9.	EC 240	NBPGR, New Delhi
10.	N 271	IGFRI, Jhansi
11.	Bundel Lobia	IGFRI, Jhansi
12.	CL 88	Ludhiana, Punjab
13.	EC 240768	NBPGR, New Delhi
14.	EC 240687	NBPGR, New Delhi
15.	UPC 9103	Pantnagar, UP
16.	UPC 94 2	Pantnagar, UP
17.	Co5	Coimbatore, TN
18.	UPC 952	Pantnagar, UP
19.	UP 9001	Pantnagar, UP
20.	IFC 8401	IGFRI, Jhansi
21.	EC 4216	NBPGR, New Delhi
22.	EC 240764 1	NBPGR, New Delhi
23.	IFC 24094	IGFRI, Jhansi
24.	CS 91	Hissar, Haryana
25.	UP 219	Pantnagar, UP
26.	IFC 9201	IGFRI, Jhansi

Table 3.1 Continued

27.	UPC 94 1	Pantnagar, UP
28.	CSRFE 8903	Pantnagar, UP
29.	IC 44696	NBPGR, New Delhi
30.	CL 334	Ludhiana, Punjab
31.	EC 241053	NBPGR, New Delhi
32.	CL 341	Ludhiana, Punjab
33.	EC 241024	NBPGR, New Delhi
34.	UPC 9202	Pantnagar, UP
35.	UPC 5286	Pantnagar, UP
36.	EC 244021	NBPGR, New Delhi
37.	CL 321 1	Ludhiana, Punjab
38.	EC 241027	NBPGR, New Delhi
39.	UPC 287	Pantnagar, UP
40.	UPC 951 B	Pantnagar, UP
41.	IFC 95102	IGRI, Jhansi
42.	EC 240744	NBPGR, New Delhi
43.	EC 24041	NBPGR, New Delhi
44.	HES 82	NBPGR, New Delhi
45.	Cl 350	Ludhiana, Punjab
46.	EC 240764 2	NBPGR, New Delhi
47.	UPC 953	Pantnagar, UP
48.	N 311	IGFRI, Jhansi
49.	EC 244024	NBPGR, New Delhi
50.	EC 240215	NBPGR, New Delhi
51.	EC 24768	NBPGR, New Delhi

2. Number of Primary Branches per Plant

The number of primary branches in each plant was counted and the mean recorded.

3. Number of Leaves per Plant

Total number of leaves from each sample plant was counted and mean recorded.

4. Total Leaf Area (cm^2)

The total leaf area of sample plants was measured using LI 300 Leaf area meter at 50 per cent flowering and expressed in cm^2.

5. Days to 50 per cent Flowering

The number of days from the date of sowing to the date of flowering of 50 per cent of the population in each plot was counted.

6. Days to Maturity

The total number of days from germination to harvest was recorded.

7. Leaf / Stem Ratio

The sample plants collected for recording dry matter yield were separated into leaf and stem, dried, weighed and the ratio between the dry weight of leaf and dry weight of stem was calculated.

8. Leaf Area Index

Leaf area was measured using LI 300 Leaf area meter.

LAI was worked out using the following equation

$$LAI = \frac{\text{Total leaf area}}{\text{Land area occupied}} \quad \text{(Watson, 1962)}$$

9. Dry Weight of Leaf (g)

The leaves were dried at 60°C for 24 hours in hot air oven and the dry weight of the leaves was recorded in g.

10. Dry Weight of Stem (g)

Weight of stem dried in hot air oven was recorded in gram.

11. Green Fodder Yield (t ha^{-1})

The green fodder yield per plot was recorded at harvest and estimated in t ha^{-1}.

12. Dry Matter Yield (t ha^{-1})

At harvest random sample was taken from each plot, weighted, dried to a constant weight and dry matter percentage was computed. Based on this estimate the total dry matter yield was computed and expressed in t ha^{-1}.

13. Crude Protein Content (%)

The nitrogen content of the plant samples was estimated following the modified Microkjeldahl method (Jackson, 1973). The crude protein content was calculated by multiplying the nitrogen content by the factor 6.25.

14. Crude Fibre Content (%)

Dried plant samples collected at the time of harvest was utilized for the estimation of crude fibre content by acid and alkali digestion method (Kanwar and Chopra, 1976).

15. Acceptability to Animals

A weighted quantity of green fodder was fed to the animals by mixing with hay in 3:1 proportion.

16. Incidence of Mosaic and Leaf Spot

Mild incidence was noticed.

17. Incidence of Aphids and Pod Borer

Mild incidence was noticed.

3.1.2.2 Statistical Analysis

Biometrical Technique Applied

Mean, variance, standard error and coefficient of variation were the basic parameters estimated. The significance of the genotypic difference were tested through analysis of variance technique. The character associations were estimated through correlation coefficient using analysis of covariance technique. Heritability coefficient (%) and genetic advance as percentage of mean were estimated. The methodology for estimation of the parameters are given below. With two characters X and Y measured on 'g' genotypes raised in completely randomised design with 'r' replications, the variance – covariance analysis (ANACOVA) is as follows.

Analysis of variance / covariance

Source	df	Mean square		
		X	Y	XY
Between genotypes	(g – 1)	Gxx	Gyy	Gxy
Error	(r – 1) (g – 1)	Exx	Eyy	Exy

Estimates of components of variance and covariance

Variate	Genotype	Environment	Phenotype
X	$\sigma^2 gx = \frac{Gxx - Exx}{r}$	$\sigma^2 ex = Exx$	$\sigma^2 px = \sigma^2 gx + \sigma^2 ex$
Y	$\sigma^2 gy = \frac{Gyy - Eyy}{r}$	$\sigma^2 ey = Eyy$	$\sigma^2 py = \sigma^2 gy + \sigma^2 ey$
XY	$\sigma gxy = \frac{Gxy - Exy}{r}$	$\sigma exy = Exy$	$\sigma pxy = \sigma gxy + \sigma exy$

Plate.1. Field view -Experiment-1

Coefficient of Variation

Phenotypic and genotypic coefficients of variations (PCV and GCV) for a trait x were estimated as:

$$GCV = \frac{\sigma_{gx}}{\bar{X}} \times 100$$

$$PCV = \frac{\sigma_{px}}{\bar{X}} \times 100$$

Where,

σ_{gx} = Genotypic standard deviation

σ_{px} = Phenotypic standard deviation

$\bar{X}$ = Mean of the character under study

Heritability Coefficient and Genetic Advance

Heritability (H^2) in broad sense was estimated as the proportion of heritable component of variation.

$$\text{Heritability coefficient } H^2 = \frac{\sigma_{gx^2}}{\sigma_{px^2}} \times 100$$

$$\text{Genetic advance as percentage of mean (GA)} = \frac{kH^2\sigma_{px}}{\bar{X}} \times 100$$

Where k is the selection differential = 2.06 if five per cent selection is to be practiced (Miller et al., 1958).

Estimation of Components of Variance

Correlation analysis

The correlation coefficients (phenotypic, genotypic and environmental) were worked out as:

$$\text{Genotypic correlation } (r_{gxy}) = \frac{\sigma_{gxy}}{\sigma_{gx} \times \sigma_{gy}}$$

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{\sigma_{pxy}}{\sigma_{px} \times \sigma_{py}}$$

$$\text{Environmental correlation } (r_{exy}) = \frac{\sigma_{exy}}{\sigma_{ex} \times \sigma_{ey}}$$

Discriminant function analysis

The discriminant function based on a number of variables was used for the formulation of selection indices to discriminate 51 genotypes. The genetic worth of the plant is defined by Smith (1936) as

$$H = a_1 G_1 + a_2 G_2 + \text{........} + a_n G_n$$

where G_1, G_2, ..., G_n are the genotypic values with respect to -- characters of the individual genotypes and a_1, a_2, ..., a_n. the economic weight assigned to each. As G-values are not measurable, another function I, which describes the phenotypic performance of an individual based on 'n' characters x_1, x_2 ...., x_n is defined as

$$I = b_1 x_1 + b_2 x_2 + \text{........} + b_n x_n.$$

where b_1, b_2........, b_n are the corresponding coefficients. The 'b' coefficients are calculated such that the correlation between H and I is maximum and the selection of genotypes using I gives maximum gain.

The genetic advance that can be expected at a selection intensity of 5 per cent was calculated as follows:

$$GA = \frac{i\, \underline{a}'\, \underset{\sim}{G}\, \underline{b}}{\sqrt{\underline{b}'\, \underset{\sim}{P}\, \underline{b}}}$$

Where,

$\underline{a}'$ is the vector of weights attached to each character,

$\underline{b}'$ is the vector of b-coefficients in the discriminant function,

$\underset{\sim}{G}$ is the genotypic variance - covariance matrix,

$\underset{\sim}{P}$ is the phenotypic variance - covariance matrix, and

i is the selection differential at a given selection intensity, which at five per cent is 2.06

3.2 EXPERIMENT II. a : HYBRIDIZATION BETWEEN LINES AND TESTERS

3.2.1 Materials

On the basis of yield and yield attributes seven top ranking female parents were selected as lines and on quality attributes alone three male parents, which are divergent from the selected lines were used as testers.

3.2.2 Methods

The seven lines and three testers were crossed and hybrid seeds of 21 cross combinations were collected. The lines, testers and their hybrids are presented in the Table 3.2.

Emasculation and Crossing

The emasculation and crossing in cowpea were executed following the procedure described by Singh *et al.* (1991).

As the dehiscence of anthers is much in advance of the blooming, the emasculation was carried out in the preceding evening. For emasculation flower buds likely to bloom on the next day were selected. They were recognized by their larger size and yellowish colour of the back of the standard petal.

Table 3.2 List of parents and hybrids

Sl. No.	Treatments	Name of variety / cross
1	L_1	IFC 95102
2	L_2	IFC 8401
3	L_3	UP 9001
4	L_4	EC 4216
5	L_5	EC 240744
6	L_6	EC 241027
7	L_7	HES 82
8	T_1	EC 241044
9	T_2	N 311
10	T_3	UPC 953
11	$L_1 x T_1$	IFC 95102 x EC 241044
12	$L_1 x T_2$	IFC 95102 x N 311
13	$L_1 x T_3$	IFC 95102 x UPC 953
14	$L_2 x T_1$	IFC 8401 x EC 241044
15	$L_2 x T_2$	IFC 8401 x N 311
16	$L_2 x T_3$	IFC 8401 x UPC 953
17	$L_3 x T_1$	UP 9001 x EC 241044
18	$L_3 x T_2$	UP 9001 x N 311
19	$L_3 x T_3$	UP 9001 x UPC 953
20	$L_4 x T_1$	EC 4216 x EC 241044
21	$L_4 x T_2$	EC 4216 x N 311
22	$L_4 x T_3$	EC 4216 x UPC 953
23	$L_5 x T_1$	EC 240744 x EC 241044
24	$L_5 x T_2$	EC 240744 x N 311
25	$L_5 x T_3$	EC 240744 x UPX 953
26	$L_6 x T_1$	EC 241027 x EC 241044
27	$L_6 x T_2$	EC 241027 x N 311
28	$L_6 x T_3$	EC 241027 x UPC 953
29	$L_7 x T_1$	HES 82 x EC 241044
30	$L_7 x T_2$	HES 82 x N 311
31	$L_7 x T_3$	HES 82 x UPC 953

For emasculation the bud was held between the thumb and the forefinger with the keeled side in the upper position, then a needle was run along the ridge where the two edges of the standard unites. The wings were separated, the keel was cut open and all the anthers were taken out carefully. From the inflorescence axis all the other buds except the emasculated one were removed, which was then covered with a butter paper bag. Pollination was done on the next morning from a protected freshly opened flower. The standard and wings were removed and by slightly depressing the keel, the stigma covered with pollen protrudes out which itself was used as a brush to transfer the pollen. After pollination, the flower was covered with a butter paper bag and tagged with a label. The bag was removed after 3-4 days. At maturity the crossed pods were collected in paper bags individually and stored.

3.3 EXPERIMENT II. B. EVALUATION OF HYBRIDS AND PARENTS

3.3.1 Materials

The lines, testers and their hybrids were raised in a randomized block design with 2 replications during Kharif 2001. The spacing was 30 cm x 15 cm in plots of size 3 m x 1.5 m. The 21 hybrids and their 10 parents were allowed for natural self pollination.

3.3.2 Methods

The recommended agronomic practices and need based plant protection measures were followed in accordance with the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2002).

3.3.2.1 *Observations*

Ten sample plants were selected randomly from each plot and the following observations recorded.

a. Plant height (cm)

b. Number of primary branches per plant

c. Number of leaves per plant

d. Total leaf area (cm^2)

e. Days to 50 per cent flowering

f. Days to maturity

g. Leaf/stem ratio

h. Leaf area index

i. Dry weight of leaf (g)

j. Dry weight of stem (g)

k. Green fodder yield (t ha^{-1})

l. Dry matter yield (t ha^{-1})

m. Crude protein content (%)

n. Crude fibre content (%)

o. Calcium content (%)

The calcium content was determined by using atomic absorption spectrophotometer (Piper, 1966).

p. Phosphorus content (%)

The phosphorus content was determined by Vanado-Molybdo-Phosphoric yellow colour method using spectrophotometer (Jackson, 1973).

q. *In vitro* dry matter digestibility

IVDMD was estimated for the hybrids which showed significant positive heterosis. The *in vitro* dry matter digestibility was determined by using the procedure given by Tilley and Terry (1963)

$$\% \text{ IVDMD} = \frac{\text{weight of sample} - \text{weight of residue}}{\text{Weight of sample}}$$

3.4.2.2 Statistical Analysis

The data collected from the parents and hybrids were initially subjected to analysis of variance for each character. The characters which were genotypically different were further subjected to Line x Tester analysis to estimate the additive and dominance components of heritable variation. The following analyses were done.

1. Combining Ability Analysis

- General combining ability
- Specific combining ability

ANOVA for Line x Tester

	Source	Df	SS	MS	Expected Mean square
	Replication	(r-l)			
	Genotypes	(g-l)			
(a)	Parents	(l+t)-l			
(i)	Females	(l-l)			
(ii)	Males	(t-l)			
(iii)	Females Vs. Males	1			
(b)	Hybrids	lt-l	SSH		
(i)	Lines	(l-l)	SSL	ML	$\sigma^2_e + r\sigma^2_{sca} + rt\sigma^2_{gca\,(l)}$
(ii)	Testers	(t-l)	SST	MT	$\sigma^2_e + r\sigma^2_{sca} + rl\sigma^2_{gca(t)}$
(iii)	Lines x Testers	(l-l) (t-l)	SSLT	MLT	$\sigma^2_e + r\sigma^2_{sca}$
(c)	Parents Vs. Hybrids	1			
	Error	(r-l) (g-l)		Me	σ^2_e

For a L x T mating design with l lines and t testers the ANOVA model is as follows:

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

Where μ = general mean effect

g_i = gca effect of i^{th} female parent (line)

g_j = gca effect of male parent (tester)

s_{ij} = sca effect of i^{th} line and j^{th} tester cross combination

r_k = j^{th} replication effect $k = 1, 2 ......,r$

e_{ijk} = environment effect peculiar to $(cjk)^{th}$ individual character measured

Y_{ijk} = the character measured on i x j cross in k^{th} replication

(Arunachalam, 1974)

(ii) Combining ability analysis

The gca effects of lines, testers and sca effects of hybrids are estimated as follows.

$$g_i = \frac{y_{i..}}{rt} - \frac{y_{...}}{rlt}, \; i = 1, 2 ...., 1$$

$$g_j = \frac{y_{j..}}{rl} - \frac{y_{...}}{rlt}, \; j = 1, 2 ......, \; t$$

$$S_{ij} = \frac{y_{ij}}{r} - \frac{y_i}{rt} - \frac{y_j}{rl} + \frac{y_{...}}{rlt}$$

Where,

$y_{i..}$ = sum of the observation with respect to crosses involving i^{th} line as one parent with all the testers over replication

$y_{j..}$ = sum of the observation with respect to crosses involving j^{th} tester as one parent with all the lines over replication

y_{ij} = sum of the observations with respect to i x j^{th} cross over the replication

$y_{...}$ = grand total of all the observations

The significance of gca effects of lines, testes and differences between two lines and two testers, sca effects of crosses and differences between sea effect of two crosses are tested using 't' test as given below.

Effect	Test criteria 't'	SE
gca		
g_i (lines)	$1\ g_i 1 / SE\ (g_i)$	$(Me / rt)^{1/2}$
g_j (testers)	$1\ g_j 1 / SE\ (g_j)$	$(Me / rl)^{1/2}$
g_i-g_j (lines)	$1\ g_i - g_j\ 1 / SE\ (g_i\text{-}g_j)$	$[(2Me) / rt]^{1/2}$
g_i-g_j (tester)	$1\ g_i\text{-}g_j\ 1 / SE\ (g_i\text{-}g_j)$	$[(2Me) / rl]^{1/2}$
sca		
S_{ij}	$1\ S_{ij} 1 / SE\ (S_{ij})$	$(Me/r)^{1/2}$
S_{ij}-S_{il}	$1\ S_{ij} - S_{kl}\ 1 / SE\ (S_{ji}\text{-}S_{il})$	$[(2Me) / r]^{1/2}$

(iii) Estimation of genetic components of variance

GCA variance $$\sigma^2_{gca} = \left(\frac{1+F}{4}\right)^2 \sigma_A^2$$

SCA variance $$\sigma^2_{sca} = \left(\frac{1+F}{2}\right)^2 \sigma_D^2$$

when F = 1

$\sigma_A^2 = \sigma_{gca}^2$

$\sigma_D^2 = \sigma_{sca}^2$

when F = 0

$\sigma_A^2 = 4\sigma_{gca}^2$

$\sigma_D^2 = 4\sigma_{sca}^2$

where F = coefficient of inbreeding

σ^2_A = additive genetic variance

σ^2_D = dominance genetic variance

2. Heterosis

Relative heterosis, heterobeltiosis and standard heterosis

The mean value over the two replications of each parent and hybrid for each character were taken for the estimation of heterosis. Heterosis was calculated as the percent deviation of the mean performance of F_1's from its midparent (MP) and standard parent (SP) for each cross combination.

1. Deviation of the hybrid mean from the mid parent value.

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

2. Deviation of the hybrid mean from the standard parental value.

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

For each character, the average value of the two parents involved in each cross combination was taken as the mid parental value (MP). The variety L_7 was taken as standard parent (SP).

The critical difference (CD) of F_1 mean over mid parent was calculated as follows :

The mean difference between a hybrid and mid parent

$$CD\ (0.05) = t_\alpha \times \sqrt{\frac{3MSE}{2r}}$$

For the mean difference between a hybrid and its standard parent

$$CD\ (0.05) = t_\alpha \times \sqrt{\frac{2MSE}{r}}$$

where t_α = critical value of t corresponding to the error d.f. at 5 % level of significance

MSE = Error mean square

r = No: of replications

3.4. EXPERIMENT III EVALUATION OF F_2 PROGENY

3.4.1 Materials

The selfed seeds of the 21 hybrids were planted along with their parents.

3.4.2 Methods

The plants were left to self pollinate and the potential of different crosses (hybrids) in the F_2 generation was studied by working out the mean and variance.

3.4.2.1 Observations

Data were recorded from all the 100 individual plants planted.

1. Leaf stem ratio
2. Dry weight of stem (g)
3. Dry weight of leaf (g)
4. Green fodder yield (t ha^{-1})
5. Dry matter yield (t ha^{-1})
6. Crude protein content (%)
7. Crude fibre content (%)
8. Acceptability to animals

For these observations data were recorded from all the 100 individual plants planted. The mean and variance were worked out.

RESULTS

4. RESULTS

The results of the present investigation on "Genetic analysis of yield and quality attributes in fodder cowpea" are presented under three major experiments.

1. Experiment I : Genetic evaluation of fodder cowpea accessions
2. Experiment II : Line x Tester analysis
3. Experiment III : Evaluation of F_2 progeny

4.1 EXPERIMENT I

Fifty one accessions of fodder cowpea were evaluated in a replicated field trial during Kharif 2000. The accessions were replicated twice in plots of size 3 m x 1.5 m with a spacing of 30 cm x 15 cm. The data were subjected to statistical analysis and the results are presented in the following subheads.

4.1.1 Estimation of mean and variability components

4.1.2 Estimation of heritability and genetic advance

4.1.3 Correlation between different characters

4.1.4 Discriminant function analysis

4.1.1 Estimation of Mean and Variability Components

Analysis of variance revealed significant genotypic differences for all characters (Table 4.1.1a) and the mean performance of the accessions along with the CD values are presented in Tables 4.1.1 b.

4.1.1.1 Plant Height

The average height of plant was 87.37 cm with a range of 62.6 cm exhibited by the accession EC 24041 to 106.6 cm recorded by the accession IFC 95102.

Table 4.1.1a Analysis of variance of 14 characters

Sl. No.	Characters	Mean square	
		Genotypes DF = 50	Error DF = 50
1	Plant height, cm	279.35**	29.62
2	Number of primary branches	0.40**	0.13
3	Number of leaves per plant	125.97**	8.06
4	Total leaf area, cm^2	26.24**	2.67
5	Days to 50 per cent flowering	36.28**	4.40
6	Days to maturity	0.067**	0.08
7	Leaf/stem ratio	12.86**	0.36
8	Leaf area index	101.87**	0.511
9	Dry weight of leaf, g	182.64**	2.68
10	Dry weight of stem, g	9.35**	0.30
11	Green fodder yield, t ha^{-1}	21.14**	0.13
12	Dry matter yield, t ha^{-1}	11.04**	0.11
13	Crude protein content, %	980130.60**	56437.76
14	Crude fibre content, %	4.94**	0.09

** Significant at 1 per cent level

4.1.1.2 Number of Primary Branches per Plant

The average number of primary branches per plant was 4.4. The lowest number of primary branches was recorded by the accessions EC 240806 and UPC 287 (3.6) and the highest by EC 240768, Co–5, UP 9001, EC 4216 and IFC 95102 (5.1).

4.1.1.3 Number of Leaves per Plant

The number of leaves per plant had an average of 31.0 with a range from 15.8 to 50.0. The minimum number of leaves per plant was exhibited by the accession N 271 (15.8) and the maximum was recorded by IFC 95102 (50.0).

4.1.1.4 Total Leaf Area

The total leaf area on an average was 2894.1 cm^2. The leaf area ranged from 1114.6 cm^2 (accession N 271) to 3895.9 cm^2 (EC 4216).

4.1.1.5 Days to 50 per cent Flowering

The number of days to 50 per cent flowering had an average of 53.0. The days to 50 per cent flowering ranged from 46.7 (UPC 94–1) to 59.9 (UPC 952).

4.1.1.6 Days to Maturity

The average number of days to maturity was observed to be 68.6 with a range of 61.7 to 75.3. The lowest number of days to maturity was expressed by the accession IFC 95102 (61.7) and the highest by UPC 9202 (75.3).

4.1.1.7 Leaf / Stem Ratio

The leaf / stem ratio had an average of 0.76. The range was from 0.4 exhibited by the accession EC 240744 and IFC 24094 to 1.2 by IFC 95102.

Table 4.1.1b Mean value of fourteen characters

Sl. No.	Accessions	Plant height, cm	Number of primary branches per plant	Number of leaves per plant	Total leaf area cm^2	Days to 50 per cent flowering	Days to maturity	Leaf / stem ratio
1	IFC 9402	89.8	4.9	20.8	2024.5	51.6	66.6	1.0
2	FC 241044	99.7	4.3	26.6	3260.6	51.7	66.8	0.9
3	IFC 9501	97.3	4.2	31.3	2843.9	53.9	71.9	0.7
4	IFC 9304	94.6	4.1	28.2	3344.5	51.0	65.5	0.8
5	IFC 9503	85.9	3.7	37.4	3735.2	49.7	64.7	0.9
6	UPC 951	87.2	4.0	38.4	3387.8	56.6	72.7	1.0
7	UPC 33–4	91.4	4.1	37.2	3416.5	52.6	70.1	0.9
8	EC 240806	74.5	3.6	25.9	1615.9	58.5	72.5	0.9
9	EC 240	100.2	4.5	34.5	2434.5	50.2	65.4	0.8
10	N 271	74.4	3.8	15.8	1114.6	51.0	66.0	0.8
11	Bundel Lobia	101.6	4.9	25.3	2270.8	58.2	73.2	0.9
12	CL–88	73.3	5.0	26.2	2385.8	53.8	71.3	0.9
13	EC 240768	64.6	5.1	22.2	2435.1	54.7	71.8	0.7
14	EC 240687	73.6	4.1	25.3	2226.0	53.9	67.8	0.7
15	UPC 9103	76.2	4.2	31.3	3223.7	51.2	65.4	1.0
16	UPC 94–2	89.0	4.1	22.1	2357.3	56.0	71.3	0.8
17	Co–5	91.8	5.1	23.0	1550.7	58.9	74.2	0.7
18	UPC 952	88.2	4.4	19.7	2190.1	59.9	74.4	0.6
19	IFC 9001	101.3	5.1	41.9	3837.2	48.4	62.7	1.0
20	IFC 8401	101.4	4.8	40.7	3891.6	49.0	63.1	1.1
21	EC 4216	101.9	5.1	39.6	3895.9	50.6	63.9	0.6
22	EC 240764–1	87.5	4.6	23.2	2715.2	50.0	64.9	0.7
23	IFC 24094	91.8	4.5	19.6	1758.6	56.7	72.3	0.4
24	CS 91	88.2	3.7	21.7	1793.9	58.0	73.8	0.7
25	UP 219	80.6	4.0	37.4	3369.4	49.1	63.8	0.8
26	IFC 9201	79.0	4.3	38.0	3506.8	53.1	65.3	0.8
27	UPC 94–1	85.9	4.6	41.9	3309.4	46.7	67.2	0.8
28	CSFRE 8903	74.8	3.7	28.8	2965.6	56.6	73.9	0.7
29	IC 44696	87.3	4.1	21.7	2638.8	53.0	67.8	1.0
30	Cl 334	94.0	4.9	27.4	2373.2	51.4	65.0	0.8

Table 4.1.1b Continued

Sl. No.	Accessions	Plant height, cm	Number of primary branches per plant	Number of leaves per plant	Total leaf area cm^2	Days to 50 per cent flowering	Days to maturity	Leaf / stem ratio
31	EC 241053	75.6	4.8	32.0	2537.9	51.8	65.2	0.5
32	Cl 341	66.9	4.5	37.2	3053.8	50.0	67.0	0.6
33	EC 241024	66.7	4.6	37.4	2855.4	51.3	73.4	0.7
34	UPC 9202	63.5	4.3	25.5	3806.5	59.5	75.3	0.7
35	UPC 5286	86.9	3.8	33.9	3193.6	58.7	79.1	0.7
36	EC 244021	99.7	4.6	34.9	3004.3	57.6	71.2	0.5
37	CL 321–1	103.9	4.3	42.5	3252.9	50.8	64.9	0.8
38	EC 241027	99.0	4.1	37.1	3742.4	48.8	64.4	0.4
39	UPC 287	102.9	3.6	43.7	3585.5	50.6	65.6	0.7
40	UPC 951–B	92.3	4.4	43.5	3596.9	58.7	75.0	1.1
41	IFC 95102	106.6	5.1	50.0	3856.2	52.3	61.7	1.2
42	EC 240744	84.6	4.8	42.8	3708.1	51.6	71.7	0.4
43	EC 24041	62.6	4.7	27.4	3359.9	53.4	69.2	0.8
44	HES 82	102.1	4.0	32.4	3735.6	48.9	63.0	0.5
45	Cl 350	93.4	4.0	27.6	2038.7	57.9	72.8	0.7
46	EC 240764–2	85.4	4.6	29.3	3023.4	50.6	65.8	0.6
47	UPC 953	73.1	4.7	25.1	2923.4	50.1	65.7	0.6
48	N 311	85.7	4.9	21.4	2291.9	58.8	74.7	0.7
49	EC 244024	96.2	4.9	28.6	2673.5	49.3	64.2	0.7
50	EC 240215	87.7	4.1	27.3	2706.5	50.3	65.3	0.8
51	EC 24768	94.2	4.9	29.4	2787.11	49.4	67.3	0.5
	Mean	87.37	4.4	31.02	2894.12	31.02	68.6	0.76
	SE	3.85	0.25	2.01	167.98	2.01	1.48	0.06
	CD	10.94	0.75	5.71	477.51	5.71	4.22	0.19

4.1.1.8 Leaf Area Index

The leaf area index had an average of 6.4 with a range of 2.5 to 8.6. The lowest leaf area index was exhibited by the accession N 271 and the highest by the accession IFC 8401 and EC 4216.

4.1.1.9 Dry Weight of Leaf, g

The dry weight of leaf ranged from 3.8 g (Bundel Lobia) to 14.3 g (EC 2407642) with an average of 9.9 g.

4.1.1.10 Dry Weight of Stem, g

The average dry weight of stem was 19.4 g with a range of 7.0 g to 13.3 g. The lowest dry weight of stem was expressed by Bundal lobia (7.0) and the highest by HES 82 and EC 2407642 (30.3).

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

Green fodder yield had an average of 32.6 t ha^{-1} and had a range of 8.7 t ha^{-1} (Bundel lobia) to 47.6 t ha^{-1} (EC 241027 and HES 82).

4.1.1.12 Dry Matter Yield, t ha^{-1}

The average dry matter yield was 6.6 t ha^{-1}. The range was from 2.1 t ha^{-1} (Bundel Lobia) to 10.3 t ha^{-1} (EC 4216).

4.1.1.13 Crude Protein Content, %

The crude protein content had an average of 26.8 per cent and the range was from 19.8 per cent (UPC 5286) to 36.5 per cent (CSFRE 8903).

4.1.1.14 Crude Fibre Content, %

The crude fibre content ranged from 12.0 per cent exhibited by the accession UPC 94–2 to 20.0 per cent observed in EC 4216. The average crude protein content was 16.4 per cent.

The genotypic and environmental component of phenotypic variance, phenotypic and genotypic coefficient of variation are presented in Table 4.1.1c and Fig 1.

Table 4.1.1b Continued

Sl. No.	Accessions	Leaf area index	Dry weight of leaf, g	Dry weight of stem, g	Green fodder yield t ha^{-1}	Dry matter yield t ha^{-1}	Crude protein content, %	Crude fibre content, %
1	IFC 9402	4.5	11.3	15.8	35.7	6.1	26.4	19.0
2	FC 241044	7.2	10.8	13.3	31.3	5.5	30.4	18.3
3	IFC 9501	6.3	8.0	11.5	27.6	4.3	25.3	19.4
4	IFC 9304	7.4	6.3	9.8	25.5	3.6	24.8	18.3
5	IFC 9503	8.3	5.3	9.8	27.2	3.5	21.3	15.8
6	UPC 951	7.5	8.8	12.3	25.0	4.6	24.6	14.8
7	UPC 33–4	7.6	6.8	7.5	18.3	3.1	26.0	14.4
8	EC 240806	3.6	6.3	11.3	25.4	3.8	26.6	12.2
9	EC 240	4.9	9.3	14.3	28.3	5.4	30.7	12.8
10	N 271	2.5	9.8	13.8	28.6	5.4	28.4	12.4
11	Bundel Lobia	5.0	3.8	7.0	8.7	2.1	30.4	15.7
12	CL–88	5.3	9.0	11.5	31.9	5.0	26.5	16.9
13	EC 240768	5.4	10.8	13.3	31.5	5.6	28.1	18.1
14	EC 240687	4.9	12.5	22.5	45.4	8.1	27.4	18.7
15	UPC 9103	7.1	6.8	12.0	17.4	4.0	20.5	18.2
16	UPC 94–2	5.2	8.3	12.0	17.2	4.2	21.5	12.0
17	Co–5	3.4	9.8	18.3	22.8	4.9	27.8	18.8
18	UPC 952	4.8	7.8	15.3	21.5	4.8	25.7	15.9
19	IFC 9001	8.5	12.8	24.8	41.8	8.6	29.6	17.6
20	IFC 8401	8.6	11.8	28.0	50.2	10.1	30.7	19.9
21	EC 4216	8.6	12.2	28.8	43.7	10.3	28.4	20.0
22	EC 240764–1	8.1	11.3	27.3	32.9	9.8	27.4	18.7
23	IFC 24094	3.9	10.8	22.3	43.3	8.5	27.4	18.2
24	CS 91	4.0	12.3	22.5	39.6	9.3	28.6	16.5
25	UP 219	7.0	10.0	17.3	44.5	5.4	25.5	14.8
26	IFC 9201	7.8	10.5	21.5	39.1	7.3	26.0	15.5
27	UPC 94–1	7.3	13.3	24.3	50.9	8.8	29.9	13.4
28	CSFRE 8903	6.6	13.8	17.3	43.5	5.9	36.5	15.4
29	IC 44696	5.9	9.8	28.8	23.3	10.3	27.5	17.9
30	Cl 334	5.3	9.0	15.0	32.0	5.5	21.8	18.1

Table 4.1.1b Continued

Sl. No.	Accessions	Leaf area index	Dry weight of leaf, g	Dry weight of stem, g	Green fodder yield, t ha^{-1}	Dry matter yield, t ha^{-1}	Crude protein content, %	Crude fibre content, %
31	EC 241053	5.7	7.8	15.3	25.0	5.3	20.4	14.5
32	Cl 341	6.8	8.0	21.3	34.6	6.5	21.4	13.4
33	EC 241024	6.3	8.3	16.5	25.0	5.6	21.4	15.9
34	UPC 9202	8.4	13.0	23.0	41.6	8.6	31.0	13.3
35	UPC 5286	7.1	6.0	10.3	25.9	4.0	19.8	16.4
36	EC 244021	7.1	10.3	20.0	33.2	7.1	29.4	12.4
37	CL 321–1	7.2	10.3	25.5	32.4	7.4	27.9	14.3
38	EC 241027	8.3	12.3	29.8	47.6	9.1	29.7	14.4
39	UPC 287	8.0	11.3	23.5	34.1	7.8	27.4	14.1
40	UPC 951–B	7.8	8.8	18.3	34.7	6.1	29.8	15.4
41	IFC 95102	8.6	13.8	29.5	47.2	9.3	31.4	19.1
42	EC 240744	8.2	9.8	25.3	30.6	8.0	30.6	18.7
43	EC 24041	7.5	7.3	17.0	22.9	6.4	24.3	13.8
44	HES 82	8.3	11.8	30.3	47.4	8.3	30.9	18.4
45	Cl 350	4.5	5.3	9.3	26.8	4.3	21.6	19.0
46	EC 240764–2	6.7	14.3	30.8	40.8	9.1	30.9	15.7
47	UPC 953	6.5	13.0	26.3	30.6	7.8	28.8	18.8
48	N 311	5.1	12.3	27.5	43.3	8.7	28.3	19.8
49	EC 244024	6.0	11.8	27.3	32.4	7.3	28.2	17.6
50	EC 240215	6.0	12.0	28.5	31.9	9.5	27.2	18.4
51	EC 24768	6.2	12.3	28.8	25.5	8.0	27.4	17.4
	Mean	6.4	9.95	19.46	32.61	6.61	26.84	16.41
	SE	0.21	0.42	0.51	1.16	0.39	0.26	0.24
	CD	0.61	1.20	1.44	3.29	1.10	0.73	0.68

Table 4.1.1c Components of variance for fourteen traits in cowpea

Sl. No.	Characters	σp^2	σg^2	σe^2	PCV %	GCV %
1	Plant height, cm	154.48	124.86	29.62	14.23	12.79
2	Number of primary branches/plant	0.26	0.13	0.13	11.66	8.38
3	Number of leaves per plant	67.01	58.95	8.05	26.39	24.75
4	Total leaf area, cm^2	519798.40	463584.70	56213.7	24.90	23.51
5	Days to 50 per cent flowering	14.45	11.78	2.67	7.16	6.47
6	Days to maturity	20.33	15.93	4.4	6.58	5.82
7	Leaf / stem ratio	0.04	0.03	0.01	25.75	22.65
8	Leaf area index	2.51	2.42	0.09	24.67	24.21
9	Dry weight of leaf, g	6.60	6.24	0.36	25.83	25.12
10	Dry weight of stem, g	51.19	50.68	0.51	36.79	36.61
11	Green fodder yield t ha^{1}	92.65	89.98	2.67	29.46	29.03
12	Dry matter yield, t ha^{1}	4.82	4.52	0.3	33.25	32.19
13	Crude protein content, %	5.57	5.46	0.11	14.38	14.23
14	Crude fibre content, %	10.63	10.50	0.13	12.15	12.0

PCV – Phenotypic coefficient of variation

σe^2 Environmental variance

GCV Genotypic coefficient of variation

σp^2 Phenotypic variance

σg^2 Genotypic variance

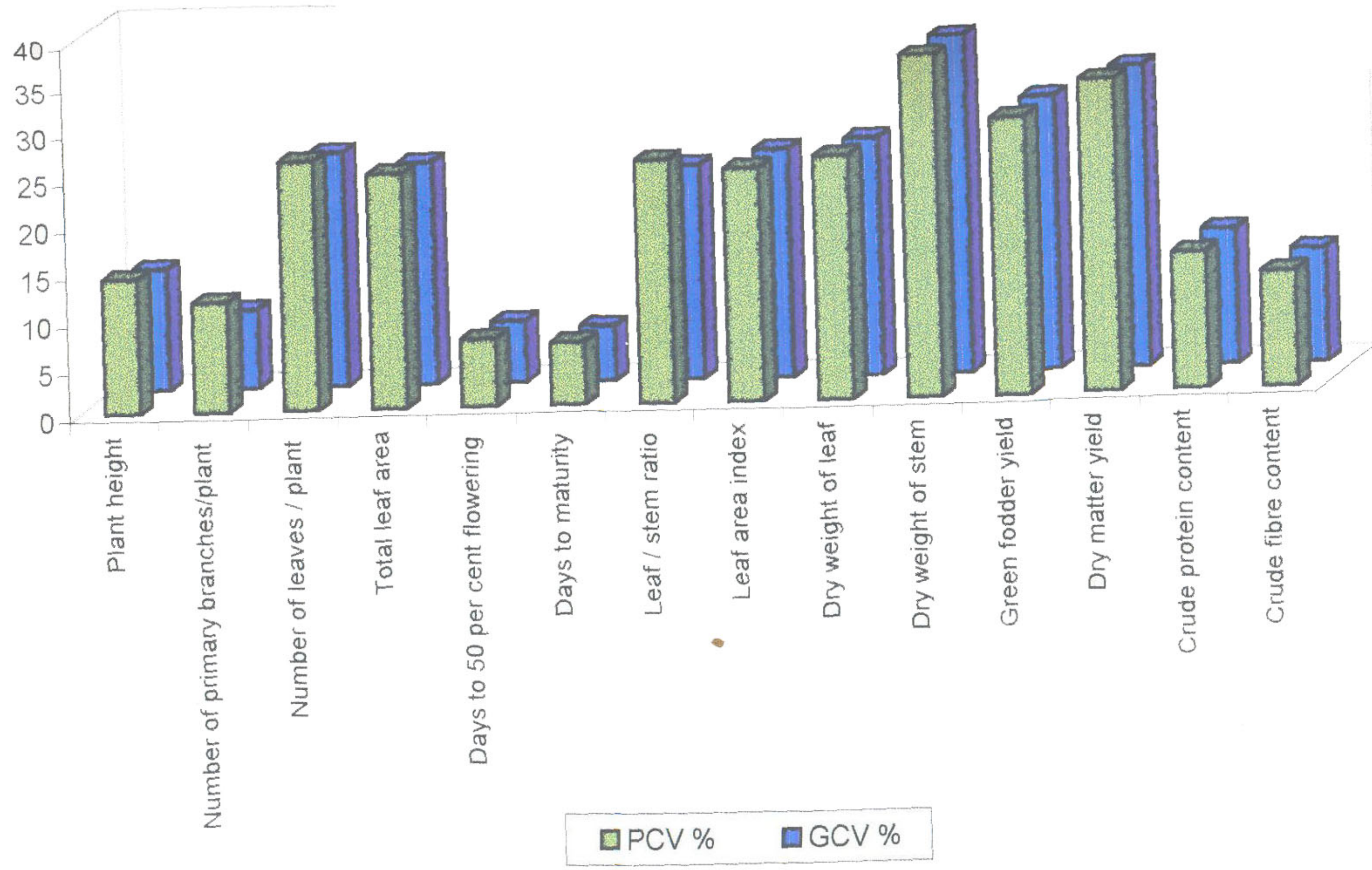
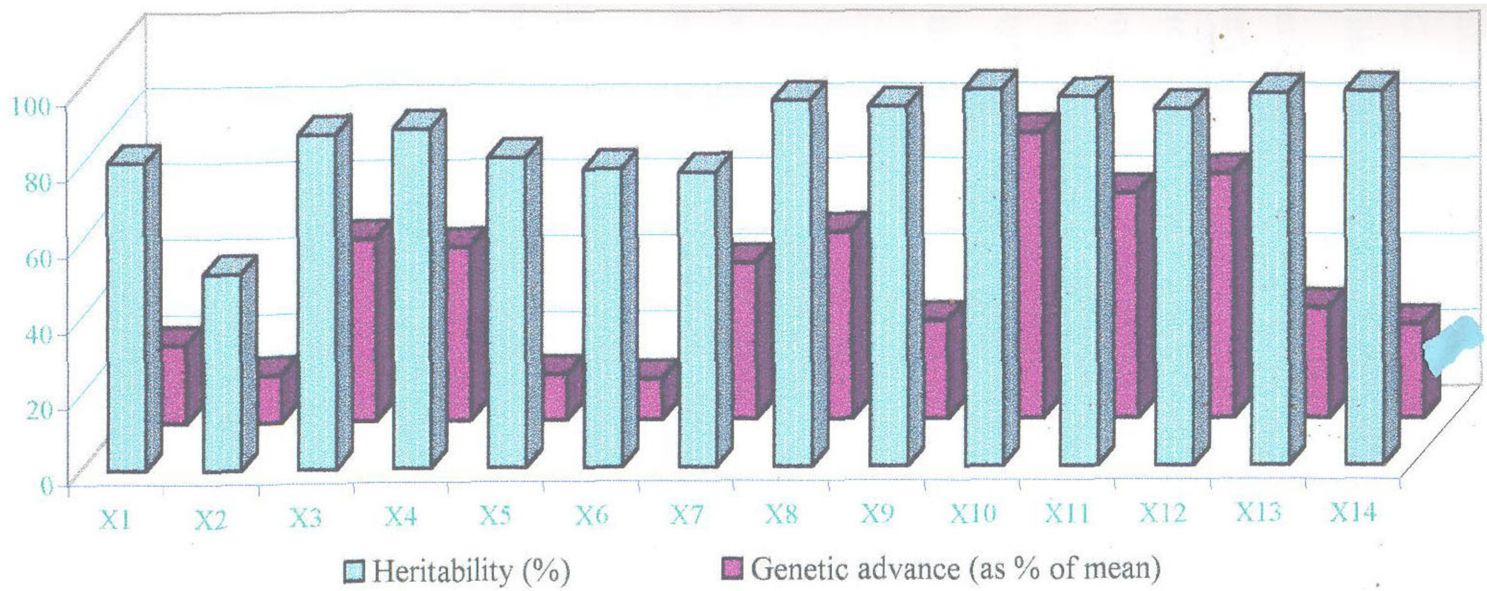


Fig. 1 Components of total variance - PCV and GCV for fourteen traits

Table 4.1.2 Heritability and genetic advance for fourteen characters in cowpea

Sl. No.	Characters	Heritability, %	Genetic advance as percentage of mean
1	Plant height, cm	80.83	20.68
2	Number of primary branches/plant	51.59	12.39
3	Number of leaves per plant	87.97	47.84
4	Total leaf area, cm^2	89.11	45.66
5	Days to 50 per cent flowering	81.50	12.02
6	Days to maturity	78.36	10.62
7	Leaf / stem ratio	77.38	41.05
8	Leaf area index	96.33	48.97
9	Dry weight of leaf, g	94.59	25.83
10	Dry weight of stem, g	99.00	75.03
11	Green fodder yield t ha^{1}	97.11	58.93
12	Dry matter yield, t ha^{1}	93.75	64.17
13	Crude protein content, %	97.98	29.04
14	Crude fibre content, %	98.77	24.74



X1 Plant height
X2 Number of primary branches/plant
X3 Number of leaves / plant
X4 Total leaf area
X5 Number of days to 50 per cent flowering
X6 Days to maturity
X7 Leaf/stem ratio
X8 Leaf area index
X9 Dry weight of leaf
X10 Dry weight of stem
X11 Green fodder yield
X12 Dry matter yield
X13 Crude protein content
X14 Crude fibre content

Fig. 2 Heritability and genetic advance for fourteen characters

Maximum variability both at phenotypic (36.79 per cent) and genotypic (36.61 per cent) levels was observed for dry weight of stem and the minimum was recorded for days to maturity (PCV 6.58 per cent and GCV 5.82 per cent). Dry matter yield and green fodder yield also recorded high values both at phenotypic and genotypic levels.

Plant height, number of primary branches per plant, total leaf area, days to 50 per cent flowering, days to maturity, crude protein content and crude fibre content were in the same order of variation both at phenotypic and genotypic levels. But number of leaves per plant, leaf / stem ratio, leaf area index and dry weight of leaf differed in their ranks at phenotypic and genotypic levels.

4.1.2 Estimation of Heritability and Genetic Advance

The estimates of heritability and genetic advance are presented in Table 4.1.2.

Allard (1960) classified heritability as low (10-30 per cent), medium (30-60 per cent) and high (above 60 per cent). As per the classification also the heritability estimates were high for almost all the characters. Heritability was highest for dry weight to stem (99.00 per cent) followed by crude fibre content (98.77 per cent) crude protein content (97.98 per cent), green fodder yield (97.11 per cent), leaf area index (96.33 per cent), dry weight of leaf (94.59 per cent) and dry matter yield (93.75 per cent). The lowest value of heritability was recorded for number of primary branches per plant (51.59 per cent). The high heritability estimate gives indication of effectiveness of selection based on phenotypic performance.

Genetic advance as percentage of mean was estimated. Maximum genetic advance was obtained for dry weight of stem (75.03 per cent) followed by dry matter yield (64.17 per cent) and green fodder yield (58.93 per cent). The minimum genetic advance was recorded for days to 50 per cent flowering (12.02 per cent).

4.1.3 Correlation among Different Characters

The phenotypic, genotypic and environmental correlations among the various characters were estimated and results are given in the Table 4.1.3 a, 4.1.3 b and 4.1.3 c.

4.1.3a. Correlation among the Yield Component Characters

Green Fodder Yield

Green fodder yield had significant positive phenotypic correlation with leaf /stem ratio (0.6144), leaf area index (0.5455), dry weight of stem (0.5350), dry weight of leaf (0.4716), plant height (0.3422) and number of primary branches per plant (0.2420).

High and significant positive genotypic correlation was found with leaf /stem ratio (0.6325), leaf area index (0.5511), dry weight of stem (0.5562), dry weight of leaf (0.4816) and plant height (0.3801) (Fig. 3 and 5).

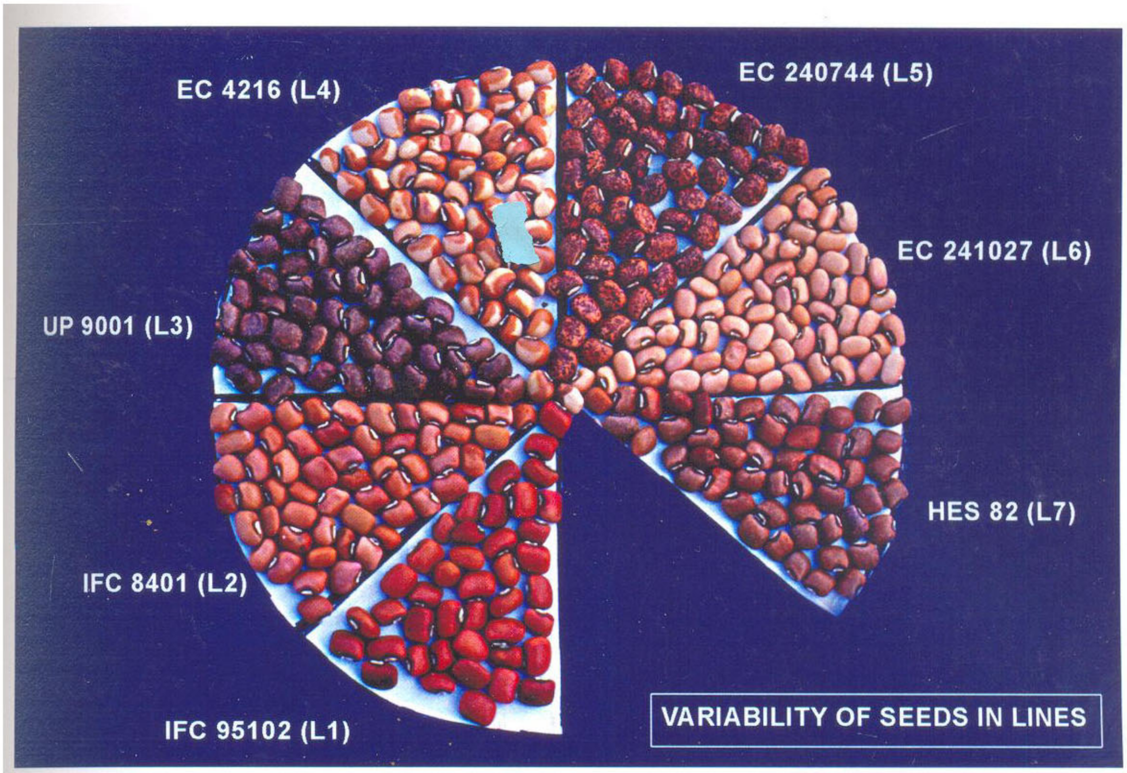
Environmental correlation was high and positive for green fodder yield with number of primary branches per plant (0.2576) and total leaf area (0.2272).

Dry Matter Yield

Dry matter yield showed high and positive phenotypic correlation with number of primary branches per plant (0.2808), leaf /stem ratio (0.2595), dry weight of stem (0.2483), dry weight of leaf (0.2032), leaf area index (0.2341) and plant height (0.2166).

The genotypic correlation was found high and positive with number of primary branches per plant (0.3644), leaf/stem ratio (0.2690), dry weight of stem (0.2617), dry weight of leaf (0.2075) and plant height (0.2335) (Fig. 4 and 6).

Dry matter yield had high positive environmental correlation with number of leaves per plant (0.2205).



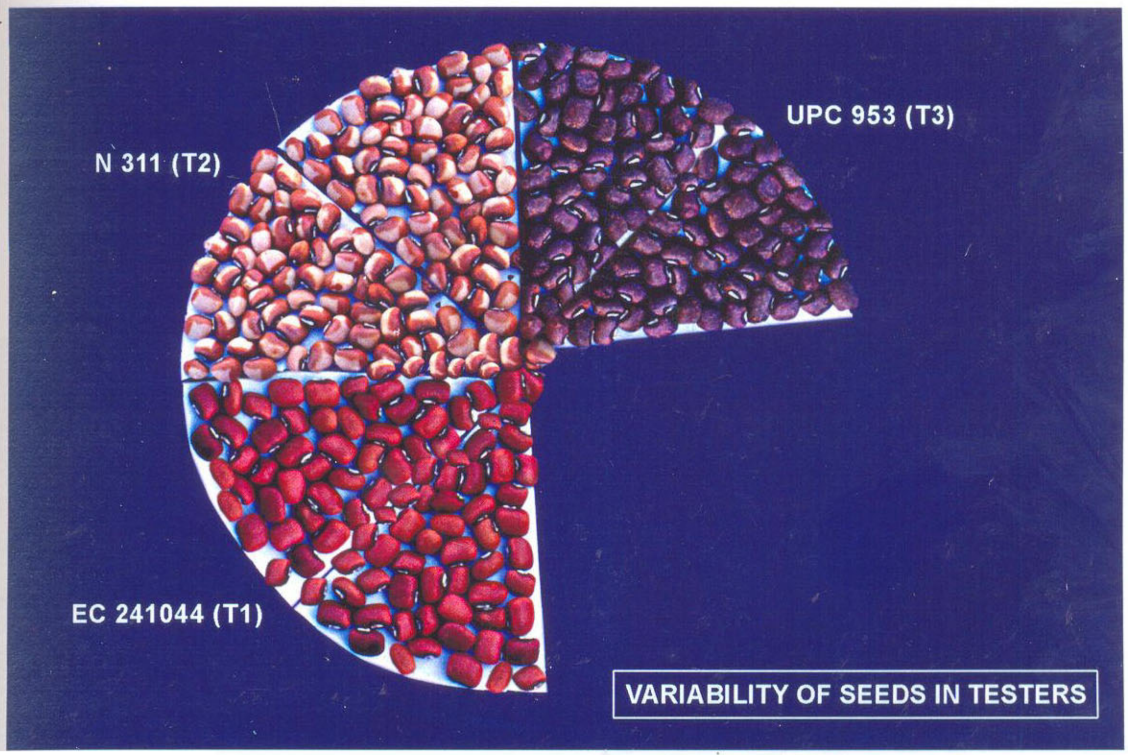


Plate.2. Variability of seeds

Table 4.1.3a Phenotypic correlation coefficients

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Plant height (X_1)														
Number of primary branches per plant (X_2)	0.0745													
Number of leaves per plant (X_3)	0.3176**	0.0587												
Total leaf area (X_4)	-0.1549	-0.1194	-0.3624**											
Days to 50% flowering (X_5)	-0.2644**	-0.0891	-0.2962**	0.7981**										
Days to maturity (X_6)	0.1272	-0.0082	0.1796	0.0047	-0.1470									
Leaf / stem ratio (X_7)	0.0809	0.1974*	0.0795	-0.2815**	-0.2987**	-0.1609								
Leaf area index (X_8)	0.2006*	0.2298*	0.2053*	-0.3665**	-0.3990**	-0.2638**	0.7982**							
Dry weight of leaf (X_9)	0.1161	0.0759	0.2922**	-0,2882**	-0.3093**	-0.1345	0.7560**	0.6469**						
Dry weight of stem (X_{10})	0.1416	0.1992*	0.1419	-0.3055**	-0.3294**	-0.1854	0.7593**	0.9265**	0.6949**					
Green fodder yield (X_{11})	0.3422**	0.2420*	0.0943	-0.0854	-0.1570	0.0333	0.6144**	0.5455**	0.4716**	0.5350**				
Dry matter yield (X_{12})	0.2166*	0.2808**	-0.1780	-0.0691	-0.0647	0.0685	0.2595**	0.2341*	0.2032*	0.2483*	0.1934			
Crude protein content (X_{13})	0.1900	0.0228	0.7335**	-0.3852**	-0.3343**	0.1283	0.1826	0.2980**	0.3236**	0.2612**	0.1543	-0.0332		
Crude fibre content (X_{14})	0.2011*	0.0461	0.7109**	-0.3929**	-0.3497**	0.0871	0.2030**	0.3418**	0.3254**	0.3073**	0.1548	-0.0031	0.9598**	

** Significant at 1 per cent level.

* Significant at 5 per cent level

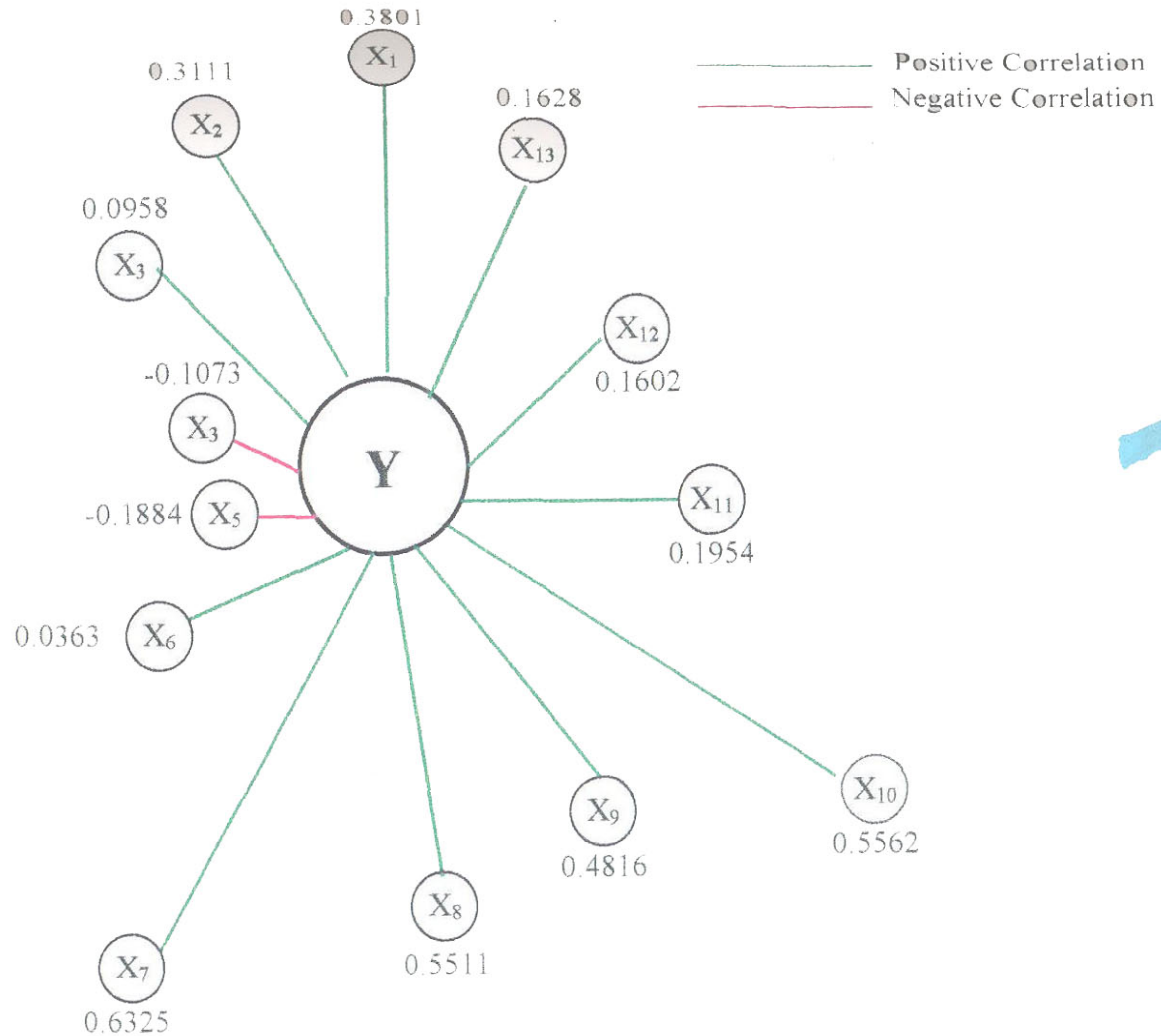


Fig. 3 Genotypic correlation of green fodder yield with other characters

4.1.3b Correlation among the Yield Component Characters

Plant Height

Plant height was strongly correlated phenotypically with number of leaves per plant (0.3176), green fodder yield (0.3422), dry matter yield (0.2166), leaf area index (0.2006) and crude fibre content (0.2011). There was significant negative association with days to 50 per cent flowering (-0.2644).

Except total leaf area and days to 50 per cent flowering all the other traits showed positive genotypic association with plant height. Highest positive genotypic correlation was with green fodder yield (0.3801) and number of leaves per plant (0.3662).

The maximum positive environmental correlation was found with dry matter yield (0.1413).

Number of Primary Branches per Plant

The phenotypic correlation of number of primary branches per plant was high and positive for drymatter yield (0.2808) followed by green fodder yield (0.2420), leaf area index (0.2298), dry weight of stem (0.1992) and leaf / stem ratio (0.1974).

Maximum positive genotypic correlation was found in dry matter yield (0.3644), leaf area index (0.3305), green fodder yield (0.3111) and leaf / stem ratio (0.3086).

High and positive environmental correlation was observed for number of primary branches per plant with green fodder yield (0.2576).

Number of Leaves per Plant

The phenotypic association of number of leaves per plant with crude protein content (0.7335), crude fibre content (0.7109), dry weight of leaf (0.2922), plant height (0.3176) and leaf area index (0.2053) was strong

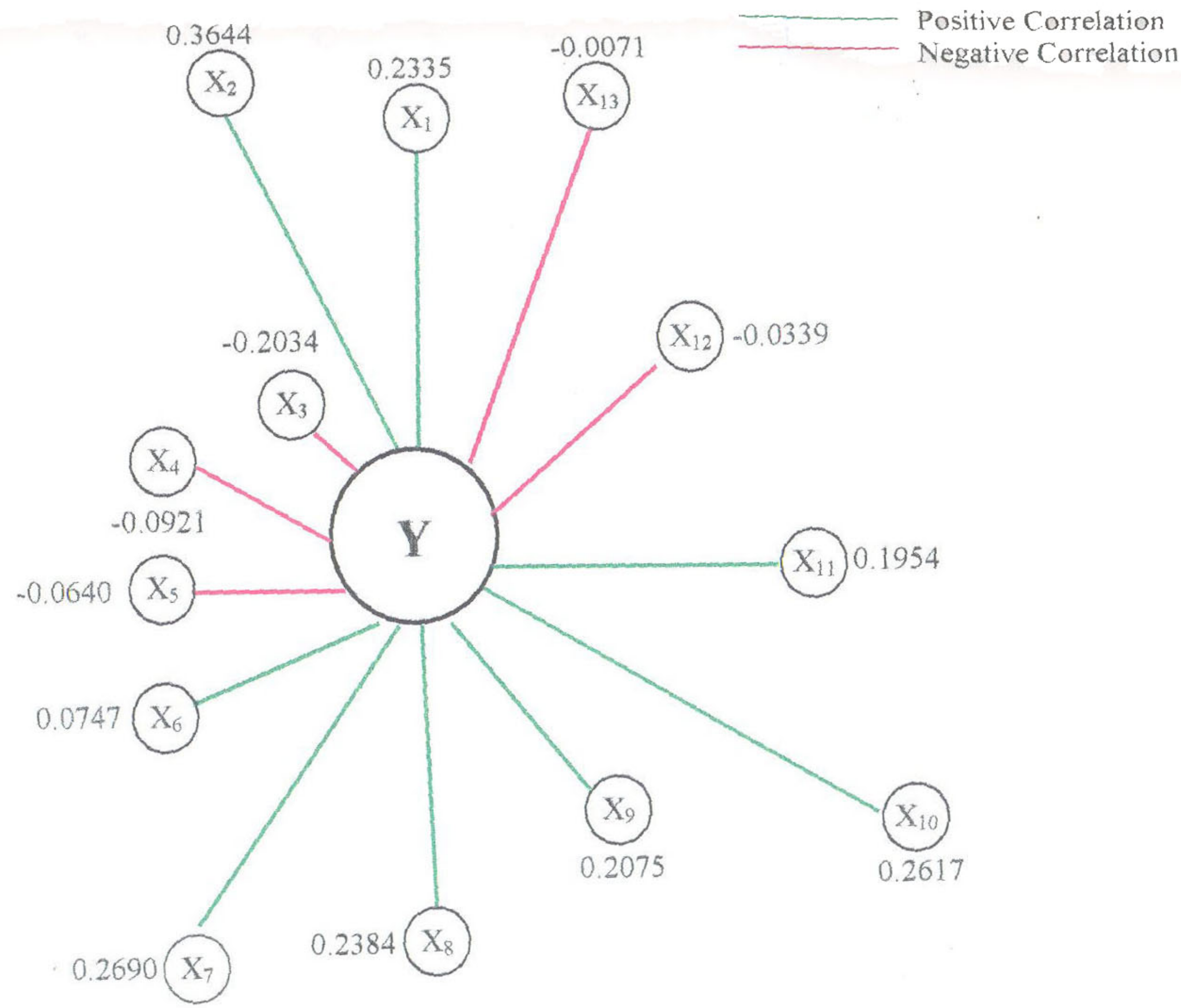
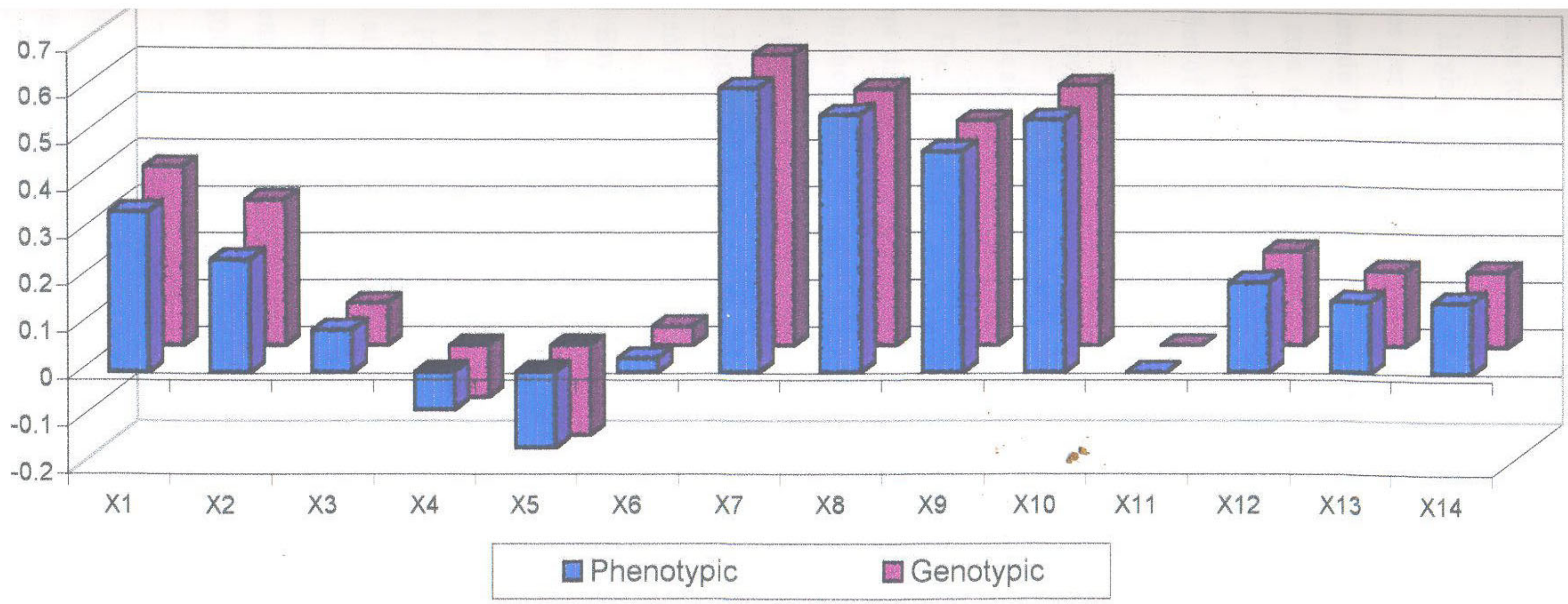


Fig. 4 Genotypic correlation of dry matter yield with other characters

Table 4.1.3b Genotypic correlation coefficients

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Plant height (X_1)														
Number of primary branches per plant (X_2)	0.1117													
Number of leaves per plant (X_3)	0.3662	0.0344												
Total leaf area (X_4)	-0.1747	-0.1862	-0.4218											
Days to 50% flowering (X_5)	-0.3624	-0.2559	-0.3646	0.9494										
Days to maturity (X_6)	0.2305	0.0007	0.2083	0.0019	-0.1396									
Leaf / stem ratio (X_7)	0.1162	0.3086	0.0886	-0.3328	-0.3582	-0.1856								
Leaf area index (X_8)	0.2223	0.3305	0.2133	-0.4108	-0.4495	-0.2981	0.8178							
Dry weight of leaf (X_9)	0.1273	0.0877	0.3053	-0.3036	-0.3554	-0.1481	0.7845	0.6574						
Dry weight of stem (X_{10})	0.1697	0.2948	0.1542	-0.3596	-0.4118	-0.2414	0.8454	0.9565	0.7340					
Green fodder yield (X_{11})	0.3801	0.3111	0.0958	-0.1073	-0.1884	0.0363	0.6325	0.5511	0.4816	0.5562				
Dry matter yield (X_{12})	0.2335	0.3644	-0.2034	-0.0921	-0.0640	0.0747	0.2690	0.2384	0.2075	0.2617	0.1954			
Crude protein content (X_{13})	0.2507	0.0375	0.8382	-0.4421	-0.3861	0.0824	0.1975	0.3151	0.3449	0.2728	0.1602	-0.0339		
Crude fibre content (X_{14})	0.2371	0.0566	0.7666	-0.4490	-0.3950	0.0734	0.2129	0.3457	0.3323	0.3242	0.1628	-0.0071	1.0006	



X1 Plant height
X2 Number of primary branches/plant
X3 Number of leaves / plant
X4 Total leaf area
X5 Number of days to 50 per cent flowering

X6 Days to maturity
X7 Leaf/stem ratio
X8 Leaf area index
X9 Dry weight of leaf
X10 Dry weight of stem

X11 Green fodder yield
X12 Dry matter yield
X13 Crude protein content
X14 Crude fibre content

Fig. 5 Phenotypic and genotypic correlation for green fodder yield

and positive while it was highly negative with total leaf area (–0.3624) and days to 50 per cent flowering (–0.2962).

High and positive genotypic correlation was recorded for number of leaves per plant with plant height (0.3662) crude protein content (0.8382) and crude fibre content (0.7666) and dry weight of leaf (0.3053). Total leaf area (–0.4218), days to 50 per cent flowering (-0.3646) and dry matter yield (-0.2034) had high negative genotypic correlation with number of leaves per plant.

Highest positive environmental association was found for number of leaves per plant with dry matter yield (0.2205).

Total Leaf Area

The phenotypic association of total leaf area with all the characters except days to 50 per cent flowering (0.7981) was negative. Significant and highest negative correlation was with crude fibre content (–0.3929), crude protein content (–0.3852) and leaf area index (–0.3665).

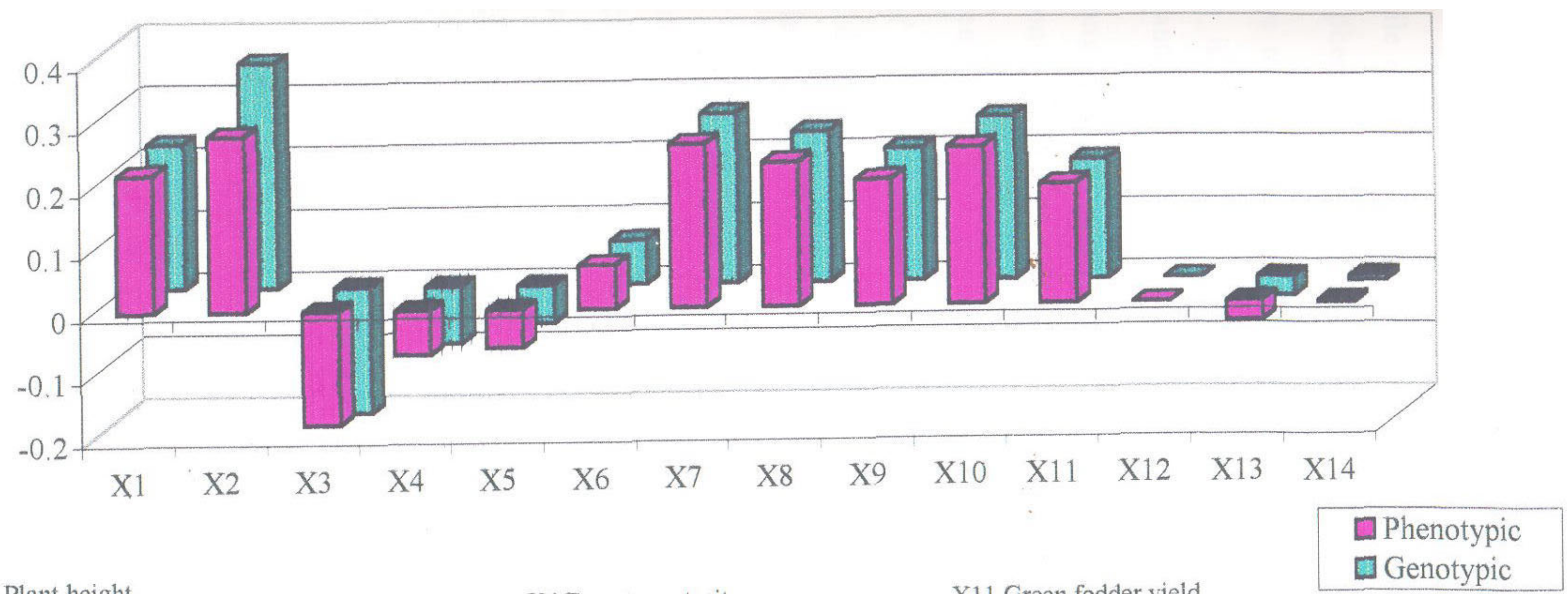
Total leaf area showed positive genotypic correlation with days to 50 per cent flowering (0.9494).

Environmental correlation was positive and significant for total leaf area with green fodder yield (0.2272) and dry matter yield (0.2147).

Days to 50 per cent Flowering

Phenotypic correlation of days to 50 per cent flowering was negative with all traits except one. Strong negative correlation was observed with leaf area index (–0.3990), crude fibre content (–0.3497), crude protein content (–0.3343), dry weight of stem (–0.3294), dry weight of leaf (–0.3093) and leaf / stem ratio (–0.2987).

The genotypic association of days to 50 per cent flowering was positive with only one traits. All other characters showed negative correlation. Highest negative correlation was shown with leaf area index (–0.4495).



X1 Plant height
X2 Number of primary branches/plant
X3 Number of leaves / plant
X4 Total leaf area
X5 Number of days to 50 per cent flowering

X6 Days to maturity
X7 Leaf/stem ratio
X8 Leaf area index
X9 Dry weight of leaf
X10 Dry weight of stem

X11 Green fodder yield
X12 Dry matter yield
X13 Crude protein content
X14 Crude fibre content

Fig. 6 Phenotypic and genotypic correlation for dry matter yield

Highest positive environmental correlation was found between days to 50 per cent flowering and number of primary branches per plant (0.2273).

Days to Maturity

While considering the character days to maturity it had significant negative phenotypic correlation with leaf area index (–0.2638).

Days to maturity had a strong negative genotypic association with leaf area index (–0.2981) and positive association with plant height (0.2305) and number of leaves per plant (0.2083).

Strong positive environmental correlation was observed with crude protein content (0.3810) and crude fibre content (0.2598).

Leaf / Stem Ratio

Leaf / stem ratio had high positive correlation with leaf area index (0.7982), dry weight of stem (0.7953), dry weight of leaf (0.7560), green fodder yield (0.6144), drymatter yield (0.2595) and crude fibre content (0.2030).

Maximum positive genotypic correlation was observed with leaf area index (0.8178), dry weight of stem (0.8454) dry weight of leaf (0.7845) and green fodder yield (0.6325).

Environmental correlation was high and positive with leaf area index (0.2936).

Leaf Area Index

Leaf area index showed high positive correlation with dry weight of stem (0.9265), leaf / stem ratio (0.7982) dry weight of leaf (0.6469), green fodder yield (0.5455), crude fibre content (0.3418) and crude protein content (0.2980).

Leaf area index had highest genotypic correlation with dry weight of stem (0.9565) followed by leaf / stem ratio (0.8178) and dry weight of leaf (0.6574) and green fodder yield (0.5511).

Table 4.1.3 c Environmental correlation coefficients

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Plant height (X_1)														
Number of primary branches per plant (X_2)	0.0077													
Number of leaves per plant (X_3)	0.0580	0.1471												
Total leaf area (X_4)	-0.0695	0.0043	-0.0357											
Days to 50% flowering (X_5)	0.1178	0.2273	0.0401	0.1967										
Days to maturity (X_6)	-0.2646	-0.0260	0.0470	0.0157	-0.1731									
Leaf / stem ratio (X_7)	-0.2029	-0.1121	-0.0171	0.1070	0.0897	-0.0191								
Leaf area index (X_8)	0.0385	-0.0912	0.1802	0.0589	-0.0681	-0.0610	0.2936							
Dry weight of leaf (X_9)	0.0444	0.1173	0.1706	-0.2477	0.0089	-0.0752	0.1059	0.1389						
Dry weight of stem (X_{10})	-0.0559	-0.0333	0.0213	0.0818	0.2025	0.1694	-0.0130	0.1979	-0.1275					
Green fodder yield (X_{11})	0.0521	0.2576	0.1298	0.2272	0.1689	0.0304	0.1180	0.0504	-0.0045	-0.0063				
Dry matter yield (X_{12})	0.1413	0.2197	0.2205	0.2147	-0.1301	0.0517	0.0171	-0.0441	0.0340	-0.0693	0.0797			
Crude protein content (X_{13})	-0.1573	-0.0113	-0.0752	-0.0594	-0.0759	0.3810	0.0159	0.0613	0.0486	0.1434	0.1085	-0.0315		
Crude fibre content (X_{14})	-0.0971	0.0465	0.0795	0.0595	-0.0733	0.2598	-0.0069	0.2210	0.1240	-0.0165	-0.1899	0.1378	0.5191	

Crude protein content recorded high and positive genotypic correlation with crude fibre content (1.0006) and number of leaves per plant (0.8382).

Environmental correlation was high and positive with crude fibre content (0.5191).

Crude Fibre Content

Crude fibre content also showed high positive phenotypic correlation with number of leaves (0.7109) and crude protein content (0.9598) along with leaf area index (0.3418), dry weight of leaf (0.3254), dry weight of stem (0.3073) and leaf area index (0.3073) and plant height (0.2011). Negative significant correlation was observed with total leaf area (–0.3929) and days to 50 per cent flowering (–0.3497).

High positive genotypic correlation was shown by crude fibre content with number of leaves per plant (0.7666) and crude protein content (1.0006).

Environmental association was high and positive with crude protein content (0.5191).

4.1.4 Selection index

A discriminant function was fitted with 12 variables to derive a selection index for the 51 accessions based on their performance. The variables used were plant height, number of primary branches per plant, number of leaves per plant, total leaf area, days to 50 per cent flowering, days to maturity, leaf / stem ratio, leaf area index, dry weight of leaf and dry weight of stem. The index values for each genotype are given in Table 4.1.4a. The index scores ranged from 2632.8 for N 271 to 8129.96 for IFC 95102. Seven top ranking accessions IFC 95102 (L_1), IFC 8401 (L_2), UP 9001 (L_3), EC 4216 (L_4), EC 240744 (L_5), EC 241027 (L_6) and HES 82 (L_7) were selected as lines (female parents) for hybridization.

Table 4.1.4a Selection index (yield and yield attributes)

Genotype	Selection Index	Rank
T_1	4150.036	46
T_2	6537.064	21
T_3	6027.132	28
T_4	6645.256	20
T_5	7482.407	9
T_6	6929.266	16
T_7	6985.719	15
T_8	3699.730	49
T_9	4963.094	38
T_{10}	2632.776	51
T_{11}	4721.931	41
T_{12}	4981.799	36
T_{13}	4997.967	35
T_{14}	4758.128	40
T_{15}	6251.041	25
T_{16}	4691.214	43
T_{17}	3513.134	50
T_{18}	4420.368	45
T_{19}	7819.189	3
T_{20}	7831.122	2
T_{21}	7811.235	4
T_{22}	7048.779	14
T_{23}	3803.725	48
T_{24}	3845.805	47
T_{25}	6654.302	18
T_{26}	7138.586	12
T_{27}	7067.526	13
T_{28}	6242.622	26
T_{29}	4964.067	37
T_{30}	4897.878	39
T_{31}	5338.237	34
T_{32}	6305.216	24
T_{33}	5994.986	29
T_{34}	7311.194	11
T_{35}	6500.841	22
T_{36}	6647.622	19
T_{37}	6899.790	17
T_{38}	7709.469	6
T_{39}	7564.634	8
T_{40}	7339.328	10
T_{41}	8129.960	1
T_{42}	7789.061	5
T_{43}	6403.646	23
T_{44}	7654.284	7
T_{45}	4424.279	44
T_{46}	6200.039	27
T_{47}	5911.736	30
T_{48}	4707.671	42
T_{49}	5557.371	32
T_{50}	5452.778	33
T_{51}	5701.140	31

Table 4.1.4b Selection index (Quality parameters)

Genotype	Selection Index	Rank
T_1	89.5170	18
T_2	96.0586	6
T_3	88.0257	22
T_4	84.7794	33
T_5	72.9489	46
T_6	76.8321	42
T_7	75.1881	43
T_8	77.7495	40
T_9	85.0786	32
T_{10}	86.9023	26
T_{11}	93.4104	9
T_{12}	87.9484	23
T_{13}	92.1936	11
T_{14}	89.7286	17
T_{15}	64.1576	51
T_{16}	79.2297	39
T_{17}	86.1073	29
T_{18}	85.2863	31
T_{19}	97.4171	3
T_{20}	99.9871	1
T_{21}	92.7873	10
T_{22}	90.0237	14
T_{23}	86.4913	28
T_{24}	85.4337	30
T_{25}	80.8691	37
T_{26}	77.6410	41
T_{27}	89.1833	19
T_{28}	87.1611	25
T_{29}	89.8284	16
T_{30}	71.7823	47
T_{31}	68.8148	49
T_{32}	68.5378	50
T_{33}	73.5400	45
T_{34}	87.3396	24
T_{35}	71.2556	48
T_{36}	82.5059	35
T_{37}	83.1665	34
T_{38}	86.8259	27
T_{39}	81.7839	36
T_{40}	89.1825	20
T_{41}	99.5088	2
T_{42}	97.2391	5
T_{43}	75.0615	44
T_{44}	97.2443	4
T_{45}	79.9180	38
T_{46}	91.9478	12
T_{47}	93.6761	8
T_{48}	94.7472	7
T_{49}	90.3318	13
T_{50}	89.9221	15
T_{51}	88.1592	21

Another discriminant function was fitted with two variables to derive an index to evaluate the quality of the 51 accessions *viz.*, crude protein content and crude fibre content. The performance index is given in the Table 4.1.4b. The index scores ranged from 64.2 for UPC 9103 to 99.9 for IFC 8401. Three top ranking accessions, which were not selected as the lines were taken as testers (male parents). They are EC 241044 (T_1), N 311 (T_2) and UPC 953 (T_3).

4.2 EXPERIMENT II : LINE X TESTER ANALYSIS

Statistical analysis of the data relating to Line x Tester experiment was done and the results are presented below.

4.2.1 Mean Performance of Parents and Hybrids

The mean performance of seven lines, three testers and their 21 hybrids are presented in Table 4.2.1. Significant differences were detected among the parents and among the hybrids with respect to all the characters.

The plant height recorded by the parents ranged from 135.7 cm (L_3) to 166.3 cm (L_5) among lines. Among testers, the range was from162.0 cm (T_2) to 171.7 cm (T_3). Among the hybrids, it ranged from 135.3 cm in L_7 x T_2 to 227.9 cm in L_1 x T_3. The average plant height of hybrids was 181.3 cm.

The mean number of primary branches ranged from 3.7 in the parents (L_3 and L_5) to 4.9 in the line L_6. The testers ranged from 4.1 (T_3) to 4.6 (T_2). In the hybrids, the range was from 3.7 in L_7 x T_2 to 6.3 in L_2 x T_1. The average number of primary branches was 5.1 for the hybrids. The mean number of leaves per plant ranged from 48.0 in L_5 to 55.3 in L_3. The testers had a range from 59.4 (T_3) to 61.4 (T_1). In the hybrids, it ranged from 49.3 in L_3 x T_1 to 89.2 in the hybrid L_7 x T_1. The average number of leaves for the hybrids was 68.1. The total leaf area observed in the parents ranged from 4100.6 cm^2 (L_4) to 4879.7 cm^2 (L_5) among lines

Plate.3 Crossing block

and from 4670.56 cm^2 (T_3) to 5128.2 cm^2 (T_1) among testers. In the hybrids the range was from 3733.1 cm^2 (L_5 x T_3) to 7704.0 cm^2 (L_7 x T_1). The average value for the hybrid was 5392.8 cm^2.

The parents showed significant difference in days to 50 per cent flowering ranging from 44.7 in L_1 to 51.6 in L_7. The range in testers was from 45.9 (T_3) to 47.4 (T_1). The range in hybrids was from 35.6 in L_6 x T_1 to 50.0 in L_7 x T_1. The hybrids had an average of 42.9.

The mean number of days to maturity in lines ranged from 72.5 in L_2 to 76.2 in L_3. In the testers, the range was from 68.3 (T_3) to 71.0 (T_2). In the hybrids, the range was from 60.8 in L_6 x T_3 to 74.0 in L_3 x T_3 and L_4 x T_3. The average was 67.9.

The minimum leaf/stem ratio was exhibited by the parent L_6 (0.8) and the maximum by the parents L_2, L_4 and L_5 (1.0). Among the testers the lowest ratio was observed in T_2 and T_3 (0.9) and the highest in T_1 (1.0). Among the hybrids, the minimum was recorded by the hybrid L_5 x T_3 (0.7) and the maximum by L_4 x T_2 (1.4). The average leaf/stem ratio was 0.9 in hybrids.

Leaf area index was minimum in the parent L_4 (4.5) and maximum in the parent L_6 (5.4). In the testers, T_3 had the minimum value (5.1) and T_1 had the maximum value (5.7). In the hybrids, it ranged from 4.1 in L_5 x T_3 to 8.5 in L_7 x T_1. The average leaf area index of hybrids was 6.0.

The mean dry weight of leaf in the lines ranged from 20.8 g (L_3) to 37.5 g (L_4 and L_7). The range was from 45.8 g (T_1 and T_3) to 47.5 g (T_2). Among the hybrids the mean dry weight of leaf ranged from 29.1g in L_1 x T_3, L_5 x T_3, L_6 x T_1 to 79.2g in L_1 x T_1 and L_7 x T_1. The average dry weight of leaf of hybrids was 55.1 g.

The minimum dry weight of stem among the lines was exhibited by the parent L_1 (20.8 g). The maximum dry weight of stem was exhibited by the parent L_7 (54.2 g). In the testers, the minimum value was observed in

Table 4.2.1 Mean performance of lines, testers and hybrids for various characters

Treatment	Plant height, cm	No. of primary branches per plant	No. of leaves per plant	Total leaf area, cm	Days to 50% flowering
L_1	152.9	4.0	49.3	4484.8	44.7
L_2	141.8	4.1	53.0	4353.1	50.9
L_3	135.7	3.7	55.3	4285.5	49.2
L_4	162.6	3.9	50.7	4100.6	49.6
L_5	166.3	3.7	48.0	4429.6	47.8
L_6	136.5	4.9	49.7	4879.7	51.3
L_7	154.3	4.2	52.6	4767.1	51.6
T_1	164.2	4.4	61.4	5128.2	47.4
T_2	162.0	4.6	60.5	5077.4	47.2
T_3	171.7	4.1	59.4	4670.6	45.9
L_1 x T_1	203.1	6.1	85.8	7233.2	37.5
L_1 x T_2	186.4	5.9	83	6608.1	40.9
L_1 x T_3	227.9	5.7	74.4	6063.6	46.7
L_2 x T_1	178.8	6.3	87.8	7360.8	43.1
L_2 x T_2	160.4	5.5	74.4	5734.3	47.2
L_2 x T_3	213.5	4.9	70.6	5093.3	41.8
L_3 x T_1	136.5	4.6	49.3	4342.4	37.6
L_3 x T_2	168.8	4.1	57.6	4223.6	43.4
L_3 x T_3	181.0	4.9	54.8	4567.1	40.3
L_4 x T_1	148.8	5.4	51.9	4016.5	40.4
L_4 x T_2	171.9	5.9	72.0	6216.1	43.1
L_4 x T_3	200.1	4.7	64.0	5189.4	42.3
L_5 x T_1	164.5	4.9	59.7	4916.4	47.3
L_5 x T_2	172.6	5.3	55.0	4198.1	47.4
L_5 x T_3	160.3	5.1	49.4	3733.1	41.1
L_6 x T_1	128.5	4.9	54.2	4276.6	35.6
L_6 x T_2	215.3	4.2	73.0	5730.6	36.8
L_6 x T_3	224.2	4.5	83.6	7162.4	44.4
L_7 x T_1	209.9	4.3	89.2	7704.0	50.0
L_7 x T_2	135.3	3.7	73.5	4238.4	47.5
L_7 x T_3	220.2	5.8	66.2	4641.7	46.9
Mean	181.33	5.08	68.07	5392.84	42.92
SE	5.2	0.14	1.81	204.77	1.57

Table 4.2.1 Continued

Treatment	Days to maturity	Leaf / stem ratio	Leaf area index	Dry weight of leaf, g	Dry weight of stem, g
L_1	73.9	0.9	4.9	29.1	20.8
L_2	72.5	1.0	4.8	33.3	29.1
L_3	76.2	0.9	4.7	20.8	33.3
L_4	75.8	1.0	4.5	37.5	41.6
L_5	73.5	1.0	4.9	29.1	41.7
L_6	73.0	0.8	5.4	25.0	37.5
L_7	72.9	0.9	5.3	37.5	54.2
T_1	70.8	1.0	5.7	45.8	45.8
T_2	71.0	0.9	5.6	47.5	20.8
T_3	68.3	0.9	5.1	45.8	45.8
$L_1 \times T_1$	61.3	1.1	8.2	79.1	70.8
$L_1 \times T_2$	65.8	1.1	7.3	70.8	66.6
$L_1 \times T_3$	66.6	0.8	6.7	29.15	37.5
$L_2 \times T_1$	60.9	0.9	8.2	62.5	62.5
$L_2 \times T_2$	70.5	0.9	6.3	70.8	62.5
$L_2 \times T_3$	61.6	1.0	5.6	75.0	62.5
$L_3 \times T_1$	73.9	1.1	4.8	62.5	50.0
$L_3 \times T_2$	73.4	0.9	4.7	45.8	54.2
$L_3 \times T_3$	74.0	0.8	5.1	50.0	62.5
$L_4 \times T_1$	71.1	1.1	4.5	33.3	33.3
$L_4 \times T_2$	69.8	1.3	6.8	54.1	29.1
$L_4 \times T_3$	74.0	1.0	5.7	70.8	58.3
$L_5 \times T_1$	71.5	0.9	5.5	41.6	41.7
$L_5 \times T_2$	67.7	1.1	4.6	62.5	45.8
$L_5 \times T_3$	68.6	0.7	4.1	29.1	29.1
$L_6 \times T_1$	65.3	0.8	4.7	29.1	29.2
$L_6 \times T_2$	67.6	0.9	6.3	58.3	58.3
$L_6 \times T_3$	60.8	1.1	7.9	70.8	62.5
$L_7 \times T_1$	61.7	0.9	8.5	79.1	79.1
$L_7 \times T_2$	69.3	0.8	5.8	45.8	37.5
$L_7 \times T_3$	71.9	0.9	5.1	37.5	37.5
Mean	67.97	0.96	6.02	55.12	50.98
SE	1.51	0.06	0.17	4.3	7.64

Table 4.2.1 Continued

Treatment	Green fodder yield, t ha[1]	Dry matter yield, t ha[1]	Crude protein content, %	Crude fibre content, %	Calcium content, %	Phosphorus content, %
L_1	26.9	5.5	10.3	28.6	4.1	1.8
L_2	24.9	6.0	9.6	29.9	3.4	1.7
L_3	21.5	6.0	9.0	25.5	3.0	1.6
L_4	23.7	7.4	9.8	27.6	2.0	1.1
L_5	28.6	7.8	10.1	29.0	2.4	2.3
L_6	31.6	9.2	11.5	28.0	2.5	1.8
L_7	29.6	11.0	12.4	26.8	2.7	1.7
T_1	31.0	12.9	13.1	27.0	3.6	2.6
T_2	27.7	8.3	13.3	26.3	4.3	2.6
T_3	34.3	8.3	12.4	28.4	3.8	2.1
$L_1 \times T_1$	51.3	16.	17.2	25.2	4.6	2.5
$L_1 \times T_2$	43.9	15.2	17.4	26.1	4.7	2.3
$L_1 \times T_3$	24.0	7.3	15.	26.	3.4	1.9
$L_2 \times T_1$	45.8	13.8	18.5	24.6	5.5	3.1
$L_2 \times T_2$	53.7	14.8	15.0	27.9	3.1	2.0
$L_2 \times T_3$	49.5	15.3	12.5	26.6	2.5	1.7
$L_3 \times T_1$	37.4	12.5	11.1	27.2	2.1	1.4
$L_3 \times T_2$	36.0	11.1	12.1	27.8	2.6	2.1
$L_3 \times T_3$	32.3	12.5	11.9	26.2	3.5	2.7
$L_4 \times T_1$	25.9	8.3	14.1	27.2	4.4	1.4
$L_4 \times T_2$	37.0	9.7	16.8	24.9	5.0	2.1
$L_4 \times T_3$	51.3	14.3	12.7	27.7	3.4	2.1
$L_5 \times T_1$	29.1	9.2	12.0	24.8	3.7	1.5
$L_5 \times T_2$	31.0	12.0	10.8	23.7	2.1	1.2
$L_5 \times T_3$	19.4	6.5	10.7	25.1	2.2	1.1
$L_6 \times T_1$	28.7	6.4	9.1	24.0	2.2	2.5
$L_6 \times T_2$	42.3	12.9	16.0	24.9	4.5	2.7
$L_6 \times T_3$	42.1	14.8	17.8	26.6	4.6	2.5
$L_7 \times T_1$	46.7	16.6	18.9	25.6	5.4	3.1
$L_7 \times T_2$	31.4	9.2	12.3	25.0	3.9	2.0
$L_7 \times T_3$	23.6	8.3	12.1	23.4	3.1	1.9
Mean	37.26	11.78	14.04	5.75	3.64	2.07
SE	1.63	1.37	0.30	0.43	0.15	0.10

T_2 (20.8) and maximum in T_1 and T_3 (45.8 g). Among the hybrids, the minimum value was expressed in L_4 x T_2 and L_5 x T_3 (29.2 g) and the maximum value in L_7 x T_1 (79.2 g). The average dry weight of stem of hybrids was 50.9 g.

Green fodder yield ranged from 21.5 t ha^{-1} [UP 9001 (L_3)] to 31.6 t ha^{-1} [EC 241027 (L_6)] in the lines and from 27.7 t ha^{-1} [N 311 (T_2)] to 34.3 t ha^{-1} [UPC 953 (T_3)] in the testers. Among the hybrids L_5 x T_3 (EC 240744 x UPC 953) recorded the minimum green fodder yield (19.4 t ha^{-1}) and the hybrids, L_2 x T_2 (IFC 8401 x N 311) recorded the maximum value (53.7 t ha^{-1}). The average value for the hybrids was 37.2 t ha^{-1}.

The lines showed significant differences in mean dry matter yield ranging from 5.5 t ha^{-1} in IFC 95102 (L_1) to 11.0 t ha^{-1} in HES 82 (L_7). The range in testers was from 8.3 t ha^{-1} [N 311 (T_2) and UPC 953 (T_3)] to 12.9 t ha^{-1} [EC 241044 (T_1)]. The hybrids also showed significant difference ranging from 7.3 t ha^{-1} in IFC 95102 (L_1) x UPC 953 (T_3) to 16.6 t ha^{-1} in HES 82 (L_7) x EC 241044 (T_1). The average dry matter yield for the hybrids was 11.7 t ha^{-1}.

The crude protein content ranged from 9.0 per cent (L_3) to 12.4 per cent (L_7) in the lines and from 12.4 per cent (T_3) to 13.3 per cent (T_2) in testers. While the range in the hybrids was from 9.1 per cent (L_6 x T_1) to 18.9 per cent (L_7 x T_1). The average crude protein content for the hybrids was 14.0 per cent.

The crude fibre content ranged from 25.5 per cent (L_3) to 29.9 per cent (L_2) among lines and from 26.3 per cent (T_2) to 28.4 per cent (T_3) among testers. Among hybrid the range was from 23.4 per cent (L_7 x T_3) to 27.9 per cent (L_2 x T_2). In the hybrids crude fibre content had an average of 25.7 per cent.

For calcium content, the minimum value recorded in lines was 2.0 per cent (L_4) and maximum value in L_1 (4.1 per cent). Among testers, the range was from 3.6 per cent (T_1) to 4.3 per cent (T_2). Among the hybrids calcium content ranged from 2.1 per cent in L_5 x T_2 and L_3 x T_1 to 5.5 per cent in L_2 x T_1. The average calcium content exhibited by hybrids was 3.6 per cent.

The lines showed a range from 1.1 per cent in L_4 to 2.3 per cent in L_5 for phosphorus content. The testers showed a range from 2.1 per cent (T_3) to 2.6 per cent (T_1 and T_2). The hybrids showed a range of variability from 1.1 per cent (L_5 x T_3) to 3.1 per cent (L_2 x T_1 and L_7 x T_1). The average phosphorus content was 2.1 per cent in hybrids.

4.2.2 Combining Ability Analysis

The general combining ability effects of lines and testers involved in the cross and the specific combining ability effects of their hybrids were evaluated and the results are presented below.

For sixteen characters, analysis of variance for combining ability was carried out and are presented in Table 4.2.2 a. The gca and sca effects were found to be significant for most of the characters. The general combining ability effects of the parents and the specific combining ability effects of the hybrids for 16 characters are given in Table 4.2.2b, 4.2.2c and Figures 8 and 9 respectively.

4.2.2.1 Plant Height

Significant differences were observed among testers and line x tester hybrids. Among the lines, three genotypes showed positive significance. They are L_1 (24.46), L_6 (7.99) and L_7 (7.15). The lines L_3 (–19.24), L_4 (–7.74) and L_5 (–15.54) recorded significant negative gca effects. Line L_2 (2.90) exhibited non significant positive gca effect. Among the testers, only T_3 (22.55) showed significant positive gca effect. The other two testers showed significant negative gca effect of –14.18 (T_1) and –8.37

Table 4.2.2a ANOVA for various characters

Source	df	Mean square							
		Plant height	No. of primary branches per plant	No. of leaves per plant	Total leaf area	Days of 50% flowering	Days to maturity	Leaf /stem ratio	Leaf area index
Replication	1	5.38	0.005	3.06	70016	0.98	5.06	0.06**	0.0002
Treatments	30	1673.42**	1.15**	335.46**	2429005**	39.82**	42.22**	0.03**	2.99**
Parents	9	331.43**	0.29**	48.51**	236995.6*	10.99	11.04*	0.009	0.30**
Crosses	20	1883.98*	1.02**	347.14**	3129779**	33.23**	42.67**	0.04**	3.77**
Parents Vs Crosses	1	9540.22**	11.49**	2684.66**	8141600**	431.12**	313.84**	0.02	11.78**
Lines (female)	6	1393.17	1.80	741.40**	4446080	58.46*	85.21**	0.04	5.89
Testers (male parent)	2	5457.19*	0.26	46.90	962624	17.66	24.84	0.04	1.19
Line x Tester	12	1533.85**	0.75**	200.04**	2832821**	23.20**	24.37**	0.04**	3.14**
Error	30	54.14	0.04	6.58	83861.34	4.98	4.6	0.008	0.06

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

(T_2). The sca effect was significant and positive for ten hybrids with the hybrids L_7 x T_1 (35.60) and L_6 x T_2 (34.34) having maximum significance. Seven hybrids exhibited significant negative sca effect with the hybrids L_6 x T_1 (–46.65) and L_7 x T_2 (–44.76) having the maximum significance.

4.2.2.2 Number of Primary Branches per Plant

Number of primary branches per plant showed significant differences among line x tester hybrids. Two of the lines exhibited positive and significant gca effects i.e., L_1 (0.82) and L_5 (1.90). None of the testers showed significance. The hybrid L_7 x T_3 (1.20) alone showed positively significant sca effect and negative sca significance was recorded in L_3 x T_1 (–6.67).

4.2.2.3 Number of Leaves per Plant

For number of leaves per plant significant differences were observed among lines and line x tester hybrids. Among lines, L_1 (13.00), L_2 (9.53), L_7 (8.23) and L_6 (2.20) showed positive significant gca values and L_3 (–14.17), L_5 (–13.37) and L_4 (–5.43) showed significant negative gca effect. Among testers T_3 (1.92) showed positive significance and T_2 (–1.72) showed negative significance. T_1 was not significant. Eight hybrids L_6 x T_3 (15.26), L_7 x T_1 (12.70), L_2 x T_1 (10.00), L_1 x T_1 (4.53), L_5 x T_1 (4.80), L_4 x T_2 (7.65), L_3 x T_3 (2.82) and L_4 x T_3 (3.29) showed positive and significant sca effect. The hybrids L_3 x T_1 (–4.80), L_4 x T_1 (–10.94), L_6 x T_1 (–16.27), L_2 x T_2 (–4.92), L_7 x T_2 (–4.52), L_1 x T_3 (–4.74), L_2 x T_3 (–5.08), L_5 x T_3 (–3.38) and L_7 x T_3 (–8.18) recorded negatively significant sca effects.

4.2.2.4 Total Leaf Area

Total leaf area differed significantly among line x tester hybrids significantly. Among the lines, L_1 (1242.15), L_2 (669.97), L_6 (330.35) and L_7 (135.17) had positively significant gca effects and negative significance was recorded by L_3 (–1015.13), L_4 (–252.18) and L_5

Table 4.2.2a Continued

Source	df	Mean square							
		Dry weight of leaf	Dry weight of stem	Green fodder yield	Dry matter yield	Crude protein content	Crude fibre content	Calcium content	Phosphorus content
Replication	1	0.02	40.63	0.08	- 0.15	0.003	1.55	0.06	0.0001
Treatments	30	633.65**	467.71**	189.10**	23.65**	16.52**	4.9**	2.11**	0.59**
Parents	9	137.51**	242.68	30.37**	10.87*	5.01**	2.97**	1.18**	0.43**
Crosses	20	590.21**	461.38**	211.76**	22.13**	16.87**	3.65**	2.49**	0.68**
Parents Vs Crosses	1	5967.64**	2619.67**	1164.49**	169.03**	113.10**	47.30**	2.83**	0.34**
Lines (female)	6	357.97	469.65	291.24	17.60	23.22	5.93	2.80	1.08
Testers (male parent)	2	150.20	21.74	81.60	2.83	6.09	0.80	2.00	0.18
Line x Tester	12	779.67**	530.52**	193.72**	27.61**	15.49**	2.99**	2.41**	0.56**
Error	30	37.02	116.87	5.35	3.77	0.18	0.37	4.78	2.35

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

EC 241027 X UPC 953 (L6XT3)

IFC 8401 X EC 241044 (L2 X T1)

IFC 95102 X EC 241044 (L1 X T1)

Plate.4. F_1 hybrids

(−1110.34). All three testers showed significant gca effects. T_1 showed positive significance of 300.01 and T_2 and T_3 expressed negative significance of −114.39 and −185.62 respectively. All the twenty one hybrids had significant sca values with eleven hybrids exhibiting positive significant sca effect and ten hybrids recording significant negative sca effects.

4.2.2.5 Days to 50 per cent Flowering

Significant differences were recorded for days to 50 per cent flowering among lines and line x tester hybrids. Lines L_3 (−2.49) and L_6 (−3.99) exhibited significant negative gca effect and lines L_5 (2.35) and L_7 (5.21) showed significant positive gca effect. None of the testers showed significance. Among the hybrids, L_1 x T_1 (−2.92), L_6 x T_2 (−2.97), L_2 x T_3 (−2.67) and L_5 x T_3 (−4.60) recorded significant and negative sca effects. The hybrid combinations L_5 x T_1 (3.31), L_1 x T_3 (4.56) and L_6 x T_3 (5.03) exhibited positive and significant sca effects.

4.2.2.6 Days to Maturity

Days to maturity varied significantly among lines and line x testers hybrids. Among lines, positive and significant gca effect was expressed by L_3 (5.8) and L_4 (3.67). L_1 (−3.40), L_2 (−3.63) and L_6 (−3.4) exhibited significant and negative gca effects. None of the testers exhibited significant gca effect. Among hybrids, negative and significant sce effect was shown by L_7 x T_1 (−4.50), L_4 x T_2 (−3.02), L_5 x T_2 (−2.76), L_2 x T_3 (−2.98) and L_6 x T_3 (−4.01). The hybrid L_5 x T_1 (3.67) exhibited positively significant sca effects.

4.2.2.7 Leaf / Stem Ratio

Among lines, L_5 (−0.48) and L_7 (−0.81) exhibited significant and negative gca effect. No significant gca effect was recorded in testers. There was no significant sca effect in the hybrids.

4.2.2.8 Leaf Area Index

For leaf area index, there was significant difference among line x tester hybrids. Positive and significant gca effect was shown by L_1 (1.40) and L_2 (0.68) among lines. L_3 (–1.19) and L_5 (–1.29) showed significant negative gca effect. Among testers, significant gca effect was not shown by any of them. Among the hybrids, L_2 x T_1 (1.15), L_7 x T_1 (1.74), L_4 x T_2 (1.20) and L_6 x T_3 (1.87) exhibited positively significant sca effect. Negative and significant sca effect was shown by L_4 x T_1 (–1.51) and L_6 x T_1 (–1.91).

4.2.2.9 Dry Weight of Leaf

Dry weight of leaf differed significantly among line x tester hybrids. Among lines only two genotypes, L_1 (4.55) and L_2 (14.30) showed highly significant positive gca effects. L_5 showed highly significant gca value of –10.72. Two of the testers had significant value, T_2 with positive significance of 3.18 and T_3 with negative significance of –3.37. The sca effect was positive and significant for hybrids like L_1 x T_1 (19.26), L_3 x T_1 (9.53), L_7 x T_1 (24.79), L_1 x T_2 (7.92), L_5 x T_2 (14.89) L_2 x T_3 (8.92), L_4 x T_3 (21.45) and L_6 x T_3 (21.45). Significant negative sca effect was shown by hybrids L_2 x T_1 (–7.14), L_4 x T_1 (–19.66), L_6 x T_1 (–23.81), L_3 x T_2 (–10.11), L_7 x T_2 (–11.49), L_1 x T_3 (–27.18), L_5 x T_3 (–11.92) and L_7 x T_3 (–13.30).

4.2.2.10 Dry Weight of Stem

The combining ability analysis for dry weight of stem displayed that line x tester hybrids differed significantly. Three genotypes, L_1 (7.34), L_2 (11.50) and L_3 (4.57) recorded significant positive gca effects and two genotypes L_4 (–10.71) and L_5 (–12.11) recorded significant negative gca effect among lines. Among testers, none of the testers had significant gca effects. Among hybrids, eight hybrids *viz.*, L_1 x T_1 (11.12), L_7 x T_1 (26.37), L_1 x T_2 (8.72), L_5 x T_2 (7.32), L_6 x T_2 (8.74), L_3 x T_3 (7.93), L_4 x

Table 4.2.2b Gca effects of lines and testers

Lines	Plant height	No. of primary branches per plant	No. of leaves per plant	Total leaf area	Days to 50% flowering	Days to maturity	Leaf/ stem ratio	Leaf area index
L_1	24.46**	0.82**	13.00**	1242.15**	−1.22	−3.40**	0.036	1.40**
L_2	2.90	0.49	9.53**	669.97**	1.11	−3.63**	−0.31	0.68*
L_3	−19.24**	−0.55	−14.17**	−1015.13**	−2.49*	5.8**	−0.14	−1.19**
L_4	−7.74**	0.25	−5.43**	−252.18**	−0.99	3.67**	0.02	−0.35
L_5	−15.54**	1.90**	−13.37**	−1110.32**	2.35*	1.3	−0.48*	−1.29**
L_6	7.99**	−0.55	2.20*	330.35**	−3.99**	−3.40**	−0.31	0.297
L_7	7.15**	−0.48	8.23**	135.17**	5.21**	0.33	−0.81**	0.45
SE	3.003	0.08	1.05	118.22	0.911	0.88	0.037	0.101
Testers								
T_1	−14.18**	0.13	−0.20	300.01**	−1.28	1.44	0.017	0.31
T_2	−8.37**	−0.14	−1.72*	−114.39**	0.84	1.19	0.04	−0.045
T_3	22.55**	0.005	1.92*	−185.62**	0.44	0.25	−0.06	−0.27
SE	1.967	0.05	0.68	77.40	0.60	0.57	0.02	0.066

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

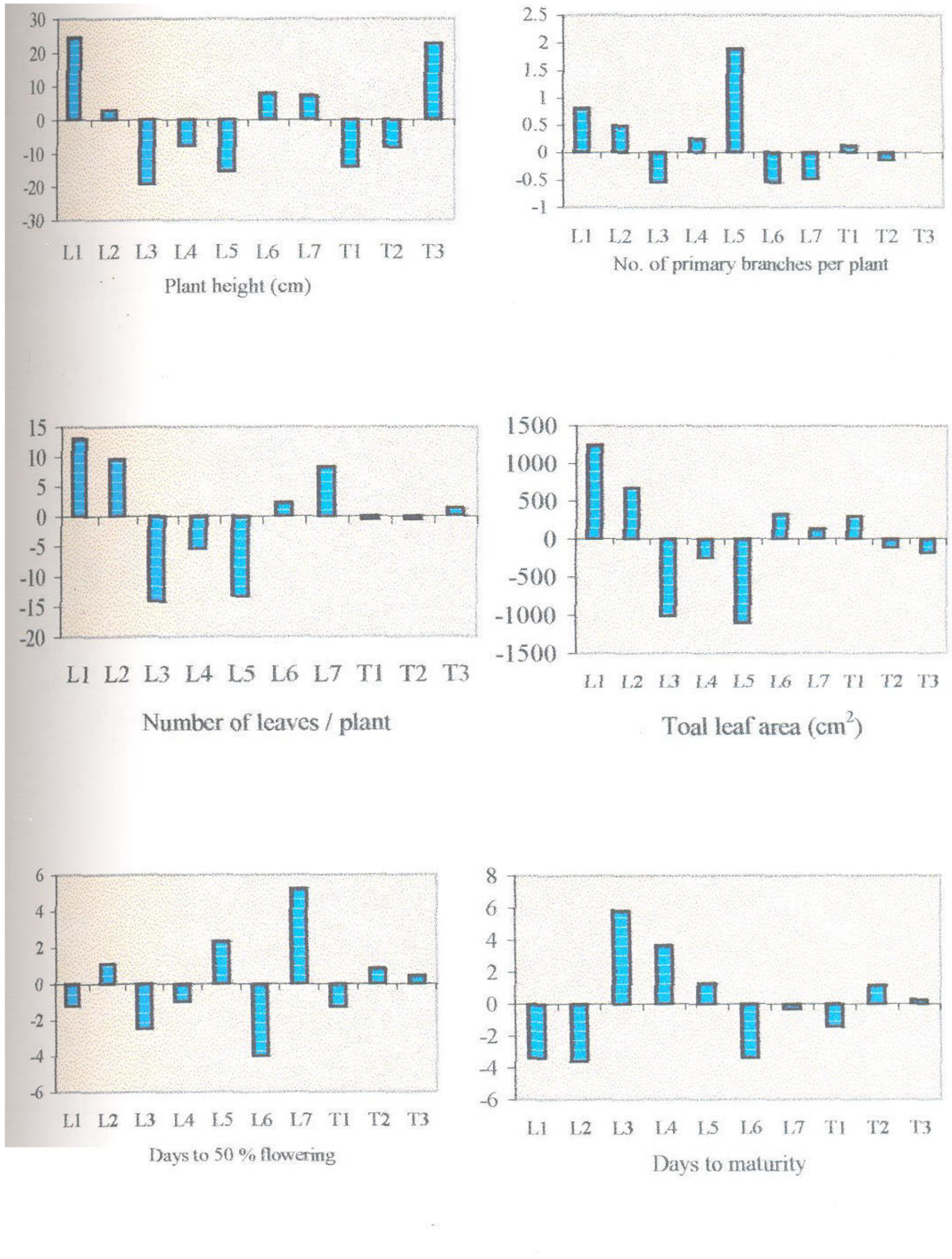


Fig. 8 General combining ability effects of parents

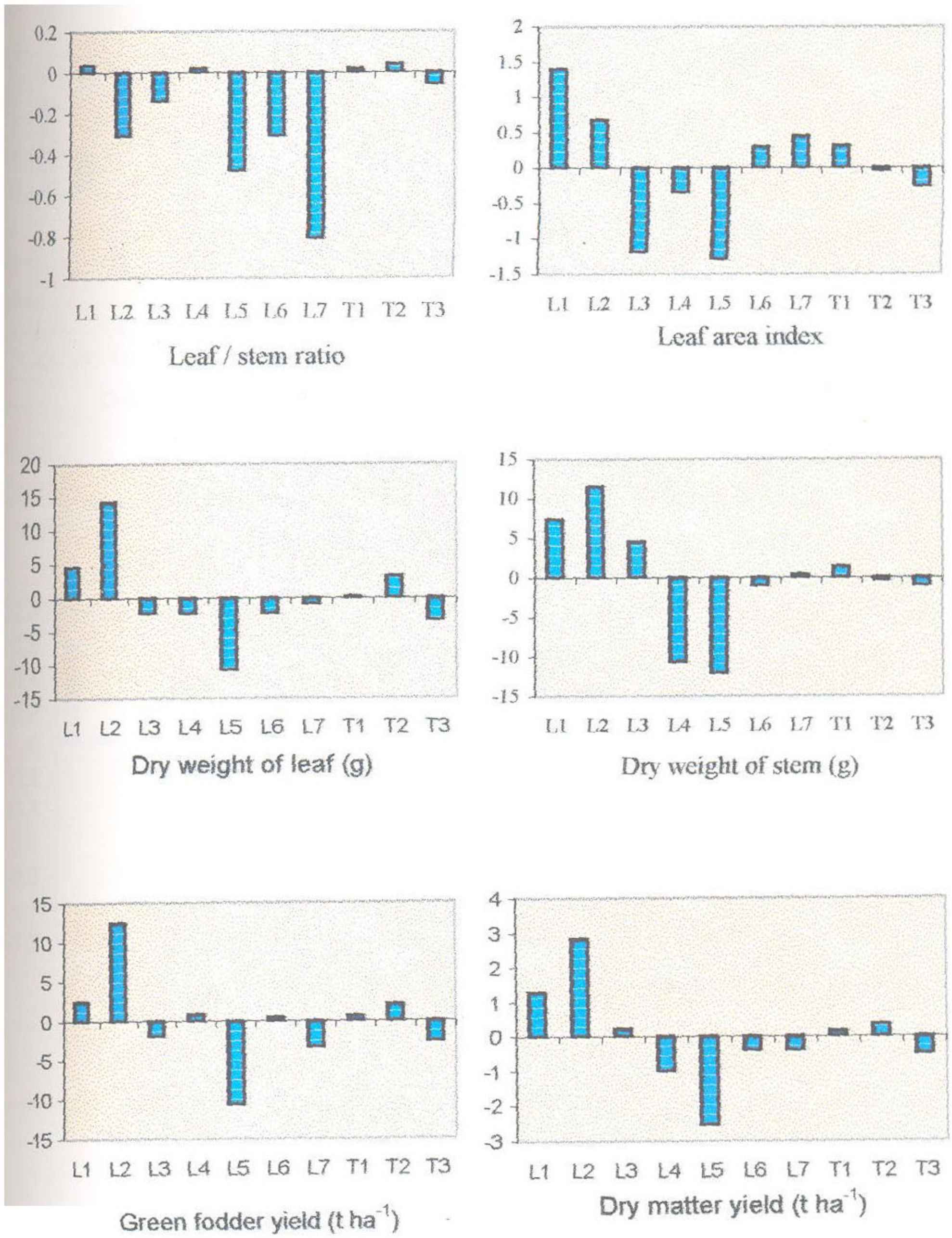


Fig. 8 Continued

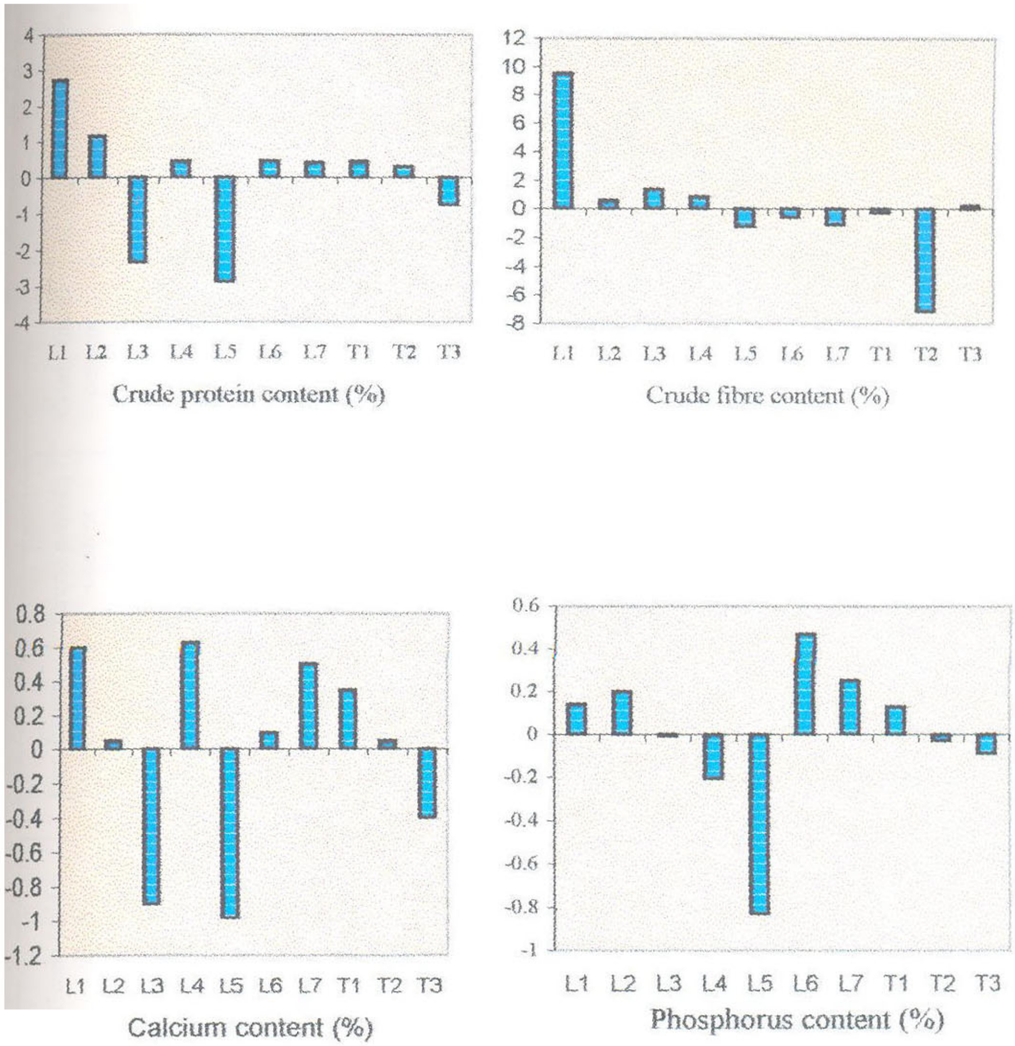


Fig. 8 Continued

Table 4.2.2b Continued

Lines	Dry weight of leaf	Dry weight of stem	Green fodder yield	Dry matter yield	Crude protein content	Crude fibre content	Calcium content	Phosphorus content
L_1	4.55**	7.34**	2.49*	1.29	2.74**	9.52**	0.60	0.14
L_2	14.30**	11.50**	12.39**	2.84**	1.15**	0.61	0.05	0.20
L_3	-2.37	4.57*	-1.997	0.23	-2.35**	1.33*	-0.90**	-0.01
L_4	-2.39	-10.71**	0.80	-1.01	0.47	0.86	0.63*	-0.21
L_5	-10.72**	-12.11**	-10.75**	-2.54**	-2.88**	-1.24*	-0.98**	-0.83**
L_6	-2.39	-0.99	0.44	-0.41	0.47	-0.57	0.10	0.47
L_7	-0.99	0.39	-3.36**	-0.41	0.40	-1.09*	0.50	0.25
SE	2.48	4.41*	0.94	0.79	0.175	0.25	0.09	0.06
Testers								
T_1	0.19	1.40	0.58	0.16	0.45	-0.24	0.35	0.13
T_2	3.18*	-0.40	2.07	0.35	0.31	-7.14**	0.05	-0.03
T_3	-3.37*	-0.995	-2.65	-0.51	-0.76*	0.24	-0.40	-0.09
SE	1.63	2.89	0.62	0.52	0.11	0.16	5.85	0.04

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

T_3 (19.06) and L_6 x T_3 (13.48) expressed significant positive sca effect. Significant negative sca effect was shown by L_3 x T_1 (–6.96), L_4 x T_1 (–8.33), L_6 x T_1 (–22.21), L_4 x T_2 (–10.73), L_7 x T_2 (–13.48), L_1 x T_3 (–19.84), L_5 x T_3 (–8.74) and L_7 x T_3 (–12.89).

4.2.2.11 Green Fodder Yield

Green fodder yield showed significant difference among line x tester hybrids. The lines IFC 95102 (L_1) (2.49) and IFC 8401 (L_2) (12.39) showed positively significant gca effect and lines EC 240744 (L_5) (–10.75) and HES 82 (L_7) (–3.36) exhibited negative significance. None of the testers were significant. Four hybrids *viz*., IFC 95102 x EC 241044 (L_1 x T_1) (11.0), HES 82 x EC 241044 (L_7 x T_1) (12.2), EC 4216 x UPC 953 (L_4 x T_3) (15.92) and EC 241027 x UPC 953 (L_6 x T_3) (7.03) showed significant positive sca effect. Significant negative sca effect was exhibited by IFC 8401 x EC 241044 (L_2 x T_1) (–4.45), EC 4216 x EC 241044 (L_4 x T_1) (–12.77), EC 241027 x EC 241044 (L_6 x T_1) (–9.60), EC 4216 x N 344 (L_4 x T_2) (–3.15), HES 82 x N 311 (L_7 x T_2) (–4.54), IFC 95102 x UPC 953 (L_1 x T_3) (–13.06), EC 240744 x UPC 953 (L_5 x T_3) (–4.43) and HES 82 x UPC 953 (L_7 x T_3) (–7.66).

4.2.2.12 Dry Matter Yield

Drymatter yield varied significantly among line x tester hybrids. Positive and significant gca effect was expressed by IFC 8401 (L_2) (2.84) among lines. Negatively significant gca effect was expressed by EC 240744 (L_5) (–2.54). None of the testers had significant gca effects. The hybrids, IFC 95102 x EC 241044 (L_1 x T_1) (3.44), HES 82 x EC 241044 (L_7 x T_1) (5.09), EC 4216 x UPC 953 (L_4 x T_3) (4.06) and EC 241027 x UPC 953 (L_6 x T_3) (3.91) exhibited positive and significant sca effects. Five hybrids *viz*., EC 4216 x EC 241044 (L_4 x T_1) (–2.61), EC 241027 x EC 241044 (L_6 x T_1) (–5.11), HES 82 x N 311 (L_7 x T_2) (–2.50), IFC 95102 x UPC 953 (L_1 x T_3) (–5.24) and HES 82 x UPC 953 (L_7 x T_3) (–2.59) displayed significant and negative gca effect.

4.2.2.13 Crude Protein Content

Crude protein content exhibited significant difference among line x tester hybrids. Positive and significant gca effect was expressed by L_1 (2.74) and L_2 (1.15). Negative significance was exhibited by L_3 (–2.35) and L_5 (–2.88). Among testers, T_3 had significant negative gca effect of –0.76. The hybrids L_2 x T_1 (2.83), L_7 x T_1 (4.03), L_4 x T_2 (1.96), L_6 x T_2 (1.21) and L_6 x T_3 (4.07) had positively significant sca effect. Significant negative sca effect was expressed by L_6 x T_1 (–5.28), L_7 x T_2 (–2.24), L_2 x T_3 (–2.31) and L_7 x T_3 (–1.61).

4.2.2.14 Crude Fibre Content

Significant difference was noticed among line x tester hybrids. Among the lines, L_1 (9.52) and L_3 (1.33) had positively significance gca effect and L_5 (1.24) and L_7 (–1.09) had significant negative gca values. Among testers, significant negative gca effect was exhibited by T_2 (–7.14). Only one hybrid, L_2 x T_2 (1.52) exhibited significant positive sca effect and three hybrids, L_2 x T_1 (–1.50), L_4 x T_2 (–1.68) and L_7 x T_3 (–1.48) had significant negative sca effect.

4.2.2.15 Calcium Content

Calcium content showed significant difference among line x testers hybrids. Negative and significant gca effect was shown by lines L_3 (–0.90) and L_5 (–0.98). None of the testers exhibited significant gca effect. Among hybrids, L_2 x T_1 (1.44), L_7 x T_1 (0.94), L_3 x T_3 (1.19) and L_6 x T_3 (1.24) expressed significant positive sca effect. Of the twenty one hybrids L_6 x T_1 (–1.91) and L_2 x T_3 (–0.81) expressed significant negative sca effect.

4.2.2.16 Phosphorus Content

Significant difference was recorded among line x tester hybrids for the character. Among lines only one genotype, L_5 recorded significant and negative gca effect of –0.83. None of the testers had significant gca effect. Out of the 21 hybrids, L_2 x T_1 (0.70), L_3 x T_3 (0.74) and L_7 x T_1

Fig. 9 Specific combining ability effects of hybrids

Fig. 9 Continued

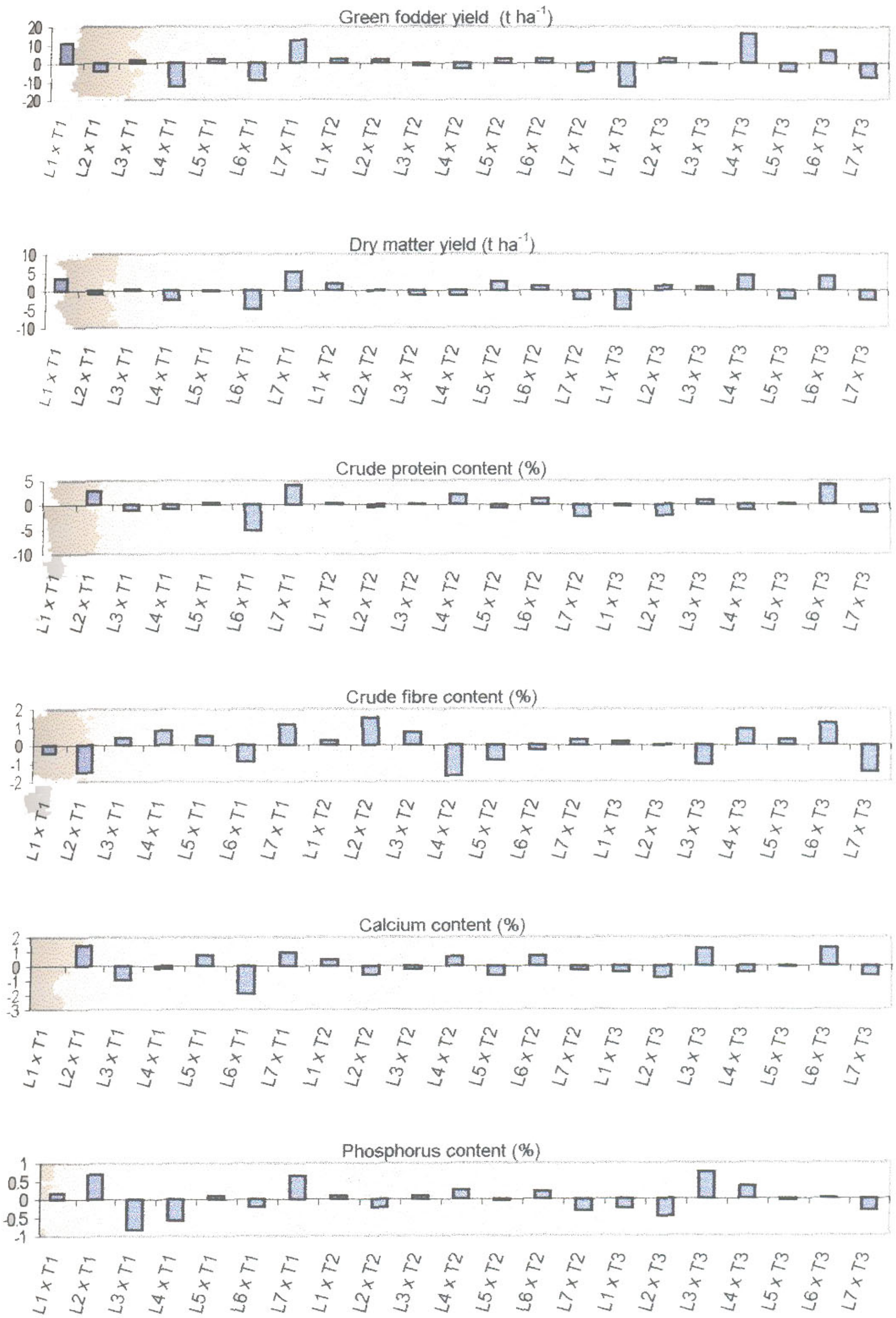


Fig. 9 Continued

Table 4.2.2c sca effects of hybrids

Sl. No.	Hybrids	Plant height, cm	No. of primary branches/ plant	No. of leaves / plant	Total leaf area, cm^2	Days to 50% flowering	Days to maturity	Leaf / stem ratio	Leaf area index
1.	$L_1 \times T_1$	11.48**	0.07	4.53**	298.22**	-2.92*	-1.83	0.10	0.49
2.	$L_2 \times T_1$	8.75**	0.60	10.00**	998.00**	0.34	-2.00	0.003	1.15**
3.	$L_3 \times T_1$	-11.42**	-6.67**	-4.80**	-335.29**	-1.56	1.57	0.15	-0.38
4.	$L_4 \times T_1$	-10.62**	-0.07	-10.94**	-1424.19**	-0.26	0.90	-0.08	-1.51**
5.	$L_5 \times T_1$	12.88**	-0.33	4.80**	333.89**	3.31*	3.67**	-0.02	0.42
6.	$L_6 \times T_1$	-46.65**	0.23	-16.27**	-1746.58**	-2.06	2.17	-0.13	-1.91**
7.	$L_7 \times T_1$	35.60**	-0.43	12.70**	1875.96**	3.14*	-4.50**	0.02	1.74**
8.	$L_1 \times T_2$	-11.03*	0.14	0.21	87.52**	-1.64	0.04	0.07	-0.05
9.	$L_2 \times T_2$	-15.46**	0.07	-4.92**	-214.09**	2.33	4.98**	-0.11	-0.34
10.	$L_3 \times T_2$	15.07**	-0.30	1.98	39.69**	2.13	-1.56	-0.08	-0.12
11.	$L_4 \times T_2$	6.67**	0.70	7.65**	1189.81**	0.33	-3.02*	0.14	1.20**
12.	$L_5 \times T_2$	15.17**	0.34	-1.42	29.94*	1.30	-2.76*	0.15	-0.07
13.	$L_6 \times T_2$	34.34**	-0.20	1.01	121.77**	-2.97*	1.84	-0.06	0.05
14.	$L_7 \times T_2$	-44.76**	-0.76	-4.52**	-1175.25**	-1.47	0.48	-0.11	-0.65
15.	$L_1 \times T_3$	0.45	-0.20	-4.74**	-385.74**	4.56**	1.79	-0.17	-0.43
16.	$L_2 \times T_3$	6.72**	-0.67	-5.08**	-783.91**	-2.67*	-2.98*	-0.15	-0.82
17.	$L_3 \times T_3$	-3.65	0.36	2.82*	374.99**	-0.57	-1.43	-0.07	0.5
18.	$L_4 \times T_3$	3.95	-0.64	3.29*	234.39**	-0.07	2.12	-0.55	0.32
19.	$L_5 \times T_3$	-28.05**	0.005	-3.38*	-363.83**	-4.60**	-0.91	-0.14	-0.35
20.	$L_6 \times T_3$	12.32**	0.04	15.26**	-1624.81**	5.03**	-4.01**	0.20	1.87**
21.	$L_7 \times T_3$	9.17**	1.20**	-8.18**	700.71**	-1.67	4.02**	0.10	-1.08

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

Table 4.2.2c Continued

Sl. No.	Hybrids	Dry wt. of leaf, g	Dry wt of stem, g	Green fodder yield, t ha^{1}	Dry matter yield, t ha^{1}	Crude protein content, %	Crude fibre content, %	Calcium content, %	Phosphorus content, %
1.	$L_1 \times T_1$	19.26**	11.12**	11.0**	3.44**	0.00	-0.43	0.01	0.17
2.	$L_2 \times T_1$	-7.14**	-1.40	-4.45**	-0.96	2.83*	-1.50*	1.44**	0.70*
3.	$L_3 \times T_1$	9.53**	-6.96**	1.58	0.31	-1.07	0.39	-0.96*	-0.83*
4.	$L_4 \times T_1$	-19.66**	-8.33**	-12.77**	-2.61*	-0.88	0.80	-0.20	-0.58
5.	$L_5 \times T_1$	-2.97	1.42	2.03	0.17	0.37	0.50	0.72	0.09
6.	$L_6 \times T_1$	-23.81**	-22.21**	-9.60**	-5.11**	-5.28**	-0.91	-1.91**	-0.21
7.	$L_7 \times T_1$	24.79**	26.37**	12.2**	5.09**	4.03**	1.15	0.94*	0.65*
8.	$L_1 \times T_2$	7.92**	8.72**	2.06	1.80	0.29	0.24	0.43	-0.09
9.	$L_2 \times T_2$	1.78	0.40	1.96	-0.20	-0.52	1.52*	-0.62	0.23
10.	$L_3 \times T_2$	-10.11**	-0.96	-1.30	-1.28	0.13	0.71	-0.22	0.09
11.	$L_4 \times T_2$	-1.79	-10.73**	-3.15**	-1.45	1.96**	-1.68*	0.65	0.24
12.	$L_5 \times T_2$	14.89**	7.32**	2.40	2.43	-0.64	-0.83	-0.64	-0.05
13.	$L_6 \times T_2$	2.36	8.74**	2.56	1.20	1.21*	-0.29	0.68	0.20
14.	$L_7 \times T_2$	-11.49**	-13.48**	-4.54**	-2.50*	-2.42**	0.32	-0.27	-0.33
15.	$L_1 \times T_3$	-27.18**	-19.84**	-13.06**	-5.24**	-0.29	0.19	-0.41	-0.26
16.	$L_2 \times T_3$	8.92**	0.100	2.49	1.16	-2.31**	0.03	-0.81*	-0.47
17.	$L_3 \times T_3$	0.58	7.93**	-0.28	0.97	0.94	-1.09	1.19**	0.74*
18.	$L_4 \times T_3$	21.45**	19.06**	15.92**	4.06**	-1.08	0.87	-0.45	0.34
19.	$L_5 \times T_3$	-11.92**	-8.74**	-4.43**	-2.26	0.27	0.32	-0.08	-0.04
20.	$L_6 \times T_3$	21.45**	13.48**	7.03**	3.91**	4.07**	1.21	1.24**	0.009
21.	$L_7 \times T_3$	-13.30**	-12.89**	-7.66**	-2.59*	-1.61**	-1.48*	-0.66	-0.32

(0.65) exhibited significant positive sca effect and one hybrid L_3 x T_1 (–0.83) had negatively significant sca effect.

4.2.3 Proportional Contribution

Proportional contribution of lines, testers and line x tester hybrids to total variance was estimated and presented in Table 4.2.3 and Fig. 7. Among different characters, the proportional contribution of lines ranged from a minimum of 18.19 per cent for dry weight of leaf to a maximum of 64.07 per cent for number of leaves per plant. In testers also proportional contribution varied very widely from a minimum of 0.47 per cent for dry weight of stem to a maximum of 28.97 for plant height. In line x tester hybrids the range was from 34.27 for days to maturity to 79.26 per cent for dry weight of leaf.

Contribution of lines to total variance was high for all the characters except plant height. For plant height, the contribution of testers to total variance was high (28.97 per cent).

4.2.4 Genetic Components of Variance

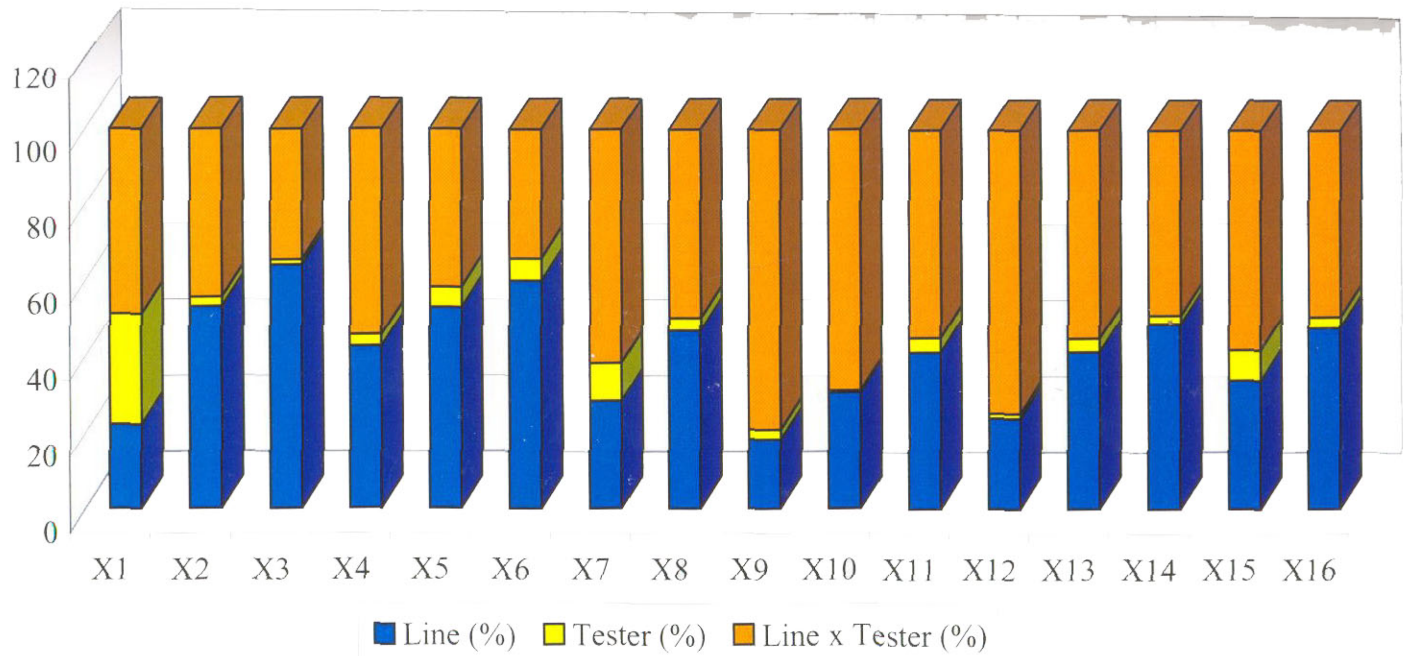
The additive variance (σ^2a) and dominance variance (σ^2d) was estimated and presented in Table 4.2.4. For all characters under study excluding number of primary branches per plant and total leaf area dominance variance was greater than additive variance and the ratio was more than unity (5.75 and 1.69 respectively). The additive to dominance ratio ranged from a minimum of 0.005 for leaf/stem ratio and calcium content to a maximum of 5.75 for number of primary branches per plant. Predominance of dominance variance to additive variance was observed for most characters indicating the predominance of non additive gene action.

4.2.5 Heterosis

The heterotic expression of the 21 hybrids in terms of relative heterosis and standard heterosis was analysed for sixteen characters and

Table 4.2.3 Proportional contribution of lines, testers and line x testers to the total variance

Sl. No.	Character	Line, %	Tester, %	Line x Tester, %
1	Plant height, cm	22.18	28.97	48.85
2	Number of primary branches per plant	53.04	2.53	44.43
3	Number of leaves per plant	64.07	1.35	34.58
4	Total leaf area	42.62	3.08	54.31
5	Days to 50% flowering	52.79	5.32	41.89
6	Days to maturity	59.91	5.82	34.27
7	Leaf / stem ratio	28.30	9.96	61.73
8	Leaf area index	46.87	3.16	49.97
9	Dry weight of leaf, g	18.19	2.54	79.26
10	Dry weight of stem, g	30.54	0.47	68.99
11	Green fodder yield t ha^{-1}	41.26	3.85	54.89
12	Dry matter yield t ha^{-1}	23.86	1.28	74.86
13	Crude protein content, %	41.29	3.61	55.09
14	Crude fibre content, %	48.72	2.19	49.09
15	Calcium content, %	33.77	8.04	58.19
16	Phosphorus content, %	47.66	2.72	49.61



X1 Plant height
X2 Number of primary branches/plant
X3 Number of leaves / plant
X4 Total leaf area
X5 Number of days to 50 per cent flowering

X6 Days to maturity
X7 Leaf/stem ratio
X8 Leaf area index
X9 Dry weight of leaf
X10 Dry weight of stem

X11 Green fodder yield
X12 Dry matter yield
X13 Crude protein content
X14 Crude fibre content
X15 Calcium content
X16 Phosphorus content

Fig. 7 Proportional contribution of lines, testers and line x tester to the total variance

Table 4.2.4 Genetic components of variance

Sl. No.	Character	Additive variance σa^2	Dominance variance σd^2	$\sigma a^2 / \sigma d^2$ (F=0)
1	Plant height, cm	27.35	739.85	0.037
2	Number of primary branches per plant	2.07	0.36	5.750
3	Number of leaves per plant	11.49	96.73	0.120
4	Total leaf area, cm^2	23199.84	13744.80	1.688
5	Days to 50% flowering	0.78	9.10	0.086
6	Days to maturity	1.43	9.88	0.140
7	Leaf /stem ratio	0.00009	0.018	0.005
8	Leaf area index	0.05	1.54	0.032
9	Dry weight of leaf, g	14.80	371.32	0.039
10	Dry weight of stem, g	5.40	206.82	0.030
11	Green fodder yield, t ha^{-1}	1.41	94.18	0.015
12	Dry matter yield, t ha^{-1}	0.43	11.92	0.036
13	Crude protein content, %	0.11	7.65	0.014
14	Crude fibre content, %	0.05	1.31	0.038
15	Calcium content, %	0.006	1.18	0.005
16	Phosphorus content, %	0.009	0.27	0.030

the results are presented in Tables 4.2.5. The standard parent taken was HES 82 (L_7). The graphical representation of relative heterosis and standard heterosis for all characters are given in Fig. 10. The values are expressed in percentage.

4.2.5.1 Plant Height

The relative heterosis of the hybrids ranged from –14.5 to 45.5 per cent. Significant relative heterosis was exhibited by all hybrids except five and the maximum positive and significant heterosis was recorded in the hybrid L_6 x T_3 (45.5). The other best hybrids with significant positive heterosis were L_6 x T_2 (44.3), L_1 x L_3 (40.4), L_2 x L_3 (36.2), L_7 x T_3 (35.1) and L_7 x T_1 (31.8). Four hybrids, L_6 x T_1 (–14.5), L_7 x T_2 (14.4), L_3 x T_1 (–8.9) and L_4 x T_1 (–8.9) showed significant negative heterosis.

The hybrid L_1 x T_3 (47.69) showed the highest positive significant heterosis over the standard parent and the hybrids L_6 x T_3 (45.3), L_7 x T_3 (42.71), L_6 x T_2 (39.33) and L_2 x T_3 (38.37) and L_7 x T_1 (36.03) also had high positively significant values. Significant negative heterosis was shown by the hybrid L_6x T_1 (–16.7).

4.2.5.2 Number of Primary Branches per Plant

The relative heterosis in this character ranged from –15.91 to 48.2. The highest positive significant heterosis was shown by the hybrid L_2 x T_1 (48.2). Other hybrids which exhibited high positive significant heterosis were L_1 x T_1 (45.2), L_1 x T_3 (40.7), L_7 x T_3 (39.7), L_4 x T_2 (38.8) and L_1 x T_2 (37.2). Two hybrids L_6 x T_2 (–11.6) and L_7 x T_2 (–15.9) had significant negative heterosis.

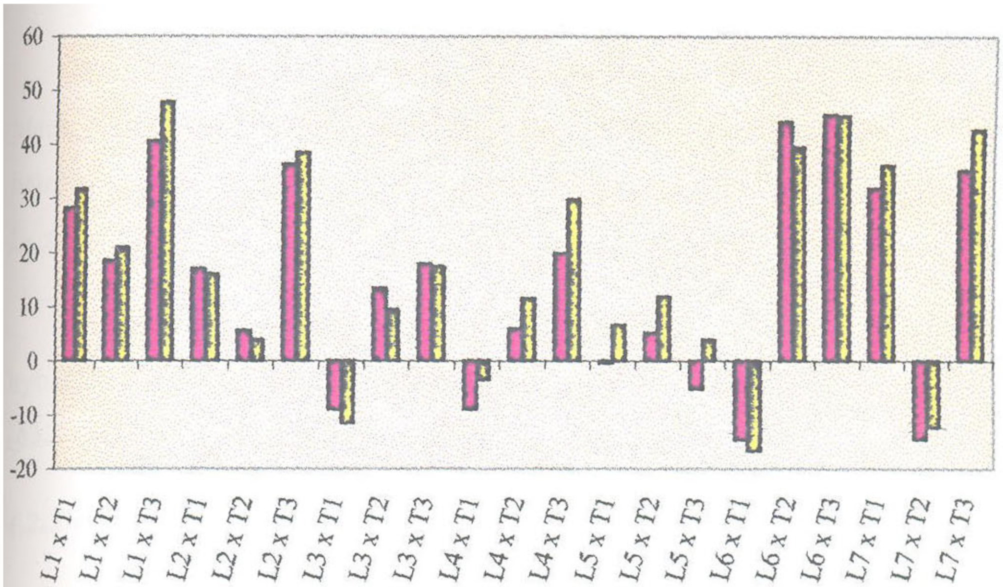
The standard heterosis ranged from –6.3 to 69.6. Maximum significant positive heterosis was shown by the hybrid L_7 x T_1 (69.6). The hybrids L_2 x T_1 (66.9), L_1 x T_1 (66.3), L_1 x T_2 (57.8), L_4 x T_2 (36.9) and L_7 x T_2 (39.7) also showed high positive standard heterosis.

Plate.4. F_1 hybrids (Continued)

Table 4.2.5 Estimates of percentage heterosis over mid and standard parents for various characters

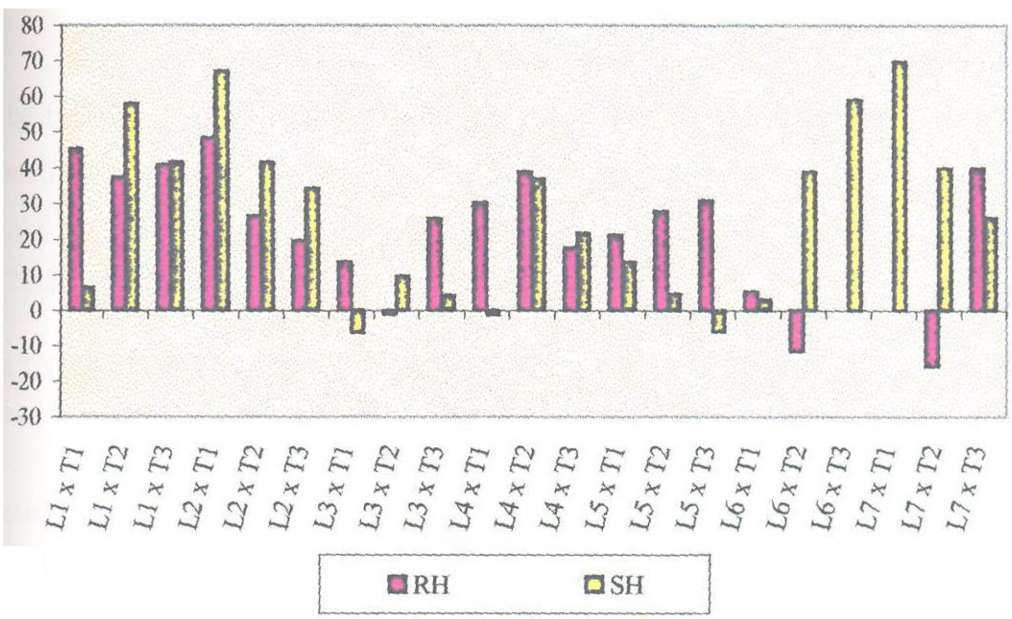
Sl. No.	Parents / hybrids	1. Plant height			2. No. of primary branches / plant		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	152.9			4.0		
2.	L_2	141.8			4.1		
3.	L_3	135.7			3.7		
4.	L_4	162.6			3.9		
5.	L_5	166.3			3.7		
6.	L_6	136.5			4.9		
7.	L_7	154.3			4.2		
8.	T_1	164.2			4.4		
9.	T_2	162.0			4.6		
10.	T_3	171.1			4.1		
11.	$L_1 \times T_1$	203.1	28.10**	31.63**	6.1	45.24**	66.31**
12.	$L_1 \times T_2$	186.4	18.39**	20.80**	5.9	37.21**	57.79**
13.	$L_1 \times T_3$	227.9	40.42**	47.69**	5.7	40.74**	41.44**
14.	$L_2 \times T_1$	178.8	16.86**	15.88**	6.3	48.24**	66.92**
15.	$L_2 \times T_2$	160.4	5.6058	3.95	5.5	26.44**	41.44**
16.	$L_2 \times T_3$	213.5	36.20**	38.37**	4.9	19.51**	34.22**
17.	$L_3 \times T_1$	136.5	– 8.97*	-11.54	4.6	13.58**	-6.27
18.	$L_3 \times T_2$	168.8	13.40**	9.40	4.1	– 1.21	9.51
19.	$L_3 \times T_3$	181.0	17.77**	17.30*	4.9	25.64**	4.18
20.	$L_4 \times T_1$	148.8	– 8.94*	-3.56	5.4	30.12**	-1.33
21.	$L_4 \times T_2$	171.9	5.91	11.41	5.9	38.82**	36.88**
22.	$L_4 \times T_3$	200.1	19.71**	29.68**	4.7	17.50**	21.67**
23.	$L_5 \times T_1$	164.5	– 0.45	6.61	4.9	20.99**	13.50**
24.	$L_5 \times T_2$	172.6	5.15	11.86	5.3	27.71**	4.56
25.	$L_5 \times T_3$	160.3	– 5.15	3.89	5.1	30.77**	-6.08
26.	$L_6 \times T_1$	128.5	– 14.53**	-16.72*	4.9	5.37	3.04
27.	$L_6 \times T_2$	215.3	44.25**	39.33**	4.2	– 11.57**	38.78**
28.	$L_6 \times T_3$	224.2	45.49**	45.30**	4.5	0	58.94**
29.	$L_7 \times T_1$	209.9	31.81**	36.03**	4.3	0.00001*	69.58**
30.	$L_7 \times T_2$	135.4	– 14.42**	-12.25	3.7	– 15.91**	39.73**
31.	$L_7 \times T_3$	220.2	35.09**	42.71**	5.8	39.75**	25.85
	CD 5%		13.01	15.03		0.35	0.41
	CD 1%		17.52	20.23		0.47	0.55

RH – Relative Heterosis, SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Plant height

RH SH



Number of primary branches / plant

RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Percentage of heterosis over mid and standard parents for various characters

4.2.5.3 Number of Leaves per Plant

The hybrids exhibited significant heterosis for number of leaves per plant. Out of the 21 hybrids, 14 hybrids showed significant positive heterosis with the hybrids L_7 x T_1 (56.5), L_1 x T_1 (55.0), L_6 x T_3 (53.3), L_2 x T_1 (53.5) and L_1 x T_2 (51.1) having high significant values.

In standard heterosis, positive significance was exhibited by 14 hybrids, of which the hybrids L_7 x T_1 (69.6) and L_2 x T_1 (66.9) and L_1 x T_1 (63.1) recorded high percentage of standard heterosis.

4.2.5.4 Total Leaf Area

Significant relative heterosis was recorded by the hybrids for total leaf area. The hybrids L_7 x T_1 (55.7), L_2 x T_1 (55.3), L_1 x T_1 (50.5) and L_6 x T_3 (49.9) had high significant positive heterosis.

Standard heterosis was positive and significant for nine hybrids with the hybrid, L_7 x T_1 (61.6) having the highest values. Other hybrids with positive significance were L_2 x T_1 (54.4), L_1 x T_1 (51.7), L_6 x T_3 (50.2), L_1 x T_2 (38.6), L_1 x T_3 (27.2), L_2 x T_2 (20.3), L_4 x T_2 (30.4) and L_6 x T_2 (20.2).

4.2.5.5 Days to 50 per cent Flowering

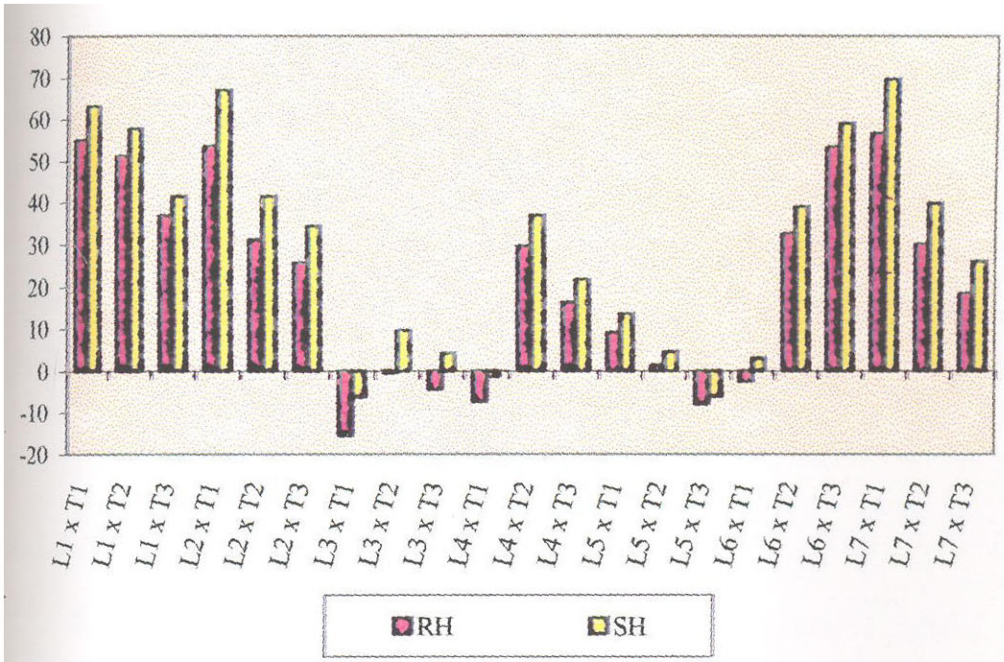
The hybrids exhibited significant negative relative heterosis and standard heterosis. Fourteen hybrids showed significant negative relative heterosis. The hybrid L_6 x T_1 (–27.86) exhibited the highest negative heterosis. This was followed closely by the hybrids L_6 x T_2 (–25.28) and L_3 x T_1 (–22.15).

Fifteen hybrids recorded significant negative standard heterosis with the hybrids L_6 x T_1 (–31.0), L_6 x T_2 (–28.7), L_1 x T_1 (-27.3) and L_3 x T_1 (–27.1) recording high negative values.

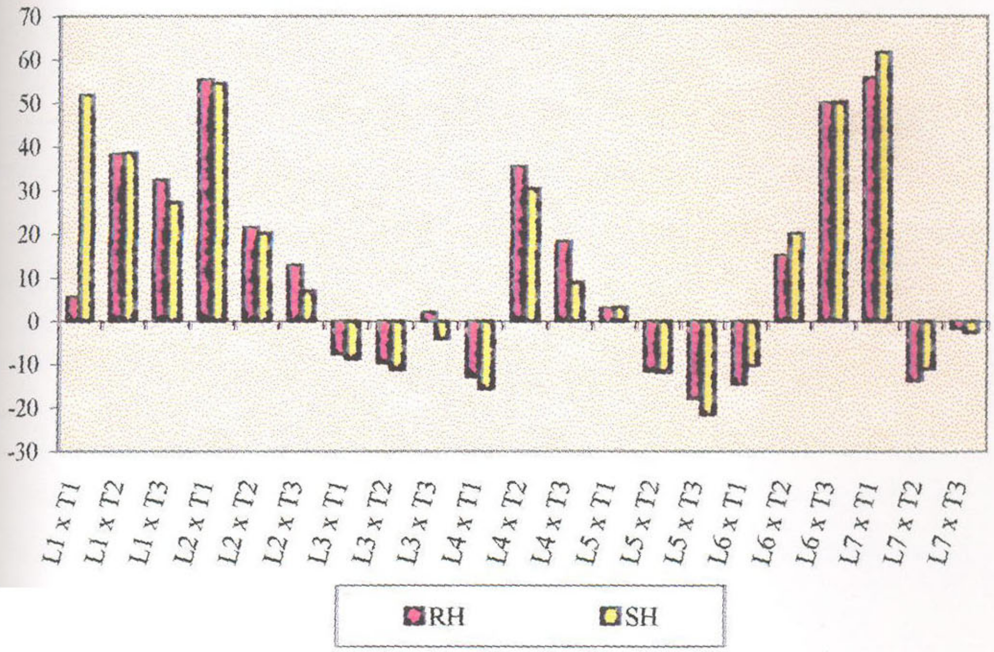
Table 4.2.5 Continued

Sl. No.	Parents / hybrids	3. Number of leaves/plant			4. Total leaf area		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	49.3			4484.85		
2.	L_2	53.0			4353.10		
3.	L_3	55.3			4285.55		
4.	L_4	50.7			4100.65		
5.	L_5	48.0			4429.60		
6.	L_6	49.7			4879.70		
7.	L_7	52.6			4767.10		
8.	T_1	61.4			5128.25		
9.	T_2	60.5			5077.40		
10.	T_3	59.4			4670.60		
11.	$L_1 \times T_1$	85.8	55.01**	63.10**	7233.25	56.49**	51.73**
12.	$L_1 \times T_2$	83.0	51.19**	57.79**	6608.15	38.21**	38.62**
13.	$L_1 \times T_3$	74.4	36.90**	41.44**	6063.65	32.46**	27.20**
14.	$L_2 \times T_1$	87.8	53.50**	66.92**	7360.85	55.27**	54.41**
15.	$L_2 \times T_2$	74.4	31.10**	41.44**	5734.35	21.61**	20.29**
16.	$L_2 \times T_3$	70.6	25.62**	34.22**	5093.3	12.89**	6.84
17.	$L_3 \times T_1$	49.3	– 15.51**	-6.27	4342.45	– 7.74	-8.91
18.	$L_3 \times T_2$	57.6	– 0.52	9.51	4223.65	– 9.78	-11.40
19.	$L_3 \times T_3$	54.8	– 4.45	4.18	4567.1	1.99	-4.20
20.	$L_4 \times T_1$	51.9	– 7.40	-1.33	4016.5	– 12.96*	-15.75*
21.	$L_4 \times T_2$	72.0	29.50**	36.88**	6216.1	35.46**	30.39**
22.	$L_4 \times T_3$	64.0	16.26**	21.67	5189.45	18.33**	8.86
23.	$L_5 \times T_1$	59.7	9.14*	13.50**	4916.45	2.88	3.13
24.	$L_5 \times T_2$	55.0	1.38	4.56	4198.1	–11.68*	-11.94
25.	$L_5 \times T_3$	49.4	– 8.01	-6.08	3733.1	–17.96**	-21.69**
26.	$L_6 \times T_1$	54.2	– 2.43	3.04	4276.65	–14.53**	-10.29
27.	$L_6 \times T_2$	73.0	32.49**	38.78**	5730.6	15.11**	20.21**
28.	$L_6 \times T_3$	83.6	53.25**	58.94**	7162.4	49.99**	50.24**
29.	$L_7 \times T_1$	89.2	56.49**	69.58**	7704	55.71**	61.61**
30.	$L_7 \times T_2$	73.5	29.97**	39.73**	4238.4	– 13.89*	-11.09
31	$L_7 \times T_3$	66.2	18.21**	25.85**	4641.7	– 1.63	-2.63
	CD 5%		4.58	5.24		512.11	591.34
	CD 1%		6.11	7.05		689.67	796.37

RH – Relative Heterosis. SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Numberof leaves / plant



Total leaf area

RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

4.2.5.6 Days to Maturity

Most of the hybrids showed negative relative heterosis and ten hybrids had significant values. The hybrids L_1 x T_1 (–15.21) and L_2 x T_1 (–15.00) had high negative values.

Highest significant negative standard heterosis was exhibited by the hybrid L_6 x T_3 (–16.6). Eight other hybrids also showed significant negative standard heterosis. They were L_1 x T_1 (–15.9), L_2 x T_3 (–15.5), L_7 x T_1 (–15.4), L_6 x T_1 (–10.4), L_1 x T_2 (–9.7), L_1 x T_3 (–8.6), L_6 x T_2 (–7.3) and L_5 x T_2 (–7.1).

4.2.5.7 Leaf / Stem Ratio

Six hybrids showed significant relative heterosis for leaf/stem ratio. Of these, five hybrids, L_6 x T_3 (25.71), L_1 x T_2 (24.32), L_1 x T_1 (17.95), L_3 x T_1 (17.95), L_5 x T_2 (17.95) showed significant positive heterosis and the hybrid L_5 x T_3 (–21.05) had negative significance.

Positively significant standard heterosis was exhibited only by five hybrids, L_4 x T_2 (42.11) L_1 x T_1 (21.05), L_1 x T_2 (21.05), L_3 x T_1 (22.1) and L_5 x T_2 (21.05). Only one hybrid showed significant negative standard heterosis L_5 x T_3 (–21.05).

4.2.5.8 Leaf Area Index

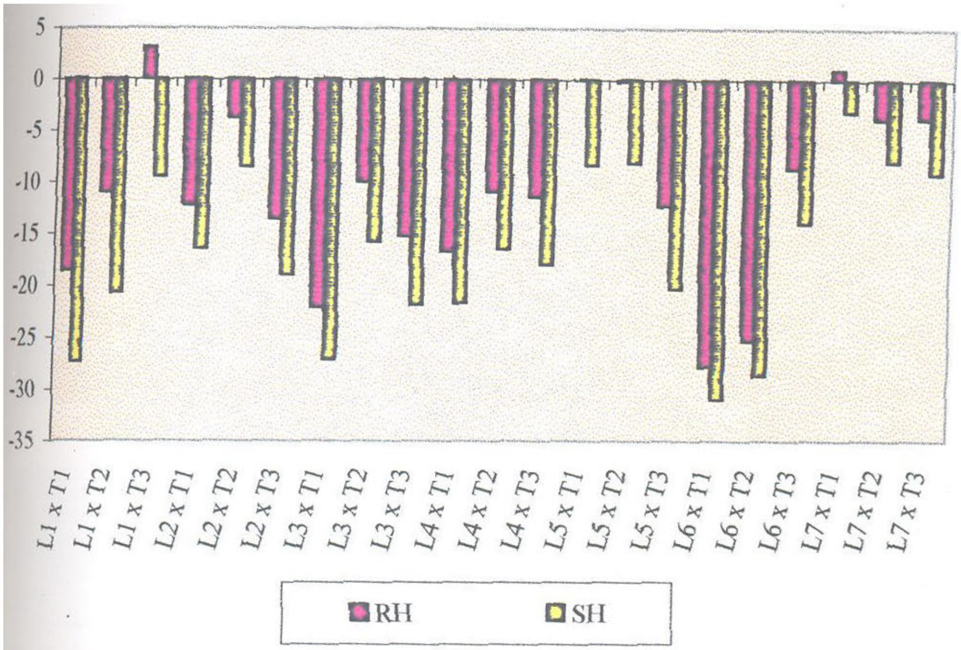
The hybrids exhibited significant heterosis for leaf area index. Ten hybrids expressed positive relative heterosis with the hybrid L_2 x T_1 (56.19) having the maximum value, closely followed by the hybrids L_7 x T_1 (55.45), L_1 x T_1 (54.93) and L_6 x T_3 (50.00).

Nine hybrids recorded significant positive standard heterosis with the hybrid L_7 x T_1 (61.32) expressing the highest value. The hybrid L_7 x T_1 exhibited high values for relative heterosis and standard heterosis and was significantly superior with respect to the character leaf area index.

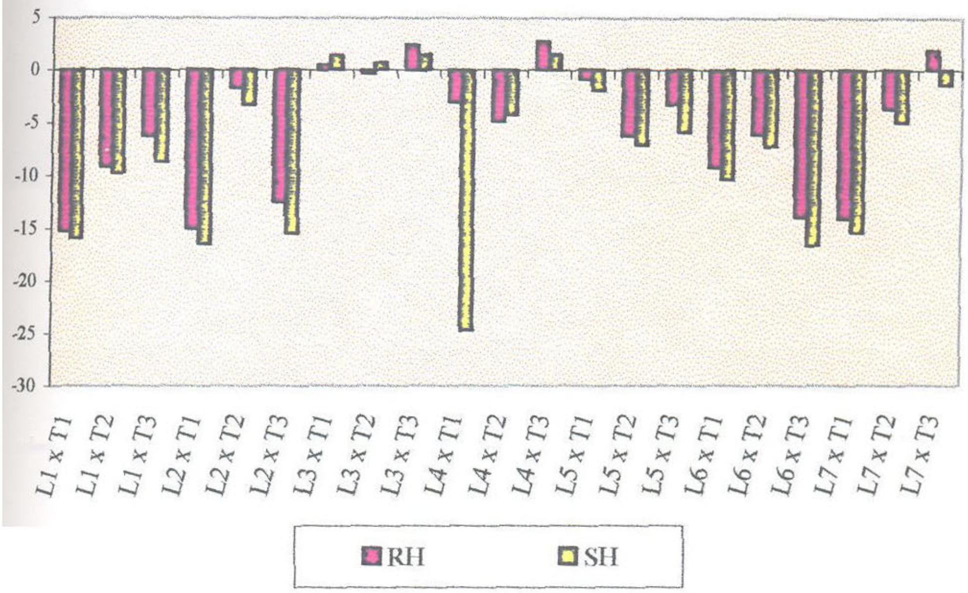
Table 4.2.5 Continued

Sl. No.	Parents / hybrids	5. Days to 50 per cent flowering			6. Days to maturity		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	44.7			73.9		
2.	L_2	50.9			72.5		
3.	L_3	49.2			76.2		
4.	L_4	49.6			75.8		
5.	L_5	47.8			73.5		
6.	L_6	51.3			73.0		
7.	L_7	51.6			72.9		
8.	T_1	47.4			70.8		
9.	T_2	47.2			71.0		
10.	T_3	45.9			68.3		
11.	$L_1 x T_1$	37.5	– 18.57**	-27.33**	61.3	–15.21**	-15.91**
12.	$L_1 x T_2$	40.9	– 10.99**	-20.74**	65.8	–9.12**	-9.74**
13.	$L_1 x T_3$	46.7	3.09	-9.45*	66.6	–6.26*	-8.64**
14.	$L_2 x T_1$	43.1	– 12.31**	-16.47**	60.9	–15.00**	-16.46**
15.	$L_2 x T_2$	47.2	– 3.77	-8.53	70.5	–1.74	-3.29
16.	$L_2 x T_3$	41.8	– 13.64**	-18.99**	61.6	–12.5**	-15.50**
17.	$L_3 x T_1$	37.6	– 22.15**	-27.13**	73.9	0.54	1.37
18.	$L_3 x T_2$	43.4	– 9.96*	-15.89**	73.4	–0.27	0.68
19.	$L_3 x T_3$	40.3	– 15.25**	-21.90**	74.0	2.42	1.51
20.	$L_4 x T_1$	40.4	– 16.70**	-21.71**	71.1	–3.00	-24.70
21.	$L_4 x T_2$	43.1	– 10.95**	-16.47**	69.8	–4.90	-4.25
22.	$L_4 x T_3$	42.3	– 11.41**	-18.02**	74.0	2.71	1.51
23.	$L_5 x T_1$	47.3	– 0.063	-8.33	71.5	–0.90	-1.92
24.	$L_5 x T_2$	47.4	– 0.21	-8.14	67.7	–6.3*	-7.13*
25.	$L_5 x T_3$	41.1	– 12.27**	-20.35**	68.6	–3.24	-5.90
26.	$L_6 x T_1$	35.6	– 27.86**	-31.01**	65.3	–9.18**	-10.43**
27.	$L_6 x T_2$	36.8	–25.28**	-28.68**	67.6	–6.11*	-7.27*
28.	$L_6 x T_3$	44.4	–8.64*	-13.95**	60.8	–13.94**	-16.60**
29.	$L_7 x T_1$	50.0	1.01	-3.10	61.7	–14.13**	-15.36**
30.	$L_7 x T_2$	47.5	–3.85	-7.95	69.3	–3.68	-4.94
31.	$L_7 x T_3$	46.9	–3.79	-9.11	71.9	1.84	-1.37
	CD 5%		3.95	4.56		3.79	4.38
	CD 1%		5.3	6.14		5.11	5.90

RH – Relative Heterosis. SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Days to 50 per cent flowering



Days to maturity

RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

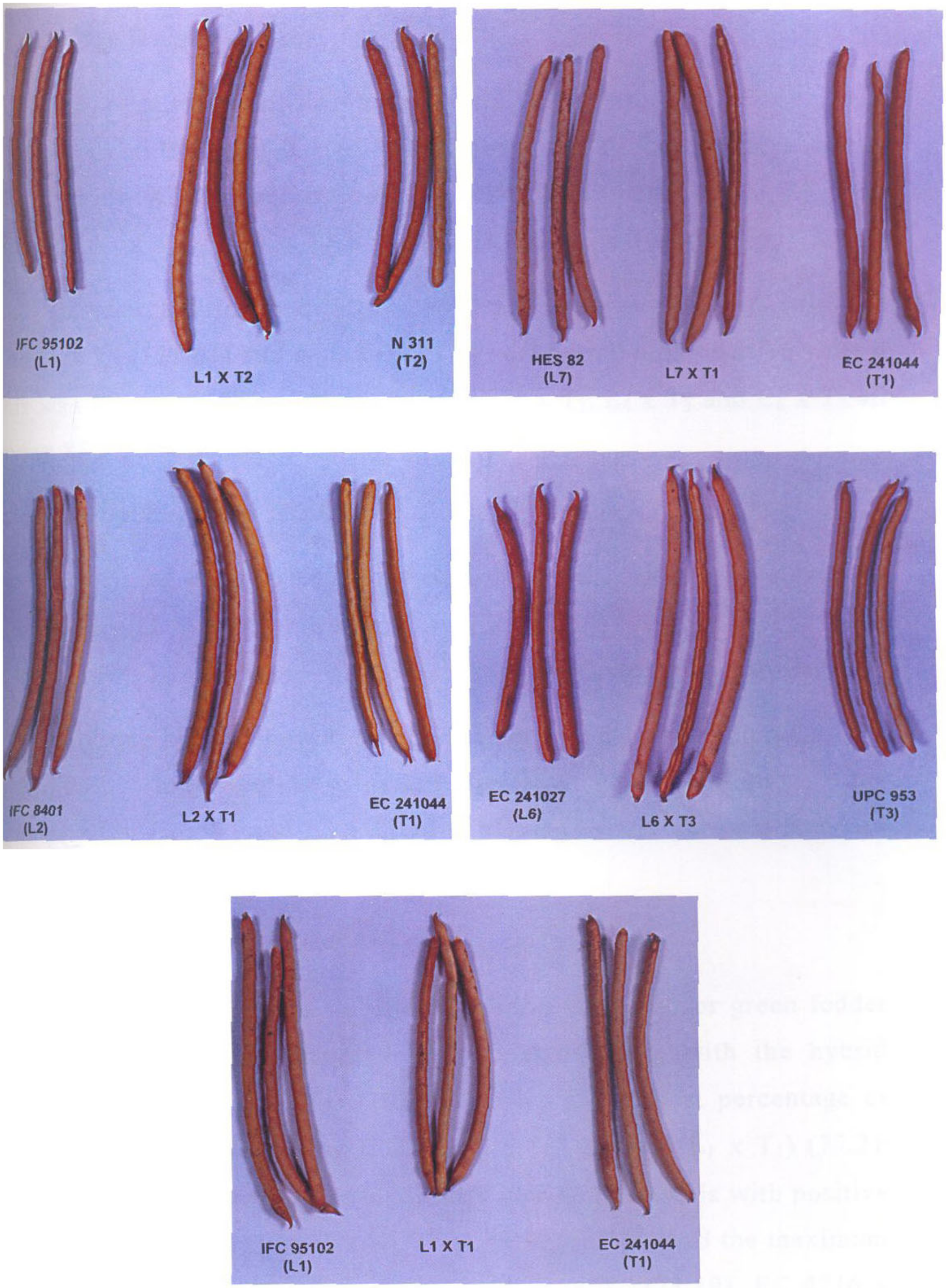


Plate.5. Pods of F_1 hybrids

4.2.5.9 Dry Weight of Leaf

The relative heterosis ranged from –22.27 to 112.45 per cent. Thirteen hybrids recorded significant values and all had positive values. The hybrids which exhibited highly significant values were L_1 x T_2 (112.45), L_1 x T_1 (111.07), L_2 x T_2 (100.14) and L_6 x T_3 (100.00).

Thirteen hybrids exhibited significant positive standard heterosis with L_1 x T_1 (111.07) and L_7 x T_1 (111.07) exhibiting high positive values. This was followed by the hybrids L_1 x T_2, L_2 x T_2, L_4 x T_3 and L_6 x T_3 all having 88.9 per cent heterosis.

4.2.5.10 Dry Weight of Stem

Significant positive relative heterosis for dry weight of stem was exhibited by 11 hybrids. The hybrids L_1 x T_2 (219.66), L_1 x T_1 (112.44), L_2 x T_2 (150), L_3 x T_2 (100.00) and L_6 x T_2 (100) having high values.

Only one hybrid showed significant positive standard heterosis L_7 x T_1 (46.03). Three hybrids exhibited significant negative values. They were L_4 x T_2, L_5 x T_3 and L_6 x T_1 all exhibiting –46.22 per cent standard heterosis.

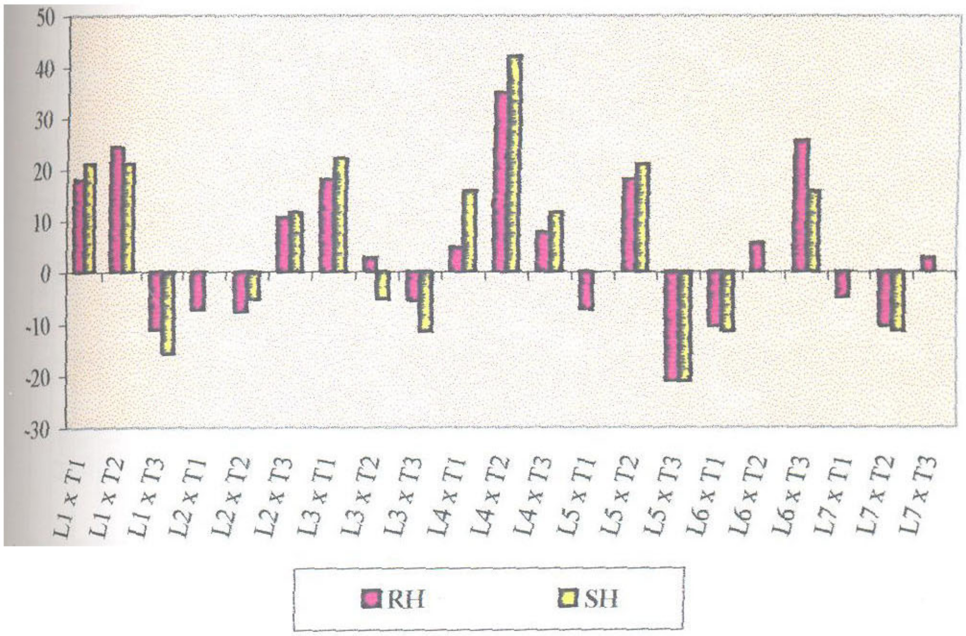
4.2.5.11 Green Fodder Yield

The hybrids exhibited significant relative heterosis for green fodder yield. Fifteen hybrids recorded positive significance with the hybrid IFC 8401 x N 311 (L_2 x T_2) (103.99) having the highest percentage of relative heterosis followed by IFC 95102 x EC 241044 (L_1 x T_1) (77.2). Among the hybrids, twelve had significant standard heterosis with positive values. The hybrid IFC 8401 x N 311 (L_2 x T_2) (81.11) had the maximum value followed by IFC 95102 x EC 241044 (L_1 x T_1) (73.19), EC 4216 x UPC 953 (L_4 x T_3) (73.19), IFC 8401 x UPC 953 (L_2 x T_3) (66.95) and HES 82 x EC 241044 (L_7 x T1) (57.5). Three hybrids recorded negative significance. They were EC 240744 x UPC 953 (L_5 x T_3) (–34.40), HES

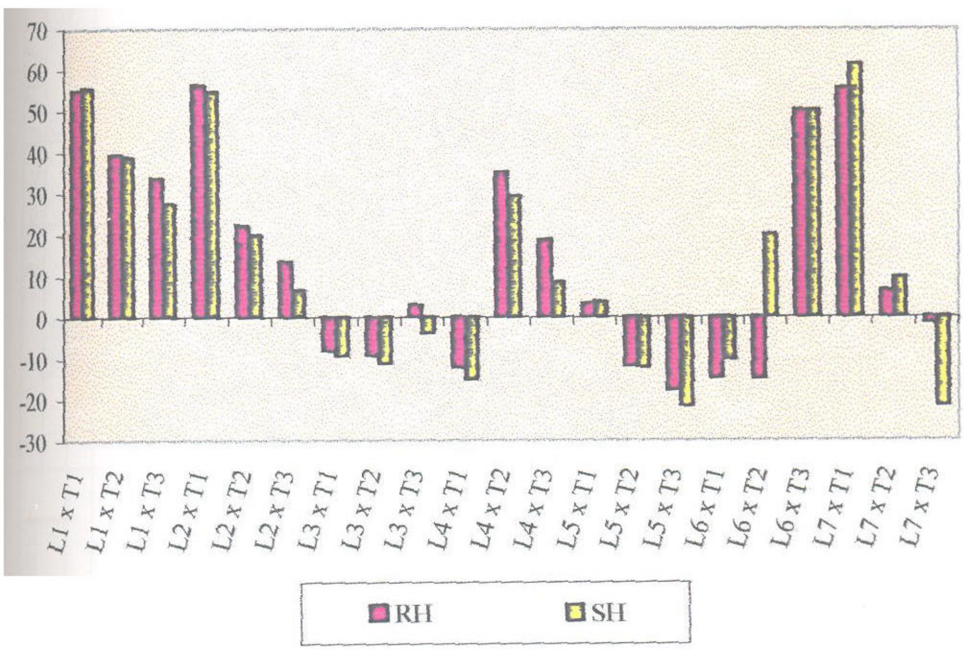
Table 4.2.5 Continued

Sl. No.	Parents / hybrids	7. Leaf /stem ratio			8. Leaf area index		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	0.90			4.95		
2.	L_2	1.00			4.80		
3.	L_3	0.90			4.75		
4.	L_4	1.05			4.55		
5.	L_5	1.00			4.95		
6.	L_6	0.85			5.45		
7.	L_7	0.95			5.30		
8.	T_1	1.05			5.70		
9.	T_2	0.95			5.60		
10.	T_3	0.90			5.15		
11.	$L_1 x T_1$	1.15	17.95*	21.05*	8.25	54.93**	55.66**
12.	$L_1 x T_2$	1.15	24.32**	21.05*	7.35	39.34**	38.68**
13.	$L_1 x T_3$	0.80	–11.11	-15.79	6.75	33.66**	27.36**
14.	$L_2 x T_1$	0.95	–7.32	0.00	8.20	56.19**	54.72**
15.	$L_2 x T_2$	0.90	–7.69	-5.26	6.35	22.12**	19.81**
16.	$L_2 x T_3$	1.05	10.53	11.58	5.65	13.57**	6.60
17.	$L_3 x T_1$	1.15	17.95*	22.10*	4.80	–8.13	-9.43
18.	$L_3 x T_2$	0.95	2.70	-5.26	4.70	–9.18*	-11.32*
19.	$L_3 x T_3$	0.85	–5.56	-11.58	5.10	3.03	-3.77
20.	$L_4 x T_1$	1.10	4.76	15.79	4.50	–12.2**	-15.09**
21.	$L_4 x T_2$	1.35	35.0	42.11**	6.85	34.98**	29.25**
22.	$L_4 x T_3$	1.05	7.69	11.58	5.75	18.56**	8.49
23.	$L_5 x T_1$	0.95	–7.32	0.00	5.50	3.29	3.77
24.	$L_5 x T_2$	1.15	17.95*	21.05*	4.65	–11.85	-12.26*
25.	$L_5 x T_3$	0.75	–21.05*	-21.05*	4.15	–17.82	-21.70
26.	$L_6 x T_1$	0.85	–10.53	-11.58	4.75	–14.8**	-10.38
27.	$L_6 x T_2$	0.95	5.56	0.00	6.35	–14.93**	19.81**
28.	$L_6 x T_3$	1.10	25.71**	15.79	7.95	50.00**	50.00**
29.	$L_7 x T_1$	0.95	–5.0	0.00	8.55	55.45**	61.32**
30.	$L_7 x T_2$	0.85	–10.53	-11.58	5.80	6.42	9.43
31	$L_7 x T_3$	0.95	2.70	0.00	5.15	– 1.44	-21.70
	CD 5%		0.158	0.183		0.451	0.521
	CD 1%		0.21	0.25		0.61	0.70

RH – Relative Heterosis. SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Leaf / stem ratio



Leaf area index

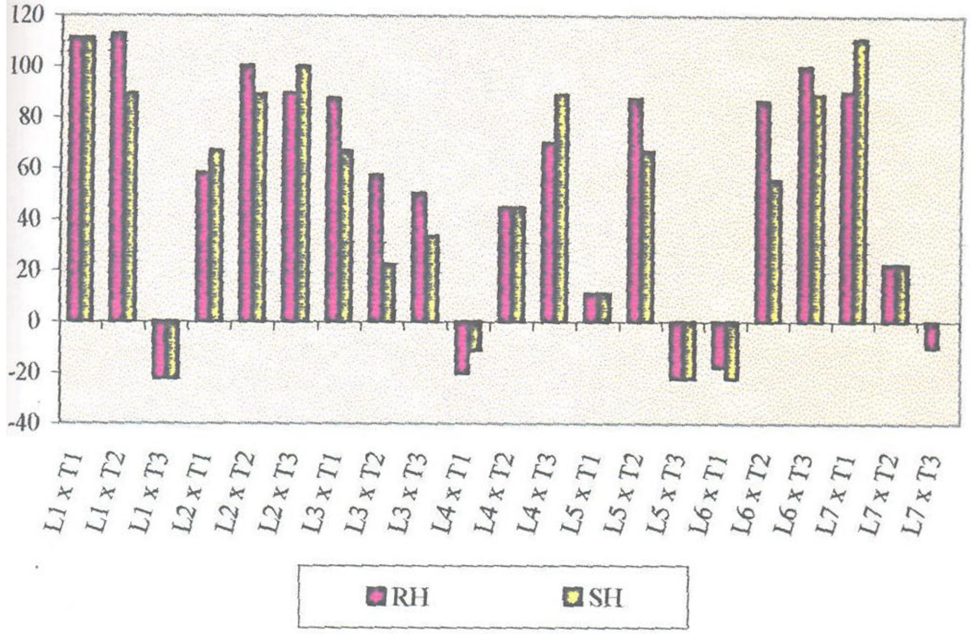
RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

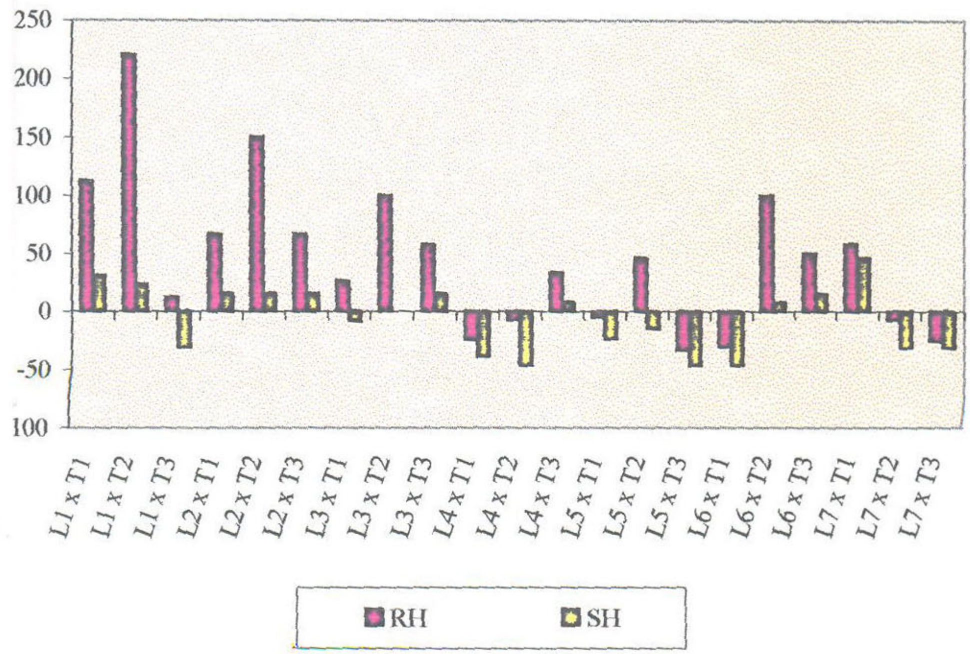
Table 4.2.5 Continued

Sl. No.	Parents / hybrids	9. Dry weight of leaf			10. Dry weight of stem		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	29.15			20.85		
2.	L_2	33.30			29.15		
3.	L_3	20.85			33.35		
4.	L_4	37.50			41.65		
5.	L_5	29.15			41.70		
6.	L_6	25.00			37.50		
7.	L_7	37.50			54.20		
8.	T_1	47.30			45.85		
9.	T_2	45.85			20.85		
10.	T_3	79.15			45.80		
11.	$L_1 x T_1$	79.15	111.07**	111.07**	70.85	112.44**	30.72
12.	$L_1 x T_2$	70.85	112.45**	88.93**	66.65	219.66**	22.97
13.	$L_1 x T_3$	29.15	−22.27	−22.27	37.50	12.53**	-30.81
14.	$L_2 x T_1$	62.50	57.93	66.67**	62.50	66.67*	15.31
15.	$L_2 x T_2$	70.85	100.14**	88.93**	62.50	150.0**	15.31
16.	$L_2 x T_3$	75.00	89.51**	100.00**	62.50	66.78*	15.31
17.	$L_3 x T_1$	62.50	87.41**	66.67**	50.00	26.26	-7.75
18.	$L_3 x T_2$	45.85	57.16**	22.27	54.20	100.00**	0.00
19.	$L_3 x T_3$	50.00	49.93**	33.33*	62.50	57.93*	15.31
20.	$L_4 x T_1$	33.30	−20.1*	−11.2	33.35	−23.77	-38.47
21.	$L_4 x T_2$	54.15	44.4*	44.4*	29.15	−6.72	-46.22*
22.	$L_4 x T_3$	70.85	70.0**	88.93**	58.35	33.45	7.66
23.	$L_5 x T_1$	41.65	11.07	11.2	41.70	−4.74	-23.06
24.	$L_5 x T_2$	62.50	87.55**	66.67**	45.80	46.44	-14.40
25.	$L_5 x T_3$	29.15	−22.27	−22.27	29.15	−33.37	-46.22*
26.	$L_6 x T_1$	29.15	−17.71	−22.27	29.15	−29.93	-46.22*
27.	$L_6 x T_2$	58.30	86.56**	55.47**	58.35	100.00**	7.66
28.	$L_6 x T_3$	70.85	100.0**	88.93**	62.50	50.06*	15.31
29.	$L_7 x T_1$	79.15	89.92**	111.07**	79.15	58.22**	46.03*
30.	$L_7 x T_2$	45.85	22.27	22.27	37.50	−6.66	-30.81
31.	$L_7 x T_3$	37.50	−10.02	0	37.50	−25	-30.81
	CD 5%		10.76	12.42		19.12	22.08
	CD 1%		14.49	16.73		25.75	29.73

RH – Relative Heterosis. SH – Standard Heterosis ** Significant at 1% level , * Significant at 5% level



Dry weight of leaf



Dry weight of stem

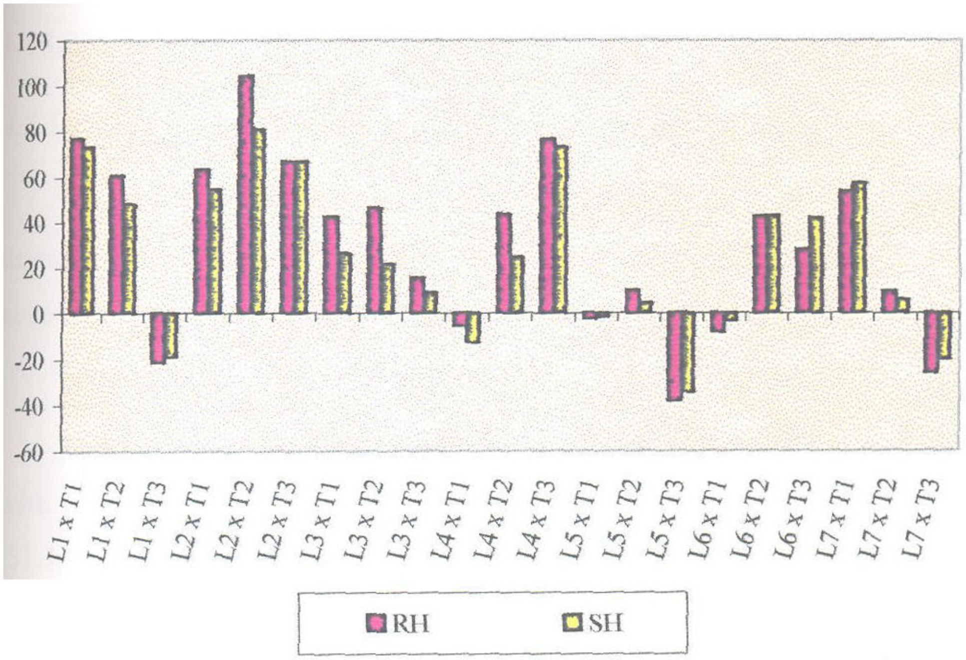
RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

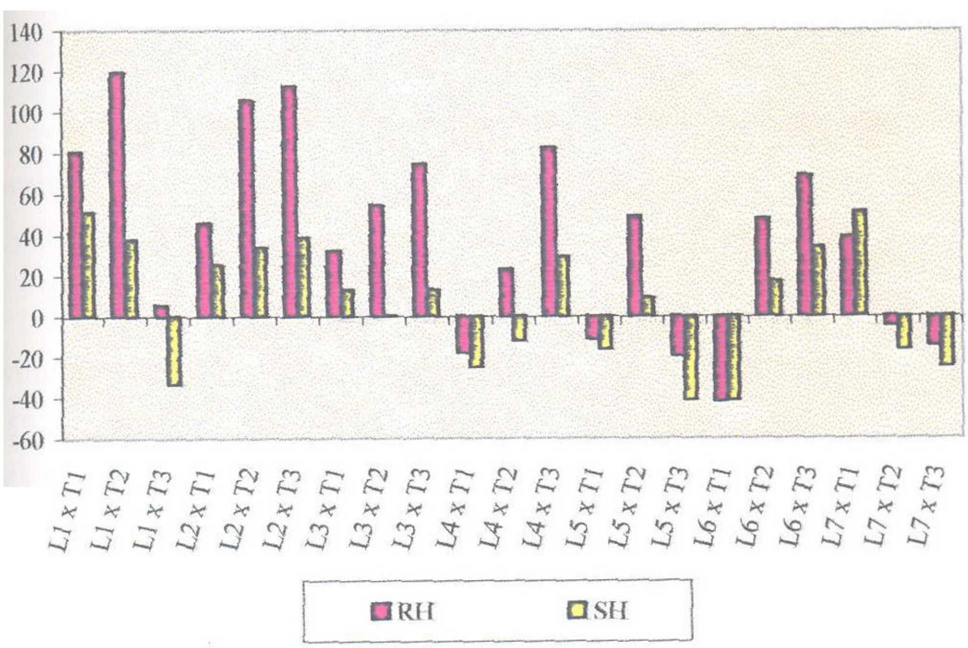
Table 4.2.5 Continued

Parents / hybrids	Green fodder yield			Dry matter yield		
	Mean	RH	SH	Mean	RH	SH
L_1	26.90			5.50		
L_2	24.95			6.05		
L_3	21.50			6.00		
L_4	23.75			7.40		
L_5	28.65			7.85		
L_6	31.60			9.20		
L_7	29.65			11.05		
T_1	31.05			12.95		
T_2	27.70			8.35		
T_3	34.35			8.35		
$L_1 \times T_1$	51.35	77.2**	73.19**	16.70	80.54**	51.13**
$L_1 \times T_2$	43.90	60.81**	48.06**	15.25	119.42**	38.01*
$L_1 \times T_3$	24.05	-21.47**	-18.88**	7.35	5.76	-33.48
$L_2 \times T_1$	45.80	63.57**	54.47**	13.85	45.79*	25.34
$L_2 \times T_2$	53.70	103.99**	81.11**	14.80	105.56**	33.94
$L_2 \times T_3$	49.50	66.95**	66.95**	15.30	112.5**	38.46*
$L_3 \times T_1$	37.45	42.53**	26.31**	12.50	31.93	13.12
$L_3 \times T_2$	36.05	46.54**	21.59**	11.10	54.70*	0.45
$L_3 \times T_3$	32.35	15.85*	9.11	12.50	74.22**	13.12
$L_4 \times T_1$	25.90	-5.47	-12.65	8.30	-17.94	-24.89
$L_4 \times T_2$	37.00	43.83**	24.79**	9.70	23.17	-12.22
$L_4 \times T_3$	51.35	76.76**	73.19**	14.35	82.22**	29.41
$L_5 \times T_1$	29.15	-2.35	-1.69	9.25	-11.06	-16.29
$L_5 \times T_2$	31.00	10.03	4.55	12.05	48.77*	9.05
$L_5 \times T_3$	19.45	-38.25**	-34.40**	6.50	-19.75	-41.18*
$L_6 \times T_1$	28.70	-8.38	-3.20	6.45	-41.76**	-41.63*
$L_6 \times T_2$	42.35	42.83**	42.83**	12.95	47.58*	17.19
$L_6 \times T_3$	42.10	27.67**	41.99**	14.80	68.66**	33.94
$L_7 \times T_1$	46.70	53.87**	57.50**	16.65	38.75**	50.68**
$L_7 \times T_2$	31.45	9.68	6.08	9.25	-4.64	-16.29
$L_7 \times T_3$	23.60	-26.25**	-20.40*	8.30	-14.43	-24.89
CD (0.05)		4.09	4.72		3.43	3.96
CD (0.01)		5.5	6.36		4.62	5.34

RH – Relative Heterosis, SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Green fodder yield



Dry matter yield

RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

82 x UPC 953 (L_7 x T_3) (–20.40) and IFC 95102 x UPC 953 (L_1 x T_3) (–18.88).

4.2.5.12 Dry Matter Yield

Thirteen hybrids exhibited significant relative heterosis for drymatter yield with 12 hybrids having positive values and one with negative significance. The hybrids IFC 95102 x N 311 (L_1 x T_2) (119.42) recorded the maximum value.

Only four hybrids expressed positive significance when compared with the standard parent. They were IFC 95102 x EC 241044 (L_1 x T_1) (51.13), HES 82 x EC 241044 (L_7 x T_1) (50.68), IFC 95102 x N 311 (L_1 x T_2) (38.01) and IFC 8401 x UPC 953 (L_2 x T_3) (38.46) had the positive values. Two hybrids EC 240744 x UPC 953 (L_5 x T_3) and EC 241027 x EC 241044 (L_6 x T_1) had negative significance of –41.18 and –41.63 per cent respectively.

4.2.5.13 Crude Protein Content

When compared with the mid parent fourteen hybrids expressed positive significance for the character crude protein content. The hybrid L_2 x T_1 (62.64) recorded the highest value.

Positive significance was exhibited by ten hybrids when compared with the standard parent. The hybrid L_7 x T_1 had the highest percentage (52.82) followed closely by the hybrids L_2 x T_1 (49.19), L_6 x T_3 (43.95), L_2 x T_1 (40.32) and L_1 x T_1 (39.11).

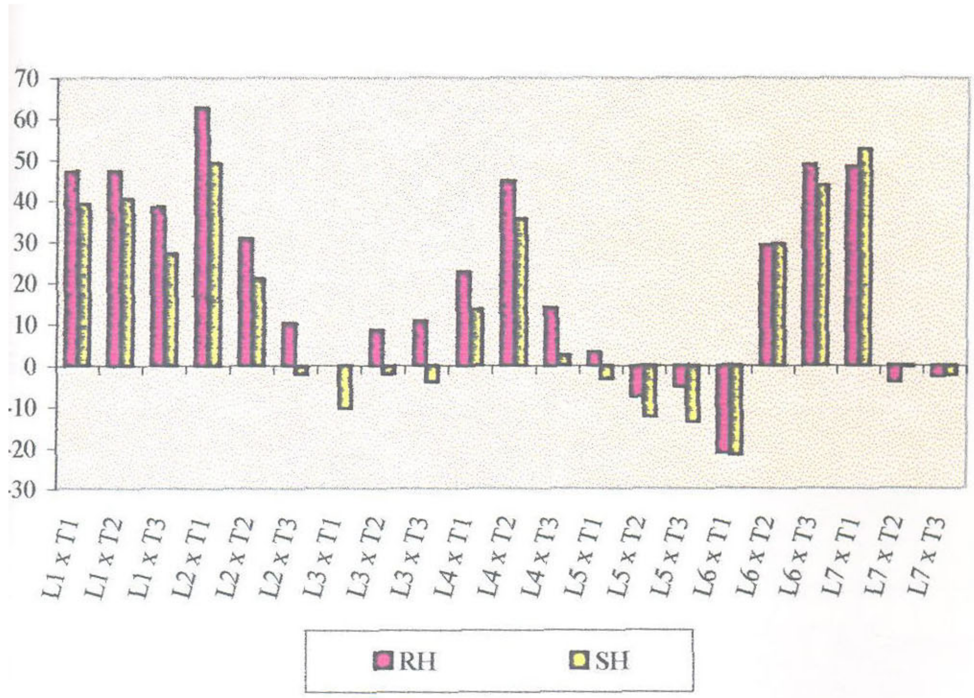
4.2.5.14 Crude Fibre Content

Fifteen hybrids recorded negative significance for the character when compared with mid parent. The highest negative and significant heterosis (–15.04) was exhibited by the hybrid L_7 x T_3 followed by the hybrid L_5 x T_2 (–14.29).

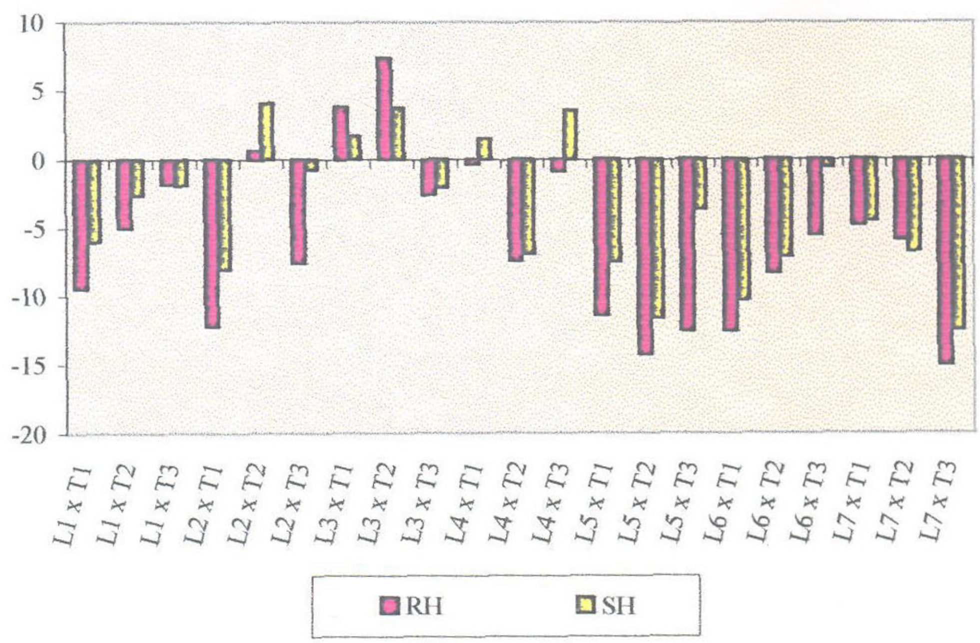
Table 4.2.5 Continued

Sl. No.	Parents / hybrids	13. Crude protein content			14. Crude fibre content		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	10.30			28.65		
2.	L_2	9.60			29.95		
3.	L_3	9.05			25.50		
4.	L_4	9.87			27.60		
5.	L_5	10.10			29.00		
6.	L_6	11.50			28.00		
7.	L_7	12.40			26.80		
8.	T_1	13.15			27.00		
9.	T_2	13.35			26.30		
10.	T_3	12.45			28.40		
11.	L_1 x T_1	17.25	47.12**	39.11**	25.20	–9.44**	-5.97**
12.	L_1 x T_2	17.40	47.15**	40.32**	26.10	–5.00*	-2.62
13.	L_1 x T_3	15.75	38.46**	27.02**	26.30	–1.8**	-1.87
14.	L_2 x T_1	18.50	62.64**	49.19**	24.65	–12.20**	-8.02**
15.	L_2 x T_2	15.00	30.72**	20.97**	27.90	0.63	4.10
16.	L_2 x T_3	12.15	10.20**	-2.02	26.60	–7.56**	-0.75
17.	L_3 x T_1	11.10	0	-10.48*	27.25	3.81	1.68
18.	L_3 x T_2	12.15	8.48**	-2.02	27.80	7.34**	3.73
19.	L_3 x T_3	11.90	10.70**	-4.03	26.25	–2.60	-2.05
20.	L_4 x T_1	14.10	22.61**	13.71**	27.20	–0.37	1.49
21.	L_4 x T_2	16.80	44.83**	35.48**	24.95	–7.42**	-6.90**
22.	L_4 x T_3	12.70	13.90**	2.42	27.75	–0.89	3.54
23.	L_5 x T_1	12.00	3.23	-3.23	24.8	–11.43**	-7.46**
24.	L_5 x T_2	10.85	–7.46**	-12.50**	23.70	–14.29**	-11.57**
25.	L_5 x T_3	10.70	–5.09	-13.71**	25.10	–12.54**	-3.64**
26.	L_6 x T_1	9.70	–21.30**	-21.77**	24.05	–12.55**	-10.26
27.	L_6 x T_2	16.05	29.18**	29.44**	24.90	–8.29**	-7.09
28.	L_6 x T_3	17.85	49.06**	43.95**	26.65	–5.50**	-0.56
29.	L_7 x T_1	18.95	48.34**	52.82**	25.60	–4.83*	-4.48*
30.	L_7 x T_2	12.35	–4.08	-0.40	25.00	–5.84**	-6.72**
31.	L_7 x T_3	12.10	–2.62	-2.42	23.45	–15.04**	-12.50**
	CD 5%		0.76	0.87		1.076	1.242
	CD 1%		1.02	1.18		1.45	1.67

RH – Relative Heterosis. SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Crude protein content



Crude fibre content

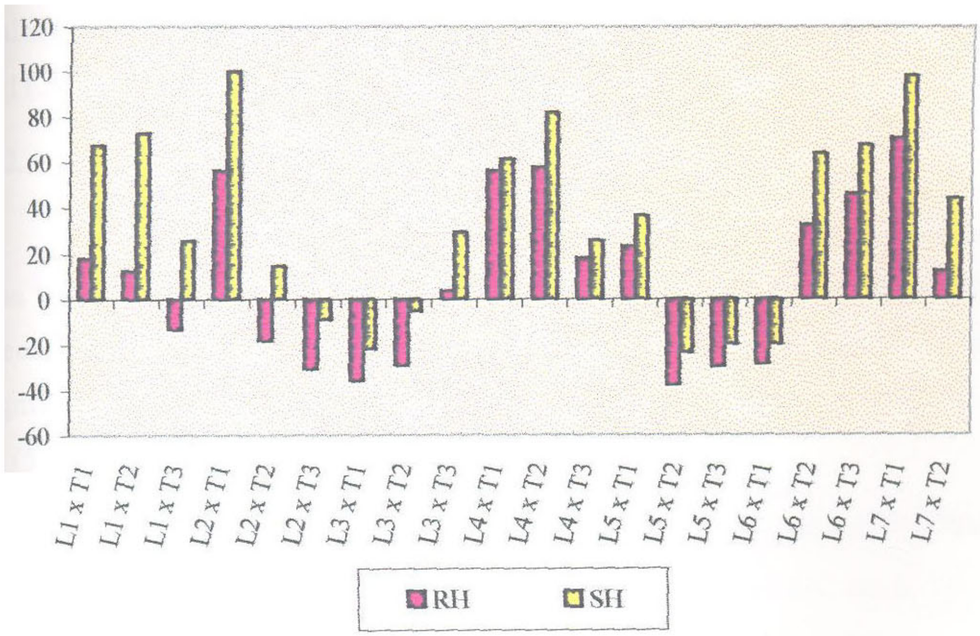
RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

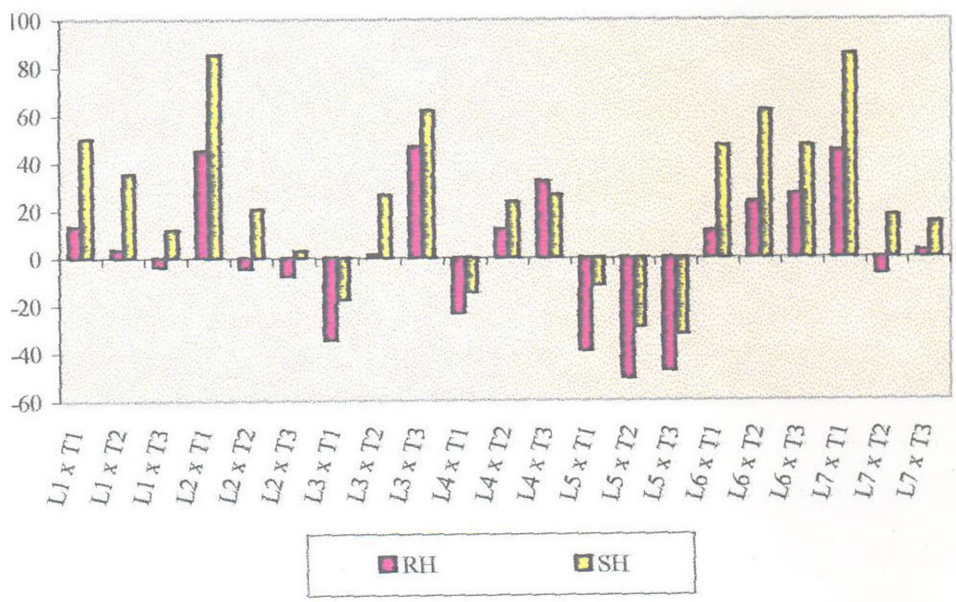
Table Continued

Sl. No.	Parents / hybrids	15. Calcium content			16. Phosphorus content		
		Mean	RH	SH	Mean	RH	SH
1.	L_1	4.15			1.85		
2.	L_2	3.40			1.70		
3.	L_3	3.05			1.65		
4.	L_4	2.05			1.15		
5.	L_5	2.45			2.30		
6.	L_6	2.50			1.85		
7.	L_7	2.75			1.70		
8.	T_1	3.65			2.65		
9.	T_2	4.30			2.60		
10.	T_3	3.80			2.10		
11.	$L_1 \times T_1$	4.60	17.95**	67.27**	2.55	13.33*	50.00**
12.	$L_1 \times T_2$	4.75	12.43*	72.73**	2.30	3.37	35.29**
13.	$L_1 \times T_3$	3.45	−13.21*	25.45**	1.90	−3.80	11.76
14.	$L_2 \times T_1$	5.50	56.03**	100.00**	3.15	44.83**	85.29**
15.	$L_2 \times T_2$	3.15	−18.18**	14.55	2.05	−4.65	20.59*
16.	$L_2 \times T_3$	2.50	−30.56**	-9.09	1.75	−7.89	2.94
17.	$L_3 \times T_1$	2.15	−35.82**	-21.81*	1.40	−34.88**	-17.65
18.	$L_3 \times T_2$	2.60	−29.25**	-5.45	2.15	1.18	26.47**
19.	$L_3 \times T_3$	3.55	3.65	29.09**	2.75	46.67**	61.76**
20.	$L_4 \times T_1$	4.45	56.14**	61.18**	1.45	−23.68**	-14.71
21.	$L_4 \times T_2$	5.00	57.48**	81.82**	2.10	12.00	23.53**
22.	$L_4 \times T_3$	3.45	17.95*	25.45**	2.15	32.31**	26.47**
23.	$L_5 \times T_1$	3.75	22.95**	36.36**	1.50	−39.39**	-11.76
24.	$L_5 \times T_2$	2.10	−37.78**	-23.64**	1.20	−51.02**	-29.42**
25.	$L_5 \times T_3$	2.20	−29.6**	-20.00*	1.15	−47.73**	-32.35**
26.	$L_6 \times T_1$	2.20	−28.46**	-20.00*	2.50	11.11	47.06**
27.	$L_6 \times T_2$	4.50	32.35**	63.64**	2.75	23.60**	61.76**
28.	$L_6 \times T_3$	4.60	46.03**	67.27**	2.50	26.58**	47.06**
29.	$L_7 \times T_1$	5.45	70.31**	98.18**	3.15	44.83**	85.29**
30.	$L_7 \times T_2$	3.95	12.06	43.64**	2.00	−6.98	17.65
31.	$L_7 \times T_3$	3.10	−5.34*	12.73	1.95	2.63	14.71
	CD 5%		0.342	0.446		0.271	0.313
	CD 1%		0.487	0.601		0.365	0.422

RH – Relative Heterosis, SH – Standard Heterosis ** Significant at 1% level, * Significant at 5% level



Calcium content



Phosphorus content

RH - Relative heterosis, SH - Standard heterosis

Fig. 10 Continued

Eleven hybrids exhibited negative significance for the character crude fibre content when compared with standard parent. The maximum value was recorded by the hybrid L_7 x T_3 (–12.5) followed by L_5 x T_2 (–11.57), L_6 x T_1 (–10.26) and L_2 x T_1 (–8.02).

4.2.5.15 Calcium Content

All hybrids except two expressed significance for relative heterosis. The values ranged from –37.78 (L_5 x T_2) to 70.31 (L_7 x T_1). Ten hybrids recorded positive significance and nine hybrids recorded negative significance for calcium content. High values were also exhibited by L_4 x T_2 (57.48), L_4 x T_1 (56.14) and L_2 x T_1 (56.03).

Positive significance for standard heterosis was exhibited by thirteen hybrids. The hybrids with the leading percentage values were L_2 x T_1 (100.00) and L_7 x T_1 (98.18).

4.2.5.16 Phosphorus Content

Significance was expressed by twelve hybrids for phosphorus content when compared with the mid parent. Seven hybrids showed positive significance with the hybrids L_3 x T_3 (46.67), L_2 x T_1 (44.83) and L_7 x T_1 (44.83) recorded high positive values.

In standard heterosis, 12 hybrids recorded positive significance. The hybrids having high percentage values were L_2 x T_1 (85.29) and L_7 x T_1 (85.29) followed by L_3 x T_3 and L_6 x T_2 with 61.76 per cent standard heterosis.

Based on the heterosis five hybrids showing good heterotic values for the characters were selected and they were used for studying the *in vitro* dry matter digestibility. The selected hybrids are L_7 x T_1, L_6 x T_3, L_1 x T_1, L_2 x T_1, L_4 x T_2. IVDMD was done in accordance with the procedure given by Tilley and Terry (1963) and the IVDMD was found to be between 56 to 70 per cent.

The IVDMD of the five selected hybrids are presented in the Table 4.2.3b.

Table 4.2.3b IVDMD

Hybrids	Weight of sample (g)	Weight of residue (g)	IVDMD (%)
L_7 x T_1	3.0	1.1	63.00
L_6 x T_3	3.0	0.9	70.00
L_1 x T_1	3.0	1.2	60.00
L_2 x T_1	3.0	1.3	56.67
L_1 x T_2	3.0	1.1	63.00

4.3 EXPERIMENT III : EVALUATION OF F_2 PROGENY

To assess the potential of different crosses in F_2 generation all the 21 hybrids along with their parents were planted (100 plants each). The F_2 generation was raised and observations were taken from all the 100 individual plants. The mean and variance were also worked out. The F_2 mean and variance are presented in Table 4.3.

4.3.1 Leaf / Stem Ratio

Among the lines the mean value was highest for L_4 (0.7) and lowest for L_3 (0.53). Among the testers, the highest mean was expressed by T_3 (0.67) and lowest by T_1 (0.57). Among hybrids, L_2 x T_2 had the highest, mean (0.99) followed by L_2 x T_3 (0.95), L_2 x T_1 (0.94), L_1 x T_2 (0.92) and L_1 x T_1 (0.91). The lowest mean was expressed by the hybrid L_5 x T_2 (0.58). The variance had a range from 0.002 (L_6) to 0.009 (L_2) among lines. The testers had a range from 0.002 (T_2) to 0.005 (T_3). Among hybrids, the lowest variance was exhibited by L_5 x T_2 and L_6 x T_1 (0.001) and the highest by L_1 x T_1 (0.008).

Table 4.3 Mean and variance of F_2 population

Treatment	Leaf / stem ratio		Dry weight of stem	
	Mean	Variance	Mean (g)	Variance
L_1	0.62	0.003	31.33	18.22
L_2	0.72	0.009	32.00	22.67
L_3	0.53	0.004	24.00	20.67
L_4	0.77	0.006	19.67	14.89
L_5	0.67	0.005	25.33	31.56
L_6	0.56	0.002	25.67	9.57
L_7	0.66	0.005	31.67	15.56
T_1	0.57	0.004	40.67	19.56
T_2	0.61	0.002	24.67	21.56
T_3	0.67	0.005	30.67	26.22
$L_1 \times T_1$	0.91	0.008	67.33	22.89
$L_1 \times T_2$	0.92	0.007	58.33	22.22
$L_1 \times T_3$	0.67	0.004	45.33	21.56
$L_2 \times T_1$	0.94	0.004	68.67	28.22
$L_2 \times T_2$	0.99	0.007	64.33	12.89
$L_2 \times T_3$	0.95	0.003	55.33	21.56
$L_3 \times T_1$	0.60	0.002	47.33	19.56
$L_3 \times T_2$	0.72	0.002	37.33	9.56
$L_3 \times T_3$	0.71	0.002	53.67	11.56
$L_4 \times T_1$	0.83	0.005	26.00	24.00
$L_4 \times T_2$	0.82	0.003	32.00	16.00
$L_4 \times T_3$	0.80	0.007	58.00	16.00
$L_5 \times T_1$	0.68	0.004	37.33	29.56
$L_5 \times T_2$	0.58	0.001	34.67	11.56
$L_5 \times T_3$	0.90	0.004	63.00	22.67
$L_6 \times T_1$	0.71	0.001	44.00	20.67
$L_6 \times T_2$	0.72	0.002	51.00	50.67
$L_6 \times T_3$	0.76	0.005	50.67	36.22
$L_7 \times T_1$	0.81	0.003	73.33	25.57
$L_7 \times T_2$	0.61	0.006	48.33	18.89
$L_7 \times T_3$	0.60	0.007	45.00	30.00

4.3.2 Dry Weight of Stem

The mean dry weight of stem was maximum for the line L_2 (32.00 g) and minimum for L_4 (19.67 g). The tester T_1 had a maximum value of 40.67 g and a minimum by T_2 (24.67 g). Among hybrids L_7 x T_1 had the leading value (73.33 g) in the F_2 population. This was followed by the hybrids L_1 x T_1 (67.33 g), L_2 x T_1 (68.67 g), L_2 x T_2 (64.33 g) and L_5 x T_3 (63.00 g). The hybrid L_4 x T_1 had the lowest F_2 mean. The highest variance was expressed by the hybrid L_6 x T_2 (50.67) and the lowest variance by the by hybrid L_3 x T_2 (9.56). Among lines, the range was from 9.57 (L_6) to 31.56 (L_5). Among testers, T_1 had a low value of 19.56 to 26.22 (T_3).

4.3.3 Dry Weight of Leaf

The F_2 mean dry weight of leaf had a range from 12.33 g (L_4) to 23.67 g (L_2) among lines. Among testers, T_2 had the lowest value of 18.33 g and T_1 had the highest value of 26.33 g. The hybrid L_7 x T_1 had the highest mean of 68.3 g followed by L_2 x T_2 (65.0 g), L_2 x T_1 (64.0 g). The variance had a range from 5.56 to 65.56. Among lines, L_1 exhibited the lowest variance of 5.56 and L_2 the highest variance of 38.22. The testers had a range from 8.89 (T_2) to 14.89 (T_1). The hybrid L_5 x T_2 had the lowest variance of 6.00 and L_1 x T_2 the highest variance of 65.56.

4.3.4 Crude Protein Content

The F_2 mean crude protein content in lines ranged from 10.07 per cent for the parent L_4 to 10.97 per cent (L_7). The range was from 12.65 per cent (T_1) to 13.04 per cent (T_2) among testers. Among the hybrids the range was from 12.21 (L_2 x T_3) to 18.73 for the hybrid L_7 x T_1. Variance ranged from 0.16 to 0.73. Lowest variance was exhibited by the line L_2 (0.28) and the highest variance by L_6 (0.73). The testers ranged from 0.16 (T_1) to 0.31 (T_3). Among hybrids the range was from 0.17 (L_5 x T_3) to 0.72 (L_5 x T_1).

4.3.5 Crude Fibre Content

In the lines, the crude fibre content mean had a range from 26.01 per cent (L_1) to 26.65 per cent (L_7). Among testers the range was from 25.81

Plate.6. Evaluation of F2 progeny - Experiment -3

Table 4.3 Continued

Treatment	Dry weight of leaf		Crude protein content	
	Mean (g)	Variance	Mean (%)	Variance
L_1	21.67	5.56	10.90	0.56
L_2	23.67	38.22	10.30	0.28
L_3	16.00	7.33	10.21	0.30
L_4	12.33	9.56	10.07	0.44
L_5	18.00	6.00	10.29	0.44
L_6	16.67	22.22	10.32	0.73
L_7	19.33	9.56	10.97	0.37
T_1	26.33	14.89	12.65	0.16
T_2	18.33	8.89	13.04	0.25
T_3	20.00	13.33	13.00	0.31
$L_1 \times T_1$	60.33	44.89	17.36	0.38
$L_1 \times T_2$	48.33	65.56	17.48	0.42
$L_1 \times T_3$	29.33	19.56	16.26	0.26
$L_2 \times T_1$	64.00	17.33	18.43	0.31
$L_2 \times T_2$	65.00	23.33	16.01	0.33
$L_2 \times T_3$	43.67	11.56	12.21	0.20
$L_3 \times T_1$	29.67	14.89	12.63	0.38
$L_3 \times T_2$	28.33	8.89	12.47	0.25
$L_3 \times T_3$	34.67	14.89	13.13	0.22
$L_4 \times T_1$	20.33	8.22	13.09	0.52
$L_4 \times T_2$	29.67	14.89	16.64	0.31
$L_4 \times T_3$	44.33	16.22	12.89	0.18
$L_5 \times T_1$	28.00	19.33	16.09	0.72
$L_5 \times T_2$	18.00	6.00	14.89	0.25
$L_5 \times T_3$	64.33	16.22	17.73	0.17
$L_6 \times T_1$	25.67	12.89	14.77	0.20
$L_6 \times T_2$	39.33	16.22	15.41	0.34
$L_6 \times T_3$	35.67	19.56	15.85	0.24
$L_7 \times T_1$	68.33	8.89	18.73	0.23
$L_7 \times T_2$	29.33	12.89	13.09	0.30
$L_7 \times T_3$	31.33	14.89	13.41	0.25

Table 4.3 Continued

Treatment	Crude fibre content		Dry matter yield		Green fodder yield	
	Mean (%)	Variance	Mean (t ha^{-1})	Variance	Mean (t ha^{-1})	Variance
L_1	26.01	0.28	49.75	86.69	77.75	90.69
L_2	26.31	0.30	55.30	107.91	71.45	145.64
L_3	26.41	0.21	46.75	84.60	68.70	72.32
L_4	26.38	0.20	37.30	57.61	63.65	43.93
L_5	26.41	0.26	42.885	68.06	65.61	57.14
L_6	26.31	0.62	46.80	38.75	74.75	180.69
L_7	26.65	0.31	49.00	50.50	78.25	118.18
T_1	26.33	0.24	66.00	41.49	89.90	60.99
T_2	25.81	0.54	48.60	75.53	77.10	100.08
T_3	26.41	0.48	53.40	112.93	73.95	39.65
$L_1 \times T_1$	21.50	0.53	126.35	93.93	158.35	107.02
$L_1 \times T_2$	20.89	1.66	105.00	90.99	144.25	180.18
$L_1 \times T_3$	24.52	0.92	82.95	123.43	95.60	86.12
$L_2 \times T_1$	19.95	0.31	128.35	107.02	160.05	93.70
$L_2 \times T_2$	20.34	0.49	121.35	419.43	155.55	204.20
$L_2 \times T_3$	23.77	1.10	103.95	121.19	145.75	132.02
$L_3 \times T_1$	23.48	0.15	83.60	312.55	89.50	264.71
$L_3 \times T_2$	23.73	0.33	70.95	48.34	88.20	209.09
$L_3 \times T_3$	24.91	0.15	81.90	83.88	85.20	424.36
$L_4 \times T_1$	22.52	0.31	50.65	154.05	111.20	374.04
$L_4 \times T_2$	24.41	0.18	72.05	233.05	90.25	68.19
$L_4 \times T_3$	25.29	0.24	92.90	335.96	112.55	425.14
$L_5 \times T_1$	24.01	0.21	71.90	144.74	82.55	142.08
$L_5 \times T_2$	25.35	0.27	52.95	49.46	83.40	137.82
$L_5 \times T_3$	21.12	0.31	108.80	475.06	154.75	79.57
$L_6 \times T_1$	25.17	0.62	78.75	360.69	91.55	163.84
$L_6 \times T_2$	25.21	0.43	96.55	324.36	105.00	441.42
$L_6 \times T_3$	26.28	0.48	86.05	115.65	92.40	161.24
$L_7 \times T_1$	19.95	0.38	127.10	283.58	162.55	91.24
$L_7 \times T_2$	22.09	1.48	84.60	481.80	101.20	53.55
$L_7 \times T_3$	22.81	0.77	78.10	86.88	81.15	75.34

per cent (T_2) to 26.41 per cent (T_3). The F_2 mean of hybrids ranged from 19.95 (L_2 x T_1 to and L_7 x T_1) to 26.28 per cent (L_6 x T_3). For the trait, lower values are desirable and the hybrids with low values were L_2 x T_1 and L_7 x T_1 (19.95 per cent), L_2 x T_2 (20.34 per cent) and L_1 x T_2 (20.89 per cent). The variance ranged from 0.15 for L_3 x T1 and L_3 x T_3 to 1.66 for L_1 x T_1. Among parents the lines had a range from 0.20 (L_4) to 0.62 (L_6) and the testers had a range from 0.24 (T_1) to 0.54 (T_2).

4.3.6 Green Fodder Yield

The mean had a range from 63.65 t ha^{-1} [EC 4216 (L_4)] to 78.25 t ha^{-1} [HES 82 (L_7)] among lines. The testers had a range from 73.95 t ha^{-1} [UPC 953 (T_3)] to 89.90 t ha^{-1} [EC 241044 (T_1)]. The green fodder yield mean values among hybrids ranged from 81.15 t ha^{-1} [HES 82 x UPC 953 (L_7 x T_3)] to 162.55 t ha^{-1} (HES 82 x EC 241044 (L_7 x T_1)). Among lines the variance ranged from 43.93 [EC 4216 (L_4)] to 180.69 [EC 241027 (L_6)]. The range was from 39.65 [UPC 953 (T_3)] to 100.08 [N 311 (T_2)] among testers. The variance was lowest for the hybrid HES 82 x N 311 (L_7 x T_2) (53.55) and highest for the hybrid EC 241027 x N 311 (L_6 x T_2).

4.3.7 Dry matter Yield

For dry matter yield the mean among lines ranged from 37.30 t ha^{-1} [EC 4216 (L_4)] to 55.30 t ha^{-1} [IFC 8401 (L_2)]. Among testers EC 241044 (T_2) had the lowest value of 48.60 t ha^{-1} and UPC 953 (T_1) had the highest value 66.00 t ha^{-1}. The hybrid EC 4216 x EC 241044 (L_4 x T_1) had the minimum mean value of 50.45 t ha^{-1} and the hybrid IFC 8401 x EC 241044 (L_2 x T_1) had the highest mean of 128.35 t ha^{-1} closely followed HES 82 x EC 241044 (L_7 x T_1) (127.1 t ha^{-1}) and IFC 95102 x EC 241044 (L_1 x T_1) (126.35 t ha^{-1}). The variance among lines ranged from 50.50 [HES 82 (L_7)] to 107.91 [IFC 8401 (L_2)] and among testers the range was from 41.49 [EC 241044 (T_1)] to 112.93 [UPC 953 (T_3)]. The hybrid UP 9001 x N 311 (L_3 x T_2) expressed the lowest variance of 48.34 and the hybrid HES 82 x N 311 (L_7 x T_2) had the highest variance of 481.8.

DISCUSSION

5. DISCUSSION

The primary aim of a plant breeding programme is to evolve superior genotypes with high yield, superior quality and other desirable attributes. Very little work on genetic aspects has been done in forage cowpea. The present investigation was undertaken to study the genetic analysis of yield and quality attributes in fodder cowpea. The information generated would help in planning crop improvement programmes in fodder cowpea.

5.1 STUDIES ON VARIABILITY AND CHARACTER ASSOCIATION

The genetic parameters like PCV, GCV, heritability, genetic advance, character association and selection index were studied and are discussed below:

5.1.1 Variability and Genetic Parameters

The results of analysis of variance for quantitative and qualitative characters revealed highly significant difference among the genotypes for all the characters. The wide range of variation observed for different characters indicate the scope for selection of desirable genetic material for further improvement. The range of mean values reflects the extent of phenotypic and genotypic variability present in the material.

High phenotypic and genotypic coefficient of variation was observed for number of leaves per plant, total leaf area, leaf / stem ratio, leaf area index, dry weight of leaf, dry weight of stem, green fodder yield and dry matter yield. Similar results were reported by Kumar and Mishra (1981), Aravindhan and Das (1995), Backiyarani and Natarajan (1996), Srinivasan and Das (1996), Ponmariammal and Das (1996), Borah and Fazlullahkhan (2000) and Manonmani *et al.* (2000) in cowpea, Ushakumari and Chandrasekharan (1992) and Vasanthi and Das (1996a) in fodder lablab.

Moderate values of PCV and GCV were observed for plant height, number of primary branches per plant, crude protein content and crude fibre content. Similar reports were given by Aravindhan and Das (1995), Srinivasan and Das (1996), Sharma *et al* (1988) and Ponmariammal and Das (1996) in cowpea, Kumar *et al.* (1997) in rice bean and Khabiruddin *et al* (1998) in fababean. Narrow difference between PCV and GCV values were observed for all the characters except number of primary branches per plant and leaf /stem ratio indicating the little influence of environment on the expression of characters.

Broad sense heritability estimate does not serve as a true indicator of genetic potentiality of genotypes. It is advisable to consider the predicted genetic advance along with heritability estimates as tool in selection programme. High heritability and genetic advance were exhibited for dry weight of stem, crude fibre content, crude protein content, green fodder yield, leaf area index, dry weight of leaf and dry matter yield. Singh and Mehndiratta (1969), Sohoo et al (1971), Kohli *et al* (1971), Angadi (1976), Manoharan (1978), Kumar and Mishra (1981), Singh (1982), Apte *et al* (1987), Roquib and Patnaik (1990), Thaware *et al* (1991), Sharma and Singhania (1992), Thaware *et al* (1992), Rewale *et al.* (1995), Ram and Singh (1997), Borah and Fazlullahkhan (2000) Kumar and Sangwan (2000) and Manonmani *et al.* (2000) in cowpea. Similar reports were also given by Solanki *et al* (1975) in guar, Singh *et al.* (1979), Kodeeswaran (1980), Yadav and Krishna (1985) and Ushakumari and Chandrasekharan (1992) in lablab, Das and Roquib (1993a) and Kumar *et al.* (1997) in rice bean.

High heritability and high genetic advance may be due to additive gene action. Non additive and additive based interactions could be associated with characters possessing high heritability coupled with moderate genetic advance. Leaf area index, number of leaves per plant and total leaf area showed high heritability and moderate genetic advance.

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The characters, days to 50 per cent flowering and days to maturity had low genetic advance values of 12.02 per cent and 10.62 per cent respectively and they had moderately high heritability values. High heritability and low genetic advance indicate lesser proportion of genotypic components in the total variability. This suggests that the character might be controlled by non additive genes and selection based on such a character may not be effective. High heritability and low genetic advance estimates were observed for leaf area index, dry weight of leaf, crude protein content and crude fibre content.

None of the characters, in the present study exhibited low heritability. Low heritability estimates were reported by Trehan *et al* (1970), Manoharan (1978) and Borah and Fazlullahkhan (2000) in cowpea.

In general, high estimates of phenotypic and genotypic coefficient of variation, heritability and genetic advance as percentage of mean were observed for dry matter yield, dry weight of stem and green fodder yield. These characters appear to be more promising for improvement in a breeding programme and can be utilized for developing high yielding fodder cowpea varieties.

5.1.2 Correlation Between Yield and its Components

Information on association among component characters and their association with a complex trait like yield is essential for a rational improvement of the yield per se. Estimates of correlation between various characters in a crop when partitioned into genotypic, phenotypic and environmental components are of great value in selection for any breeding programme.

Green fodder yield showed positive and significant phenotypic and genotypic correlation with leaf / stem ratio, leaf area index, dry weight of stem, dry weight of leaf and plant height. The highest positive significant correlation of green fodder yield was recorded with leaf / stem ratio.

Dry matter yield recorded positive significant phenotypic and genotypic correlation with number of primary branches per plant, leaf/stem ratio, dry weight of leaf and plant height. Positive association of stem thickness, number of leaves and branches and leaflet length with both green fodder yield and dry matter yield was also reported in fodder cowpea by Dangi and Paroda (1974). In the same crop, Katoch and Singh (1974) reported that both plant height and number of leaves had a positive association with dry matter yield. Chopra and Singh (1977) in fodder cowpea also reported strong association between number of leaves and green fodder yield and dry matter yield. Similar results were also reported by Manoharan, 1978; Kodeeswaran, 1980; Singh, 1982; Yadav and Krishna, 1985 and Ushakumari, 1985 in cowpea. Sharma *et al* (1988) reported significant positive correlation of green forage yield with days to 50 per cent maturity, days to first flowering, and plant height in cowpea. Jatasra and Dahiya (1988) in forage cowpea reported that forage yield was significantly and positively correlated with leaf weight, stem weight, plant height and branch number. Roquib and Patnaik (1989) reported positive association between green fodder yield and leaf area index and leaf / stem ratio in cowpea. Akundabweni *et al* (1990) reported positive correlation between days to flowering and green fodder yield in cowpea. Sohoo *et al.* (1990) reported positive relationship between green fodder yield and dry matter yield in forage cowpea. Significant positive relationship between green fodder yield and plant height, specific leaf weight and number of branches was reported by Thaware *et al* (1992) in forage cowpea. Similar results were also reported by Deshmukh *et al* (1993) in forage cowpea; Das and Roquib (1993b) in rice bean and Aravindhan and Das (1995) in cowpea. Ponmariammal and Das (1996) and Srinivasan and Das (1996) reported significant and positive correlation of green fodder yield with days to flowering, plant height and number of leaves in cowpea. Positive correlation of green fodder yield with number of branches per plant, leaf fodder yield with number of branches per plant, leaf length and weight has also reported in cowpea by Manonmani *et al.* (2000).

To achieve an effective selection for the improvement of yield, based on yield components, it is important that the components should be highly heritable and strongly correlated with yield genotypically and genotypic correlations among the components should not be negative (Doku, 1970). Besides the strong correlation with green fodder yield and dry matter yield, leaf area index, dry weight of stem and dry weight of leaf had high heritability estimates combined with high genetic advance as percent of mean (Table 4.1.2). When the heritability is mainly due to additive gene effects, a high genetic gain could be expected. The inter-correlations among these three characters *viz.*, leaf area index, dry weight of stem and dry weight of leaf were also positive and significant. Evidently these three characters should be given importance in selection for the improvement of fodder yield in cowpea.

In the present investigation none of the characters showed a significant negative association with green fodder yield and dry matter yield. Negative association between important characters is undesirable for any breeding programme. Negative correlation between plant height and green fodder yield was reported by Dangi and Paroda (1974) in cowpea. Manoharan (1978) reported negative association of plant height with number of branches and number of leaves in fodder cowpea. Deshmukh *et al* (1993) reported significant negative association of days to 50 percent flowering with green fodder yield.

Among the component characters plant height was significantly and positively associated with number of leaves per plant, leaf area index and crude fibre content. Tamilselvam and Das (1994) reported positive correlation of plant height with days to 50 per cent flowering in cowpea. Number of primary branches per plant was positively associated with leaf area index, dry weight of stem and leaf / stem ratio, number of leaves per plant with crude protein content, crude fibre content and dry weight of leaf. Total leaf area was associated positively with only days to 50 percent flowering. Days to 50 percent flowering had strong significant negative correlation with leaf area index, crude fibre content, crude protein content, dry weight of stem, dry weight of leaf and leaf / stem ratio and days to maturity had a negative association with leaf area index.

Positive correlation was observed for leaf / stem ratio with leaf area index, dry weight of stem and dry weight of leaf, for leaf area index with dry weight of stem, dry weight of leaf, crude fibre content and crude protein content, for dry weight of leaf with dry weight of stem, crude protein content and crude fibre content and dry weight of stem was positively correlated with crude protein content and crude fibre content. This indicated the possibility of simultaneous improvement of the traits by simple selection. Similar findings were reported by Dangi and Paroda (1974) in fodder cowpea, Biradar *et al* (1991) in cowpea and Singh *et al* (1991) in cluster bean.

Significant positive environmental correlation was observed for green fodder yield with number of primary branches per plant and total leaf area and for dry matter yield with number of leaves per plant. This shows the predominance of environmental effect on these character combinations. Manoharan (1978) reported significant positive environmental correlation for dry matter yield with plant height, number of branches and number of leaves in fodder cowpea. Ushakumari (1985) reported significant positive environmental correlation for dry weight of leaf with number of leaves in fodder lablab.

5.2 STUDIES ON COMBINING ABILITY AND HETEROSIS

Twenty one hybrids developed by crossing seven lines with three testers were evaluated for combining ability in a Line x Tester mating design. Relative heterosis and standard heterosis were estimated for fodder yield and quality traits.

5.2.1 Combining Ability and Heterosis

The combining ability analysis gives useful information regarding selection of parents in terms of performance of their hybrids. Further, it serves as a powerful tool to elucidate the nature and magnitude of various types of gene action involved in the expression of quantitative traits. There are several techniques for the evaluation of varieties or strains in terms of their genetic make up. Of these, Line x Tester technique is a commonly employed one. The Line x Tester technique is a good approach for screening the germplasm and more number of parents on the basis of *gca* and *sca* variances. It also enables us to understand the nature of gene action involved in the expression of various quantitative traits. The technique measures the *gca* and *sca* variances and the genetic components of variances (σ^2A and σ^2D). It, however, fails to detect and estimate the epistatic variance. The concept of combining ability is now increasingly used in crop improvement programmes.

Heterosis refers to the increased or decreased vigour of F_1 over its parental values. The presence of heterosis indicates the ability of the parents to combine well in a hybridization programme. For varietal breeding programme, mere knowledge of the extent of heterosis is of no use and so it is necessary to understand the causes of heterosis in F_1. Higher expression of F_1 may be due to fixable (additive) type of gene action and or non-additive type of gene action. Thus combining ability analysis helps in identifying desirable cross combinations.

The results of combining ability and heterosis are discussed character wise.

5.2.1.1 Plant Height

Considerable genetic variation was observed among lines, testers and line x tester hybrids as evidenced by significant differences in parents, crosses, parents Vs crosses and line x testers. The ratio of additive to dominance variance was less than unity indicating the predominant effect of non additive genes. Similar results were reported by Ushakumari and Chandrasekharan (1992) in fodder lablab.

Involvement of both additive and non additive type of gene effects were reported for plant height by Jhorar and Jatasra (1990) and Thiyagarajan *et al.* (1990) in fodder cowpea.

General combining ability effects of both lines and testers varied widely both in magnitude and direction. Three of the seven lines had significant negative gca effect and three had significant positive gca effect indicating the presence of additive genes for lower and higher plant height respectively. The lines L_1, L_6 and L_7 were found to be good combiners for higher plant height and lines L_3, L_4 and L_5 for lower plant height. Among the testers, only T_3 showed positively significant gca effect . The other two testers had significant negative gca effect.

Ten hybrids were found to be good specific combiners for higher plant height with the hybrids L_7 x T_1 and L_6 x T_2 being the best. Seven hybrids were good specific combiners for lower plant height.

Significant positive heterosis over mid parent was recorded by all hybrids except five. The hybrids L_6 x T_3 and L_6 x T_2 recorded the highest. Four hybrids had significant negative heterosis. The hybrids L_1 x T_3, L_6 x T_3, L_7 x T_3, L_6 x T_2, L_2 x T_3 and L_7 x T_1 exhibited significant positive standard heterosis. The hybrids L_6 x T_3, L_6 x T_2, L_7 x T_3 and L_2 x T_3 also had significant sca effects. Heterotic vigour for plant height in cowpea was also observed by Mylswami (1988) and Sawant *et al.* (1994).

5.2.1.2 Number of Primary Branches per Plant

Highly significant variation was exhibited for parents, crosses, parents Vs crosses and line x testers. The gca variance showed higher magnitude than sca variance indicating the presence of additive gene action. Predominance of both additive and non additive gene effects were reported by Jhorar and Jatasra (1990) and Thiyagarajan *et al.* (1990) in fodder cowpea. Jain *et al.* (1981) observed predominance of non additive gene effects for number of primary branches per plant.

The significant gca effect indicated the predominance of additive gene action for the character. The lines *viz.,* L_1 and L_5 exhibited positive significant gca effect favouring more number of branches. None of the other lines and testers showed any significance. Among the hybrids, L_7 x T_3 alone showed positively significant sca effect. The hybrid L_3 x T_1 had negative significance.

Fifteen hybrids exhibited significant positive relative heterosis with L_2 x T_1, L_1 x T_1, L_1 x T_3, L_7 x T_3, L_4 x T_2 and L_1 x T_2 having the maximum heterosis. Significant negative relative heterosis was expressed by two hybrids L_6 x T_2 and L_7 x T_2.

When compared with standard parent, the high positive heterosis was shown by hybrid L_7 x T_1 followed by L_2 x T_1, L_1 x T_1, L_1 x T_2, L_4 x T_2 and L_7 x T_2. Similar results were presented by Chaudhary and Lodhi (1981) in cluster bean. High degree of heterosis for the character was also reported by Singh *et al.* (1986) in cowpea.

5.2.1.3 Number of Leaves per Plant

Considerable genetic variation was observed among the parents and hybrids as evidenced by significant differences in parents, crosses, parents Vs crosses, lines and line x testers. The magnitude of sca variance was predominant compared to gca variance revealing the major involvement of non additive gene action for number of leaves per plant. Similar results were reported by Jain *et al.* (1981) in cowpea and by Ushakumari and Chandrasekharan (1992) in fodder lablab. Jhorar and Jatasra (1990) reported the predominance of both additive and non additive gene effects in the inheritance of number of leaves per plant.

The lines L_1, L_2, L_7 and L_6 and tester T_2 were good combiners for number of leaves per plant since they recorded significant positive gca effects. The other three lines L_3, L_5 and L_4 and the tester T_3 showed significant negative gca effect. Eight hybrids L_6 x T_3, L_7 x T_1, L_2 x T_1, L_4 x T_2, L_5 x T_1, L_1 x L_1, L_4 x T_3 and L_3 x T_3 recorded significant positive sca effects.

Fourteen hybrids expressed significant positive heterosis when compared with mid parent. High relative heterosis was exhibited by the hybrids L_7 x T_1, L_1 x T_1, L_6 x T_3, L_2 x T_1 and L_1 x T_2. Chaudhary and Lodhi (1981) in cluster bean reported similar results.

When compared with the standard parent, fourteen hybrids expressed heterosis and the maximum percentage of standard heterosis was recorded by L_7 x T_1, L_2 x T_1 and L_1 x T_1. Hybrid vigour for number of leaves per plant was also reported by Singh *et al.* (1986) in cowpea.

5.2.1.4 Total Leaf Area

Substantial amount of genetic variation in the material was evident from the analysis of variance. For total leaf area the ratio of additive to dominance variance was more than unity indicating the predominant effect of additive genes. Similar results were reported by Ushakumari and Chandrasekharan (1992) in fodder lablab.

Among the lines, L_1, L_2, L_6 and L_7 exhibited significant positive gca effect. Among testers T_1 showed positive significance. The rest of the lines and testers were negatively significant. Among the hybrids all had significant sca effects with eleven hybrids exhibiting positive and ten hybrids exhibiting negative sca effects. The maximum positive sca effect was observed in the hybrids L_7 x T_1 and L_6 x T_3.

Significant heterosis was recorded by different hybrids which reflects the predominance of sca variance. Eleven hybrids exhibited significant relative heterosis with the hybrids L_7 x T_1, L_2 x T_1, L_1 x T_1 and L_6 x T_3

recording high positive values. For nine hybrids standard heterosis was positive and significant with the hybrids L_7 x T_1, L_2 x T_1, L_1 x T_1 and L_6 x T_3 showed high values.

5.2.1.5 Days to 50 per cent Flowering

Highly significant variation among crosses, parents Vs crosses, lines and line x testers substantiated genetic variation for the trait in the material under study. The involvement of non-additive gene action for days to 50 per cent flowering was indicated by the predominance of sca variance over gca variance. The predominance of additive gene action for this character was reported by Jain *et al.* (1981), Patil and Bhapkar (1986) and Ponmariammal and Das (1996) in cowpea. The involvement of both additive and non additive gene action was reported by Mishra *et al.* (1987) in cowpea.

The lines L_2 and L_6 exhibited significant negative gca effect and were good general combiners. None of the testers exhibited significant gca effects. L_5 x T_3, L_6 x T_2, L_1 x T_1 and L_2 x T_3 were good specific combinations as they exhibited significant sca effects.

Fourteen hybrids exhibited significant heterosis over mid parent with the hybrid. L_6 x T_1, L_6 x T_2 and L_3 x T_1 having maximum negative values. Significant negative standard heterosis was recorded by fifteen hybrids with the hybrids L_6 x T_1, L_6 x T_2, L_1 x T_1 and L_3 x T_1 recording high values. Hybrid vigour in cowpea for this character was earlier reported by Premsekar and Raman (1972). Low heterotic effects for days to 50 per cent flowering was reported by Singh *et al.* (1986) in cowpea.

5.2.1.6 Days to Maturity

There were significant differences among the parents, crosses, parents Vs crosses, lines and line x testers indicating the diversity of the material for days to maturity. The sca variance was higher than gca variance which suggested that non additive effects were more important than additive genetic effects in controlling this character.

Predominance of both additive and non additive gene effects was reported earlier by Singh and Dabas (1992) in cowpea. Patil and Bhapkar (1986) and Singh and Dabas (1986) in cowpea observed predominance of additive genetic effects.

The estimates of gca effects for lines and testers indicated that the lines L_1, L_2 and L_5 were good general combiners as they recorded significant negative values. None of the testers showed significant gca effect. The specific combining ability effects of the hybrids showed that L_7 x T_1, L_4 x T_2, L_5 x T_2, L_2 x T_3 and L_6 x T_3 were good specific combiners for days to maturity.

When compared with mid parent, ten hybrids had significant negative values. L_1 x T_1 and L_2 x T_1 were the hybrids with high relative heterosis. Standard heterosis was highest for L_6 x T_3 followed by L_2 x T_1 and eighteen other hybrids also recorded significant negative values.

Hybrid vigour for days to maturity in cowpea was reported by Premsekar and Raman (1972).

5.2.1.7 Leaf / Stem Ratio

There was significant variation among crosses and line x testers. Specific combining ability variance was significant and of higher magnitude indicating the predominance of non-additive gene action in the expression of leaf / stem ratio. Similar results were reported by Das and Dana (1978) in ricebean.

The lines L_5 and L_7 had significant and negative gca effect. None of the testers exhibited significant gca effect. In the hybrids also, the sca effect was not significant.

Significant positive relative heterosis was recorded by six hybrids *viz.*, L_4 x T_2, L_6 x T_3, L_1 x T_2, L_1 x T_1, L_3 x T_1 and L_5 x T_2. The hybrid L_5

x T_3 exhibited negative significance. Positively significant standard heterosis was exhibited by only five hybrids, L_4 x T_2, L_1 x T_1, L_1 x T_2, L_3 x T_1 and L_5 x T_3. Five hybrids showed significant negative standard heterosis. Negative average heterosis for leaf / stem ratio over better and standard parents was reported by Aravindhan and Das (1996) in cowpea.

5.2.1.8 Leaf Area Index

There was significant difference among the parents, crosses, parent Vs crosses and line x testers indicating the diversity of the material for this trait. The ratio of additive to dominance variance was less than unity and hence it indicates the predominance of non-additive gene action for leaf area index. The estimates of gca effects for lines indicated that lines L_1 and L_2 were good general combiners. Significant gca effect was not shown by any of the testers. Four hybrids L_2 x T_1, L_7 x T_1, L_4 x T_2 and L_6 x T_3 exhibited positively significant sca effect.

Significant heterosis expressed in the hybrids for leaf area index supported the results of combining ability analysis. Ten hybrids expressed positive relative heterosis and among them L_2 x T_1, L_7 x T_1, L_1 x T_1 and L_6 x T_3 were having high values. Nine hybrids recorded positively significant standard heterosis. The hybrids L_7 x T_1 which had significant sca effect recorded maximum positive heterosis when compared with mid parent and standard parent. Presence of relative heterosis and heterobeltiosis was also reported by Kohli (1990), Sohoo *et al.* (1990), Sanghi and Kandalkar (1991) and Aravindhan and Das (1996) in cowpea.

5.2.1.9 Dry Weight of Leaf

Higher magnitude of variation was observed among the parents, crosses, parents Vs crosses, and line x testers for dry weight of leaf. The sca variance showed higher magnitude than gca variance indicating the presence of non-additive gene action.

Only two lines *viz.,* L_1 and L_2 showed significant positive gca effect. Line L_5 had negative significance. Among testers, only T_2 showed positively significant gca effect. Eight hybrids *viz.,* L_7 x T_1, L_6 x T_3, L_4 x T_3, L_1 x T_1, L_5 x T_2, L_3 x T_1, L_2 x T_3 and L_1 x T_2 exhibited significant positive sca effects, thereby making them good specific combiners.

Significant heterosis expressed in the hybrids for dry weight of leaf supported the results of combining ability analysis. All the hybrids identified as good specific combiners also exhibited positively significant relative heterosis and standard heterosis. Thirteen hybrids recorded positive significance when compared with midparent and standard parent. The hybrids L_1 x T_1, L_7 x T_1, L_2 x T_2 and L_6 x T_3 recorded high positive values when compared with mid and standard parents. Hybrid vigour over better and standard parent was also reported by Chaudhary and Lodhi (1981) in cluster bean and Vasanthi and Das (1995) in lablab.

5.2.1.10 Dry Weight of Stem

There was significant differences among crosses, parent Vs crosses and line x testers indicating the diversity of the material for dry weight of stem. The magnitude of sca variance was higher than gca variance. This indicated predominance of non-additive gene action. Similar results were reported by Ushakumari and Chandrasekharan (1992) in fodder lablab.

Three lines *viz.*, L_1, L_2 and L_3 were found to be good general combiners for dry weight of stem as they had significant positive gca effect. None of the testers had significant gca effect. The hybrids L_7 x T_1, L_4 x T_3, L_6 x T_3, L_1 x T_1, L_1 x T_2, L_6 x T_2, L_3 x T_3 and L_5 x T_2 exhibited highly significant positive sca effects indicating substantial non-additive gene action for this character.

Significant heterosis was recorded by the different hybrids. Eleven hybrids recorded positively significant relative heterosis and significant standard heterosis was exhibited by only one cross combination. The hybrids L_7 x T_1, L_1 x T_1 and L_1 x T_2 which were good specific combiners also exhibited highly significant positive values on comparison with mid parent and standard parent. High heterosis was also reported by Singh *et al.* (1986) in cowpea and Vasanthi and Das (1995) in lablab.

5.2.1.11 Green Fodder Yield

High genetic variation for the trait green fodder yield was substantiated by presence of highly significant variation among parents, crosses, parents Vs crosses and line x testers. The sca variance had higher magnitude than gca variance which indicated that non-additive gene action was more important than additive gene action. Similar results were reported by Aravindhan and Das (1996) in cowpea and Ushakumari and Chandrasekharan (1992) in fodder lablab.

Among lines IFC 95102 (L_1) and IFC 8401 (L_2) had significant positive gca values and EC 240744 (L_5) and HES 82 (L_7) had significant negative values. None of the testers had significant gca values. Four hybrids EC 4216 x UPC 953 (L_4 x T_3), HES 82 x EC 241044 (L_7 x T_1), IFC 95102 x EC 241044 (L_1 x T_1) and EC 241027 x UPC 953 (L_6 x T_3) showed significant positive sca effect. Significance of both additive and non additive gene effects were also reported for green fodder by Jatasra (1979), Singh and Dabas (1986) and Jhorar and Jatasra (1990) in cowpea.

Significant positive heterosis for green fodder yield was observed in almost all the hybrids. Fifteen hybrids exhibited positive significance on comparison with mid parent and twelve hybrids on comparison with standard parent. The hybrid IFC 8401 x N 311 (L_2 x T_2) had the highest percentage of relative heterosis and standard heterosis. Significant heterotic effects for green fodder yield were also reported by Chaudhary and Lodhi (1981) in cluster bean. Relative heterosis was reported by Ushakumari (1985) in lablab and standard heterosis by Lodhi *et al.* (1990) in cowpea. Hybrid vigour in cowpea for the trait was also reported by

Singh *et al.* (1986). Ushakumari (1985) in lab lab, Koholi (1990), Sohoo *et al.* (1990), Sanghi and Kandalkar (1991) and Aravindhan and Das (1996) in cowpea reported both relative heterosis and heterobeltiosis for the character.

5.2.1.12 Dry Matter Yield

Variance for combining ability for parents, crosses, parents Vs crosses and line x testers were significant for dry matter yield. This indicated that there is high genetic variation for the trait. This trait was found to be controlled predominantly by non-additive gene action since dominance variance was more than additive variance. Non additive gene action for this character was reported by Das and Dana (1978) in rice bean and Ushakumari and Chandrasekharan (1992) in fodder lablab. Among lines IFC 8401 (L_2) had significant positive gca value and EC 240744 (L_5) had significant negative value. None of the testers had significant gca effects. The hybrids HES 82 x EC 241044 (L_7 x T_1), EC 4216 x UPC 953 (L_4 x T_3), EC 241027 x UPC 953 (L_6 x T_3), IFC 95102 x EC 241044 (L_1 x T_1) and EC 240744 x N 311 (L_5 x T_2) expressed positive and significant sca effects. Similar results were also reported by Jatasra (1979) in cowpea where both sca and gca variance were predominant.

When compared with mid parent, thirteen hybrids exhibited positive significance with the hybrids IFC 95102 x N 311 (L_1 x T_2) and IFC 8401 x N 311 (L_2 x T_2) having high values. Standard heterosis was positive and significant for four hybrids viz. IFC 8401 x EC 241044 (L_2 x T_1), HES 82 x EC 241044 (L_7 x T_1), IFC 95102 x N 311 (L_1 x T_2) and IFC 8401 x UPC 953 (L_2 x T_3). The hybrids IFC 95102 x N 311 (L_1 x T_2) and IFC 8401 x N 311 (L_2 x T_2) recorded the maximum positive heterosis when compared with mid parent and standard parent. Significant heterotic effects for dry matter yield were also reported by Chaudhary and Lodhi (1981) in cluster bean, Singh *et al.* (1986), Lodhi *et al.* (1990), Kohli

(1990), Sohoo *et al.* (1990), Sanghi and Kandalkar (1991) and Aravindhan and Das (1996) in cowpea. Vasanti and Das (1995) also reported hybrid vigour for dry matter yield in lab lab.

5.2.1.13 Crude Protein Content

For crude protein content, the combining ability variance was significant for parents, crosses, parents Vs crosses, line x testers. Here also the dominance variance was greater than additive variance indicating the predominance of non additive gene action. Similar reports were given by Jain *et al.* (1980) in fodder cowpea, Ushakumari and Chandrasekahran (1992) in fodder lablab, Aravindhan and Das (1996) in cowpea, Vasanthi and Das (1996) in lablab and Ponmariammal and Das (1996) in cowpea.

Positive and significant gca effect was expressed by the line L_1. Lines L_3 and L_5 had negative significance. Among testers, T_3 had significant negative gca effect. Significant sca effects were exhibited by hybrids L_2 x T_1, L_7 x T_1, L_4 x T_2, L_6 x T_2 and L_6 x T_3. Most of the hybrids showed significant heterosis. Fourteen hybrids expressed positive relative heterosis with the hybrid L_2 x T_1 recording the highest value followed by L_6 x T_3 and L_7 x T_1. Significant standard heterosis was exhibited by ten hybrids. When compared with standard parent the hybrid L_7 x T_1 had the highest percentage followed by L_2 x T_1, L_6 x T_3, L_2 x T_1 and L_1 x T_1. These three hybrids also had significant sca effects. Significant heterotic effect for crude protein content was reported by Singh *et al.* (1986) and Lodhi *et al.* (1990) in cowpea and Vasanthi and Das (1995) in lablab.

5.2.1.14 Crude Fibre Content

In the analysis for crude fibre content significant combining ability effects of gca and sca were recorded for parents and hybrids indicating the importance of both types of combining ability for the trait. The ratio of additive to dominance variance was less than unity indicating that the character was predominantly under the control of non additive gene action. Similar results were reported by Aravindhan and Das (1996).

Positively significant gca effect was observed in the lines L_1 and L_3. The lines L_5 and L_7 had negatively significant gca value which is desirable for this trait. Among testers significant negative gca effect was exhibited by T_2. Among hybrids L_4 x T_2, L_2 x T_1 and L_7 x T_3 had significant negative sca effect.

The hybrids had a very high degree of heterosis for crude fibre content. Fifteen hybrids exhibited significant negative relative heterosis and eleven hybrids exhibited significant negative standard heterosis. The maximum negative relative heterosis and standard heterosis were observed in the hybrids L_7 x T_3 and L_5 x T_2.

5.2.1.15 Calcium Content

Highly significant variation among parents and hybrids substantiated the high genetic variation for the trait. The magnitude of sca variance was higher than gca variance, which indicated that non additive gene action was more important than additive gene action in the expression of calcium content.

The lines L_3 and L_5 showed negatively significant gca effect. None of the lines had positive significance and none of the testers had significant gca effect. Among hybrids, L_2 x T_1, L_6 x T_3, L_3 x T_3 and L_7 x T_1 had positive sca effect.

On comparison with mid parent, all hybrids except two expressed significance, with ten hybrids recording positive significance. In comparison with standard parent, thirteen hybrids exhibited positive significance. For both types of heterosis the hybrids L_7 x T_1 and L_2 x T_1 recorded high values.

5.2.1.16 Phosphorus Content

Considerable genetic variation was observed among the parents and hybrids as evidenced by significant differences in parents, crosses, parents Vs crosses and line x testers. The magnitude of sca variance was predominant compared to gca variance revealing the major involvement of non-additive gene action for phosphorus content. Similar results were reported by Vasanthi and Das (1996) in lablab. Among lines, only one genotype L_5 recorded negatively significant gca effect. None of the testers were significant. Among hybrids, L_2 x T_1 and L_3 x T_3 exhibited positively significant sca effect.

Seven hybrids recorded positive significance on comparison with mid parent. For standard heterosis twelve hybrids expressed positive significance. The hybrids L_7 x T_1, L_2 x T_1 and L_3 x T_3 had the maximum values on comparison with mid parent and standard parent.

5.3 EVALUATION OF F_2 PROGENY

The potential of 21 different crosses in F_2 generation along with their parents were assessed by studying the mean and variance.

For leaf/ stem ratio, the line L_4 and tester T_3 had the highest mean value. Among hybrids, L_2 x T_2 had the highest mean closely followed by L_2 x T_3, L_2 x T_1, L_1 x T_2 and L_1x T_1. The variance was maximum for L_2 among lines, T_3 among testers and L_1 x T_1 among hybrids. The mean dry weight of stem was maximum for the line L_2 and tester T_1. Among hybrids L_7 x T_1 had the leading mean value followed by L_1 x T_1, L_2 x T_1, L_2 x T_2 and L_5 x T_3. Variance for dry weight of stem was highest for the line L_5, tester T_3 and hybrid L_6 x T_2.

Maximum dry weight of leaf among F_2 population was expressed by line L_2, tester T_1 and hybrid L_7 x T_1. L_2 x T_2 and L_2 x T_1 also had high values. Variance for this character was maximum for the line L_2, tester T_1 and hybrid L_1 x T_2. The F_2 mean for crude protein content was maximum in L_7 among lines, in T_2 among the testers and L_7 x T_1 among the hybrids. Variance was highest for the line L_6, tester T_3 and hybrid L_5 x T_1. For crude fibre content, lowest value was desirable and the line L_1, tester T_2 and hybrids L_2 x T_1 and L_7 x T_1 had low mean values. Low variance for this trait was exhibited by the hybrids L_3 x T_2 and L_3 x T_3. The line L_4 and tester T_1 had low variance.

For green fodder yield, line HES 82 (L_7) and tester EC 241044 (T_1) had maximum mean values. The hybrid HES 82 x EC 241044 (L_7 x T_1) had the highest mean value and EC 241027 x N 311 (L_6 x T_2) had the highest variance for this trait. The variance was maximum for the line EC 241027 (L_6) and tester N 311 (T_2). For dry matter yield, the mean was maximum for the line IFC 8401 ($L_{2,}$) tester UPC 953 (T_3) and the hybrids IFC 8401 x EC 241044 (L_2 x T_1), followed by HES 82 x EC 241044 (L_7 x T_1) and IFC 95102 x EC 241044 (L_1 x T_1). The variance among lines were maximum for IFC 8401 (L_2) and among testers for UPC 953 (T_3). The hybrid HES 82 x N 311 (L_7 x T_2) had the highest variance.

It is seen that the hybrid HES 82 x EC 241044 (L_7 x T_1) had the highest mean values for all the characters studied. Similar reports were given by Thiyagarajan *et al.* (1990) in cowpea, Ushakumari and Chandrasekharan (1992) in fodder lablab and Singh *et al.* (1994b) in pea.

SUMMARY

6. SUMMARY

An investigation on "Genetic analysis of yield and quality attributes in fodder cowpea [*Vigna unguiculata* (L.) Walp] was carried out during 1999-2002 in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani involving fifty one accessions of cowpea of diverse origin. The study was carried out under the following subheads: variability, heritability, genetic advance, correlation, combining ability, heterosis and gene action.

The salient conclusions of the present investigation are :

The genotypes recorded significant differences for all the yield and quality attributes. High estimates of phenotypic and genotypic coefficient of variation were recorded for dry weight of stem, dry matter yield and green fodder yield

High heritability and genetic advance were observed for leaf area index, green fodder yield, dry matter yield, dry weight of leaf, dry weight of stem and crude fibre content. Leaf/stem ratio, leaf area index, dry weight of stem, dry weight of leaf, plant height and number of primary branches per plant were found to be highly correlated with both green fodder yield and dry matter yield

Lines (female parents) and testers (male parents) were selected based on selection index. Seven top ranking accessions were selected as lines. They were IFC 95102 (L_1), IFC 8401 (L_2), UP 9001 (L_3), EC 4216 (L_4), EC 240744 (L_5), EC 241027 (L_6) and HES 82 (L_7). Another discriminant function was fitted to derive a selection index to evaluate the quality parameters *viz.*, crude protein content and crude fibre content. Three top ranking accessions which were not selected as lines were selected as testers *viz.*, EC 241044 (T_1), N 311 (T_2) and UPC 953 (T_3).

The combining ability analysis revealed significant GCA variance for most of the characters. The lines L_2 (IFC 8401) and L_1 (IFC 95102) were good general combiners for green fodder yield and the line L_2 (IFC 8401) was a good general combiner for dry matter yield also.

The crosses *viz.*, L_1 x T_1 (IFC 95102 x EC 241044) L_7 x T_1 (HES 82 x EC 241044), L_4 x T_3 (EC 4216 x UPC 953) and L_6 x T_3 (EC241027 x UPC 953) exhibited significant sca effects for green fodder yield and dry matter yield. The hybrids L_2 x T_1 (IFC 8401 x EC 241044, L_7 x T_1 (HES 82 x EC 241044) and L_6 x T_3 (EC 241027 x UPC 953) expressed significant sca effect for crude protein content.

Among the twenty one hybrids, the combinations L_7 x T_1 (HES 82 x EC 241044) and L_6 x T_3 (EC 241044 x UPC 953) showed maximum positive sca significance for green fodder yield, dry matter yield, number of leaves per plant, total leaf area, leaf area index, dry weight, calcium content and phosphorus content. The hybrid HES 82 x EC 241022 (L_7 x T_1) also had high positive sca significance for plant height and negative significance for days to maturity. So this hybrid (HES 82 x EC 241044) can be considered the best along with L_6 x T_3 (EC 241027 x UPS 953) and they can be either directly popularized as hybrid variety or can be carried forward to evolve high yielding fodder varieties.

Among the twenty one hybrids, five hybrids *viz.*, IFC 95102 x EC 241044 (L_1 x T_1), HES 82 x EC 241044 (L_7 x T_1), IFC 8401 x EC 241044 (L_2 x T_1), EC 241027 x UPC 953 (L_6 x T_3) and IFC 95102 x N 311 (L_1 x T_2) excel others by exhibiting positively significant heterosis for most of the characters. These five hybrids also had significant positive heterosis for green fodder yield and dry matter yield and they were used for studying the *in vitro* dry matter digestibility and the IVDMD was found to be good (between 56 to 70 per cent).

The mean and variance were estimated in F_2 population and the hybrid L_7 x T_1 had the maximum mean values for dry weight of stem, dry weight of leaf, crude protein content and crude fibre content, green fodder yield and dry matter yield.

The hybrids HES 82 x EC 241044 and EC 241027 x UPC 953 were identified as the promising hybrids and they can be carried forward to develop fodder varieties with high yield and quality.

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GENETIC ANALYSIS OF YIELD AND QUALITY ATTRIBUTES IN FODDER COWPEA [*Vigna unguiculata* (L.) Walp]

By

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ABSTRACT OF THE THESIS
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ABSTRACT

An experiment on "Genetic analysis of yield and quality attributes in fodder cowpea [*Vigna unguiculata* (L.) Walp.]" was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1999-2002 with the objective of estimating combining ability heterosis and gene action.

Fifty one diverse genotypes were evaluated for yield and quality attributes. Each genotype was replicated twice. The observations on plant height, number of primary branches per plant, number of leaves per plant, total leaf area, days to 50 per cent flowering, days to maturity, leaf/stem ratio, leaf area index, dry weight of leaf, dry weight of stem, green fodder yield, dry matter yield, crude protein content, crude fibre content, calcium content and phosphorus content were recorded. Variability studies indicated high GCV and PCV for dry weight of stem, dry matter yield and green fodder yield. High estimates of heritability (>70 per cent) were recorded for all the characters except number of primary branches per plant. High heritability and genetic advance were observed for dry weight of stem, dry weight of leaf, green fodder yield, dry matter yield, leaf area index and crude fibre content.

Leaf/stem ratio, leaf area index, dry weight of stem, dry weight of leaf, plant height and number of primary branches per plant showed positive significant correlation with both green fodder yield and dry matter yield. A discriminant function was fitted with 12 variables to derive a selection index for 51 accessions based on their yield and yield attributes. The top ranking seven accessions, IFC 95102, IFC 8401, UP 9001, EC 4216, EC 240744, EC 241027 and HES 82 were selected as lines (female parents) for hybridization. Another discriminant function was fitted to derive a selection index to evaluate the quality parameters *viz.*, crude protein content and crude fibre content. Three top

ranking accessions not selected as lines were selected as testers (EC 241044, N 311 and UPC 953).

Combining ability analysis showed that the lines IFC 8401 and IFC 95102 were good general combiners for green fodder yield and the line IFC 8401 was a good general combiner for dry matter yield. Among the twenty one hybrid combinations, significant sca variance was observed in the hybrids IFC 95102 x EC 241044, HES 82 x EC 241044, EC 2416 x UPC 953 and EC 241027 x UPC 953 for green fodder yield and dry matter yield. The hybrid HES 82 x EC 241044 exhibited high sca significance for plant height, number of leaves per plant, total leaf area, leaf area index, dry weight of leaf, dry weight of stem, crude protein content, calcium content and phosphorus content and significant negative significance for days to maturity. The hybrid EC 241027 x UPC 953 also exhibited superior values for most of the characters.

Of the twenty one hybrids, five combinations *viz.* IFC 95102 x EC 241044, HES 82 x EC 241044, IFC 8401 x EC 241044, EC 241027 x UPC 953 and IFC 95102 x N 311 excel others by exhibiting positively significant heterosis for most of the characters including green fodder yield and dry matter yield.

These five hybrids were used for studying *in vitro* dry matter digestibility and the percentage IVDMD was between 56 and 70.

In the F_2 population the mean and variance were estimated and here also the hybrid HES 82 x EC 241044 gave superior mean values for all characters studied.

The hybrids HES 82 x EC 241044 and EC 241027 x UPC 953 were identified as the promising hybrids and they can be carried forward to develop fodder varieties with high yield and quality.