QUANTITATIVE VARIATION AND GENETIC DIVERGENCE IN FODDER RICE BEAN

[*Vigna umbellata* (Thunb.) Ohwi and Ohashi]

By

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THESIS

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2002

To

AMY

DECLARATION

I hereby declare that this thesis entitled **"Quantitative variation and genetic divergence in fodder rice bean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi]"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Quantitative variation and genetic divergence in fodder rice bean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi]"** is a record of research work done independently by Ms. Salu B. Appan 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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Introduction

1. INTRODUCTION

The importance of livestock of Indian agriculture reflects the importance of fodder crops. The state's fodder resources are inadequate to meet the requirement of livestock population. Since there is very little scope for increasing the area under fodder crops, the only alternative is to increase production of existing fodder crops through the development of improved varieties.

Rice bean (*Vigna umbellata* (Thunb.) Ohwi and Ohashi) is one of the important under exploited pulses in India. It is an excellent source of protein and can be used as food, fodder and cover crop. It is richer than cowpea and black gram in protein, calcium and phosphorous and contains good amounts of vitamins, especially thiamine, niacin and riboflavin.

Any crop improvement programme begins with the search for variability in the germplasm. Selection of genotypes exhibiting high heritability and genetic advance for desirable yield component characters is a pre requisite in the development of high yielding varieties.

Hybridization is a powerful technique in crop improvement, the main objective being creation of genetic variability. This is achieved when genes from divergent parents are brought together in F_1. Mahalanobis D^2 statistic helps in the selection of genetically divergent parents for hybridization programmes.

The present investigation was undertaken with the objective of estimating the variability in the important economic characters and the genetic divergence among the accessions in order to group them into clusters based on the magnitude of genetic distance using Mahalanobis D^2 statistic.

Review of Literature

2. REVIEW OF LITERATURE

Rice bean, a potential legume crop, is one of the non–traditional under-utilized legumes which has recently gained attention as a supplementary food crop. Rice bean possesses immense potential due to its nutritional quality and its multipurpose use as food, animal feed, cover crop, green manure and as soil enricher. Studies have shown that this crop possesses rich genetic diversity which provides ample scope for breeding. A review of the reports on research already made in the above context is presented here.

2.1 Variability

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

Sharma *et al.* (1988) studied 35 genotypes of *Vigna unguiculata* and reported maximum genotypic coefficient of variation for dry matter yield, plant height, green forage yield, pods per plant, seed weight, green pod yield and days to 50% maturity.

Mendoza *et al.* (1990) evaluated the chemical composition of 33 accessions of 7 legume species. They found that the mature seeds contained 18-30% protein and 50-60% carbohydrates. Seed protein contents of *Canavalia ensiformis, Canavalia gladiata, Mucuna pruriens* and *Clitoria ternatea* ranged from 28-30%,those of *Dolichos lablab* and *Phaseolus lunatus* ranged from 18.5-26.1% and *Vigna umbellata* had the lowest protein content of 17.4-17.6%.

Ushakumari and Chandrasekharan (1991) reported that in fodder lablab the maximum genotypic coefficient of variation was for dry matter production followed by total leaf area.

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, seeds per pod, 100 seed weight, yield per plant and days to 50% flowering.

Thaware *et al.* (1992) reported considerable variation for green fodder yield and nutrient composition in 30 varieties of fodder cowpea.

Mishra *et al.* (1995) studied genetic variability and inter-relationships between yield and its components in rice bean and reported moderate to high genotypic coefficients of variation for all traits except seeds per pod.

In rice bean, phenotypic and genotypic coefficients of variation were high for seed yield per plant, effective nodes per plant, pods per plant, days to 50% flowering and pod maturity, 100 seed weight and plant height (Das *et al.*, 1997).

Kumar *et al.* (1997) reported significant variability for all the nine characters studied in 30 selected rice bean mutant lines.

In green gram, Das and Chakraborty (1998) reported high genotypic coefficients of variation for characters like plant height, branches per plant, pods per plant, pod length and yield per plant.

Variability studies by Sharma (1999) in 42 diverse genotypes of cowpea showed that the genotypes differed significantly for all the characters studied.

Yadav *et al.* (1999) studied variability parameters in 40 diverse genotypes of chickpea planted under normal and late sown conditions at two locations for two crop seasons. The analysis of variance revealed high variability for different traits studied.

Based on variability studies Borah and Khan (2000) reported considerable variation among genotypes of fodder cowpea for all the characters studied. 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.

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

The extent to which the variability of a quantitative character is transferable to the progeny is referred to as heritability for that particular character. Heritability estimates along with genetic advance is usually more useful in predicting the resultant effect through selection of the best individual.

Das *et al.* (1978) conducted variability and correlation studies in 36 strains of fodder cluster bean and reported that number of branches per plant had high heritability followed by plant height and dry fodder yield.

Based on genetic studies using 30 genotypes of fodder lablab, Ushakumari and Chandrasekharan (1991) reported high heritability for number of leaves, followed by plant height and dry matter production while it was moderate for crude protein content.

Mishra *et al.* (1995) reported moderate to high heritability and high genetic gain for seed yield ,days to 50% flowering, plant height, 1000 seed volume and test weight in rice bean.

High heritability and genetic advance were reported for days to 50% flowering, pod maturity, seed yield per plant, effective nodes per plant, pods per plant and plant height in rice bean by Das *et al.* (1997).

Kumar *et al.* (1997) reported high heritability estimates together with high genetic advance for plant height in 30 selected rice bean mutant lines.

Sharma (1999) reported high heritability values for most of the characters studied and high genetic advance coupled with high heritability for plant height in cowpea.

Borah and Khan (2000) reported high heritability along with high genetic advance for number of branches, number of leaves, dry weight of stem, dry weight of leaves, dry matter yield, green fodder yield and plant height in fodder cowpea.

M.:nonmani *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% flowering.

2.3 Correlation

Das *et al.* (1978) conducted correlation studies in 36 strains of fodder clusterbean and reported that dry fodder yield and number of branches had positive and significant correlation with number of clusters per plant.

Correlation analysis in forage cluster bean showed that leaf weight and stem weight had high positive correlation with both green fodder yield and dry matter yield (Shanmugam and Balasubramanian, 1983).

Sharma *et al.* (1988) reported that in fodder cowpea, green forage yield was positively and significantly correlated with days to 50% maturity, days to first flowering, plant height, pods per plant and seeds per pod.

Based on correlation studies in fodder cowpea, Jindal (1989) reported that green fodder yield, leaf weight, stem weight, number of branches, plant height, leaf number and stem girth were positively and significantly correlated among themselves.

Based on genetic studies using 30 genotypes of fodder lablab Ushakumari and Chandrasekharan (1991) reported that green fodder yield had high positive and significant genotypic correlation with plant height, dry weight of leaf and stem and dry matter production.

Aravindan and Das (1995) based on correlation studies 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.

Correlation studies by Ponmariammal and Das (1996) revealed that green fodder yield in cowpea was positively correlated with days to flowering, plant height, number of leaves, number of branches, leaf area index, dry matter yield, leaf stem ratio and protein content. Plant height, number of leaves and number of branches were positively associated among themselves. Dry matter yield was positively correlated with leaf : stem ratio and crude protein content.

Singh *et al.* (1998) reported that in cowpea genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficients.

Chaudhari *et al.* (2000) reported that in rice bean grain yield was positively correlated with plant height, branches per plant, pods per cluster, pods per plant and pod length.

In fodder cowpea Manonmani *et al.* (2000) reported positive correlation of green fodder yield with number of branches per plant , leaf length and leaf width.

Correlation studies in rice bean revealed that plant height showed positive correlation with grain yield (Thaware *et al.*, 2000).

2.4 Path coefficient analysis

Jindal(1989) studied path coefficient analysis in fodder cowpea and reported that green fodder yield. leaf weight, stem weight, number of branches, plant height, leaf number and stem girth were positively and significantly correlated among themselves. Branches per plant was found to be the major component for fodder yield in cowpea.

Renganayaki and Sree Rengaswamy (1992 a) found that in blackgram, primary leaf area and plant height had higher positive direct effect on seed yield.

In cowpea, it was reported that plant height exerted maximum positive direct effect on seed yield followed by primary leaf area (Renganayaki and Sree Rengaswamy, 1992 b).

In fodder cowpea, Ponmariammal and Das (1996) reported that days to flowering, plant height, number of leaves, number of branches and leaf : stem ratio showed positive direct effect on green fodder yield. Plant height had positive indirect effect on green fodder yield through number of branches, number of leaves, dry matter yield and crude protein content.

Path analysis in fodder cowpea done by Srinivasan and Das (1996) revealed that a desirable plant type for higher forage yield would be late flowering with a tall plant stature and more number of larger leaves.

Path analysis in rice bean revealed maximum positive direct effect of number of clusters per plant followed by days to maturity and days to 50% flowering on grain yield per plant (Sonone *et al.*, 1999).

2.5 Genetic divergence

Jindal and Gupta (1985) reported that analysis of data on 7 traits using Mahalanobis D^2 statistic led to the grouping of 39 strains of fodder cowpea into 5 clusters. Leaf number per plant and branch number per plant contributed most to total divergence.

Based on divergence studies in green gram, Tawar *et al.* (1988) reported that variability observed in parents was related to the genetic diversity of the parents selected under the study.

Dharmalingam and Kadambavanasundaram (1989) assessed the genetic divergence for 8 characters among 40 geographically diverse varieties of cowpea by multivariate analysis using Mahalanobis D^2 statistic and found that they were widely divergent.

In cluster bean, Henry and Krishna (1990) reported considerable divergence for days to flower initiation and 50% flowering, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, number of seeds per pod, 100 seed weight, straw yield, seed yield and days to maturity.

Murthy and Dorairaj (1990) reported that 40 early maturing genotypes of pigeon pea from different geographic regions when analysed using D^2 and canonical analysis, fell into three clusters. Genetic diversity was independent of geographic origin. High variability could be obtained for earliness, seed yield and protein content in crossing programme involving genotypes from widely related clusters.

Roquib and Das (1995) applied D^2 statistic to 63 strains of rice bean, regarding seven seed and forage yielding characters. They noted that the merits of days to 50% flowering, dry matter and green forage yield in contributing towards total divergence in both the years were stable enough while days to 50% flowering had a more profound effect on genetic divergence than other characters under study.

Kumar *et al.* (1996) reported that 30 radiation induced rice bean M4 mutants and a control variety were grouped into 8 clusters by D^2 analysis.

Sharma *et al.* (1996) studied diversity of 28 genotypes of rice bean by Mahalanobis D^2 analysis. The genotypes were grouped into 6 clusters. Clusters II, III and V were the most divergent, with a high mean yield expression.

Rewale *et al.* (1996), in a divergence analysis in cowpea, grouped the 70 genotypes studied into 19 clusters of which 11 had only one genotype each.

Days to initiation of flowering, 50% flowering and maturity, number of inflorescences and pods per plant, pod length, 100 seed weight, seed yield per plant and harvest index made the largest contribution to total divergence.

Deshmukh and Patil (1998) reported that five genotypes of chickpea were grouped into eleven clusters on the basis of D^2 analysis.

Divergence studies conducted by Mandal and Dana (1998) revealed that number of pods per plant, days to 50% flowering and number of effective nodes per plant contribute maximum towards genetic divergence in rice bean.

Based on divergence analysis in dolichos bean, Nandi *et al.* (1998) reported that 28 genotypes were grouped into 10 clusters, with a maximum number of 7 genotypes per cluster. There was a lack of relationship between genetic and geographic diversity. Green pod yield per plant and pod weight accounted for 87.4% of total genetic variation.

In rice bean, Singh *et al.* (1998) reported the existence of considerable diversity among cultivars of different ecogeographic origin.

Kumar *et al.* (1998) reported that for varietal improvement, the hybridization among the genotypes of divergent clusters should be done rather than depending on those genotypes of the cluster having maximum divergence.

Singh *et al.* (1999) studied genetic divergence of 31 local rice bean cultivars from the Manipur hills. Based on Mahalanobis D^2 values of data from 7 yield components, the genotypes were classified into 5 different clusters following Torher's method. Depending upon the inter cluster distance, cluster mean value and mean per se performance of the best genotype within the cluster, cross combinations involving different selected parents for various breeding objectives were suggested.

Sivakumar and Muthiah (2000) carried out divergence studies in 126 chickpea genotypes using Mahalanobis D^2 statistics. The varieties were grouped into 7 clusters. Maximum divergence was observed in the clusters IV and VII and the minimum between IV and V. The intercluster divergence varied from 0 to 2.99. The maximum intracluster distance was in cluster I with 108 genotypes.

Basavarajappa and Byregowda (2000) studied genetic diversity among 144 collections of field bean. The accessions revealed considerable diversity and were grouped into 15 clusters. The genetic diversity observed was not related to geographic diversity.

The nature and magnitude of genetic divergence assessed in 32 genotypes of cowpea using Mahalanobis D^2 value indicated considerable diversity in the material studied. The genotypes were grouped into 6 clusters, cluster IV had the maximum number of genotypes. The 'intra and inter' cluster average D^2 values indicated maximum statistical distance between clusters I and V followed by III and V. Geographic diversity was not related to genetic diversity. Single plant yield, harvest index and earliness in flowering contributed considerably and accounted to 80% of total divergence (Backiyarani *et al.*, 2000).

Ushakumari *et al.* (2000) grouped 50 genotypes of cowpea into 13 clusters by Mahalanobis D^2 statistic. Among the yield attributing characters, seeds per pod, number of branches, number of pods per cluster and pod length were the important traits responsible for the divergence recorded.

Thombre *et al.* (2000) analysed 64 genotypes of pigeonpea. They formed 15 diverse clusters. Genetic diversity was independent of their pedigree. Sufficient amount of variability was observed in these genotypes which indicated scope for selecting more diverse parents to produce high heterotic effects and desirable segregants.

Mitra *et al.* (2000) evaluated two hundred and thirty one germplasm lines of clusterbean along with 3 checks for seed yield and its components. Following non-hierarchial Euclidean analysis, all the 234 genotypes were grouped into 12 clusters with variable number of genotypes. On the basis of genetic divergence and mean performance, 8 diverse and superior genotypes were selected for further use in crossing programmes.

Nandi *et al* (2000) used Mahalanobis D^2 statistic to analyse genetic diversity in 28 genotypes of hyacinth bean. The genotypes were grouped into 5 clusters. The average intercluster D^2 values indicated maximum statistical divergence between clusters II. and V.

Two hundred germplasm lines of mungbean, along with six commercial varieties were evaluated over four diverse environments for seed yield and its components. The genotypes were grouped into 7 clusters. On the basis of this analysis, diverse genotypes with desirable level of particular characters have been identified (Raje and Rao, 2001).

On the basis of D^2 analysis, Samal *et al.* (2001) grouped 23 mutant lines of pigeon pea into 9 clusters of which cluster I was the largest followed by cluster III.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani from September to November, 1999.

3.1 Materials

The materials for the study included 60 accessions of fodder rice bean collected from Punjab Agricultural University, Ludhiana. The details of the accessions are presented in Table 1.

3.2 Methods

A field experiment with 60 accessions was conducted in randomized block design with two replications. The crop was raised as per the technical programme of AICRP on forage crops. Five plants were selected at random from each plot, the data on the following characters were recorded and the corresponding means were subjected to statistical analyses.

a. Plant height at harvest (cm)

The height of the plant at harvest was measured in centimeters from the ground level to the tip of the growing point.

b. Number of branches per plant

The number of primary branches on each of the five observational plants was counted and the mean worked out.

Table 1. Details of rice bean accessions

Sl. No.	Accession number	Source
1.	RBL 3	PAU, Ludhiana
2.	RBL 11	"
3.	LRB 12	"
4.	RBL 14	"
5.	LRB 16	"
6.	LRB 20	"
7.	LRB 24	"
8.	RBL 25	"
9.	LRB 26	"
10.	LRB 29	"
11.	LRB 30	"
12.	LRB 41	"
13.	RBL 44	"
14.	RBL 47	"
15.	LRB 51	"
16.	LRB 52	"
17.	LRB 53	"
18.	RBL 54	"
19.	RBL 57	"
20.	RBL 61	"
21.	RBL 62	"
22.	RBL 64	"
23.	RBL 71	"
24.	RBL 74	"
25.	RBL 77	"
26.	LRB 77	"
27.	RBL 78	"
28.	LRB 82	"
29.	RBL 89	"
30.	LRB 95	"

Table 1. Contd...

Sl. No.	Accession number	Source
31.	LRB 96	PAU, Ludhiana
32.	RBL 98	"
33.	LRB 99	"
34.	LRB 100	"
35.	LRB 103	"
36.	LRB 109	"
37.	LRB 110	"
38.	LRB 114	"
39.	RBL 116	"
40.	RBL 118	"
41.	LRB 127	"
42.	LRB 136	"
43.	LRB 145	"
44.	LRB 152	"
45.	LRB 160	"
46.	LRB 177	"
47.	LRB 182	"
48.	LRB 195	"
49.	LRB 198	"
50.	LRB 199	"
51.	LRB 199	"
52.	LRB 207	"
53.	RBL 219	"
54.	LRB 221	"
55.	LRB 225	"
56.	LRB 227	"
57.	LRB 228	"
58.	LRB 233	"
59.	LRB 235	"
60.	LRB 242	"

A view of fodder rice bean plants in the field

c. Number of leaves per plant

The total number of leaves from each sample plant was counted and the average recorded.

d. Leaf : stem ratio

The sample plants collected for recording dry matter yield were separated into leaf and stem, dried, weighed and the leaf: stem ratio was worked out on dry weight basis.

e. Leaf area index

Leaf area was measured using LI 300 leaf area meter at 50% flowering and expressed in square centimeters.

LAI was worked out using the following equation.

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

f. Duration of crop

The total number of days from germination to harvest was recorded as duration of the crop.

g. Leaf weight per plant (g)

Five plants selected at random from each plot were harvested, leaves separated, the mean leaf weight per plant was estimated and expressed in grams.

h. Green fodder yield (t/ha)

The green fodder yield per plot was recorded at harvest and estimated in tonnes per hectare.

i. Dry matter yield (t/ha)

At harvest random sample was taken from each plot, weighed, 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 tones per hectare.

j. 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 (Simpson *et al.*, 1965).

k. 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).

3.2.1. Statistical analysis

The data collected were subjected to the following statistical analyses.

3.2.1.1 Analysis of variance and covariance

Analysis of variance and covariance were done

(i) to test the significance of differences among the accessions with respect to various characters under study

(ii) to estimate the variance components and other parameters like correlation coefficients, heritability and genetic advance.

Table 2 represents the analysis of variance / covariance. Other genetic parameters were estimated from this table.

Variance	**X**	**Y**
Environmental variance ($\sigma^2 e$)	$= \sigma^2 e_x = E_{xx}$	$\sigma^2 e_y = E_{yy}$
Genotypic variance ($\sigma^2 g$)	$= \sigma^2 g_x = \dfrac{G_{xx}-E_{xx}}{r}$	$\sigma^2 g_y = \dfrac{G_{yy}-E_{yy}}{r}$
Phenotypic variance ($\sigma^2 p$)	$= \sigma^2 p_x = \sigma^2 g_x + \sigma^2 e_x$	$\sigma^2 p_y = \sigma^2 g_y + \sigma^2 e_y$

3.2.1.2 Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) are estimated as follows.

$$GCV = \frac{\sigma g_x}{\bar{x}} \times 100$$

$$PCV = \frac{\sigma p_x}{\bar{x}} \times 100$$

where σg_x = genotypic standard deviation

σp_x = phenotypic standard deviation

3.2.1.3. Heritability (Broad sense)

Heritability was estimated as given in Jain (1982)

$$H^2 = \frac{\sigma^2 g_x}{\sigma^2 p_x} \times 100$$

3.2.1.4 Genetic advance as percentage of mean

$$GA = \frac{kH^2 \sigma p_x}{\bar{x}} \times 100 \text{ (Miller } et\ al.\text{, 1958)}$$

where k = selection differential = 2.06 at 5% selection

and $\bar{x}$ = mean

3.2.1.5 Correlation

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

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

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

3.2.1.6 Path coefficient analysis

Path coefficient analysis was carried out by the method suggested by Dewey and Lu (1959).

Value of path coefficients can be obtained by matrix solution.

i.e., $P = G^{-1}R$

where, P - Vector of path coefficients

G - Correlation matrix of causes

R - Correlation vector of cause and effect

3.2.1.7. Mahalanobis D^2 analysis

Mahalanobis D^2 statistic was applied to cluster the 60 accessions of fodder rice bean. For i^{th} and j^{th} accessions, D^2 value is computed as

$$D^2 = \sum_{l=1}^{K} (X_{il} - X_{jl})^2$$

where k is the number of characters, X_{il} and X_{jl} are the uncorrelated means for the characters X_i and X_j in the l^{th} genotype. The significance of D^2 values were tested by chi square test with k degrees of freedom.

The genotypes were grouped into several clusters based on these D^2 values following Tocher's method of clustering (Rao, 1952).

Results

4. RESULTS

The data collected from the experiment were statistically analysed and the results are presented below.

4.1 Evaluation of accessions

Data on plant height at harvest, number of branches per plant, number of leaves per plant, leaf : stem ratio, leaf area index, leaf weight per plant, green fodder yield, dry matter yield, crude protein content and crude fibre content collected from 60 accessions were subjected to analysis of variance and covariance and the results are presented below.

4.1.1 Mean performance of the accessions

4.1.2. Variability components and related genetic parameters

4.1.3. Correlation analysis

4.1.4. Path coefficient analysis

4.1.5. Genetic divergence analysis

4.1.1 Mean performance of the accessions

The mean values of ten characters studied are presented in the Table 2. The analysis of variance revealed that there was significant difference among the accessions for all the characters except duration of the crop.

Plant height at harvest (cm)

Plant height at harvest ranged from 58.8 cm in LRB 221 to 202.8 cm in LRB 145, with a coefficient of variation 12.0%.

Table 2. Mean values of various characters in fodder rice bean

Sl.No.	Accession No.	Plant height at harvest (cm)	Number of branches per plant	Number of leaves per plant	Leaf stem ratio	Leaf area index	Duration of crop (days)	Leaf weight per plant (g)	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Crude protein content (%)	Crude fibre content (%)
1	LRB 199	106.0	3.4	37.7	0.29	5.7	95	51.0	26.1	7.8	16.9	30.7
2	LRB 51	116.4	3.7	34.0	0.32	3.8	98	46.3	23.4	6.6	16.0	28.0
3	LRB 198	108.1	4.0	43.7	0.36	3.6	95	64.2	30.6	8.3	18.4	31.5
4	LRB 182	107.7	3.2	33.2	0.25	2.7	100	45.5	29.7	7.7	16.8	33.4
5	LRB 207	114.3	4.2	26.9	0.32	2.7	103	38.0	18.6	5.2	16.7	24.6
6	LRB 96	99.5	3.7	50.3	0.31	4.3	95	50.2	25.3	7.1	16.5	29.1
7	LRB 127	126.8	3.0	35.4	0.28	4.4	97	38.7	21.2	5.9	15.9	27.7
8	LRB 177	110.7	3.5	28.4	0.25	2.9	100	29.5	17.5	4.9	15.8	24.5
9	LRB 242	112.0	2.7	49.5	0.29	5.8	95	41.5	22.1	6.2	17.2	31.4
10	LRB 199	94.3	2.8	19.9	0.25	2.8	102	29.7	18.3	5.1	15.5	22.5
11	LRB 29	108.8	4.4	46.8	0.28	5.0	97	69.3	19.4	5.4	16.2	28.3
12	LRB 136	96.8	4.1	30.5	0.31	2.9	95	40.5	20.6	5.8	16.5	28.5
13	LRB 95	123.5	3.4	37.9	0.27	3.8	95	33.3	18.8	5.3	16.5	28.5
14	LRB 227	106.2	4.0	48.2	0.33	3.6	95	50.0	24.2	6.8	16.3	30.7
15	RBL 78	107.2	3.5	25.8	0.28	3.3	95	41.8	22.8	6.4	16.5	24.3
16	RBL 219	96.0	3.4	25.6	0.2	3.8	95	21.2	15.2	4.3	17.5	26.5
17	LRB 109	119.8	4.4	29.2	0.3	3.3	102	38.1	19.5	5.5	16.7	26.5
18	RBL 54	117.8	3.4	22.4	0.25	3.0	100	31.8	18.9	5.3	15.6	28.6
19	LRB 228	98.7	5.0	24.2	0.25	3.1	100	30.6	18.1	5.1	16.4	28.5
20	RBL 25	104.3	2.9	21.5	0.27	3.0	95	34.4	19.5	5.5	16.4	24.5
21	LRB 24	88.1	3.4	25.9	0.3	3.1	103	27.5	12.3	3.5	15.9	24.0

Table 2. Contd...

Sl.No.	Accession No.	Plant height at harvest (cm)	Number of branches per plant	Number of leaves per plant	Leaf: stem ratio	Leaf area index	Duratio of crop (days)	Leaf weight per plant (g)	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Crude protein content (%)	Crude fibre content (%)
22	LRB 30	104.8	3.9	28.5	0.28	3.5	97	34.6	19.0	5.3	16.3	24.6
23	RBL 74	107.1	4.2	28.9	0.29	3.1	95	40.9	21.9	6.1	16.3	24.6
24	LRB 110	148.4	4.4	41.9	0.34	4.2	95	55.2	25.7	7.2	18.4	30.2
25	RBL 77	92.4	3.7	19.5	0.31	3.0	96	46.3	23.3	6.5	16.2	24.7
26	LRB 152	95.0	4.9	24.5	0.28	3.5	95	35.6	19.5	5.5	16.9	25.4
27	RBL 11	100.0	4.5	32.2	0.31	3.2	95	42.7	21.4	6.0	16.5	24.5
28	LRB 52	102.3	4.4	30.9	0.32	4.0	98	42.4	20.9	5.8	16.5	24.5
29	LRB 221	58.8	3.2	25.2	0.29	3.6	95	34.5	18.6	5.2	17.6	25.6
30	RBL 89	103.8	4.0	38.7	0.34	4.0	95	51.0	23.9	6.7	16.9	28.2
31	LRB 77	105.3	4.0	28.9	0.29	3.4	98	40.6	21.8	6.1	15.9	28.1
32	LRB 114	113.3	4.2	35.7	0.29	4.9	102	25.0	13.5	3.8	17.0	29.3
33	LRB 195	112.1	3.9	34.9	0.34	4.6	98	51.5	24.3	6.8	18.4	30.2
34	RBL 44	86.1	3.9	32.2	0.3	3.3	95	44.3	23.1	6.5	16.6	26.7
35	LRB 233	157.2	5.1	39.5	0.31	4.4	95	61.2	31.3	8.7	16.3	28.7
36	RBL 47	81.6	3.7	39.3	0.36	4.1	95	48.3	22.0	6.2	15.6	24.5
37	LRB 103	95.2	4.0	35.5	0.28	3.7	95	31.3	17.1	4.8	17.0	26.3
38	RBL 62	140.8	4.9	33.3	0.28	3.6	95	38.3	21.1	5.9	17.3	28.4
39	LRB160	119.9	3.2	24.0	0.37	2.9	103	32.7	14.7	4.1	16.5	28.5
40	LRB 235	151.8	4.5	38.0	0.27	3.6	100	37.8	20.8	5.8	16.7	28.4
41	LRB 53	76.2	4.2	16.2	0.28	2.3	100	19.5	11.6	3.2	16.4	28.5
42	LRB 145	202.8	4.0	45.7	0.23	5.0	103	31.2	19.8	5.5	15.3	28.5

Table 2. Contd...

Sl.No.	Accession No.	Plant height at harvest (cm)	Number of branches per plant	Number of leaves per plant	Leaf: stem ratio	Leaf area index	Duration of crop (days)	Leaf weight per plant (g)	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Crude protein content (%)	Crude fibre content (%)
43	LRB 100	19.9	4.7	30.7	0.27	4.1	103	34.3	19.8	5.5	15.3	28.5
44	RBL 14	81.0	3.3	26.8	0.32	3.7	95	25.2	22.6	6.3	15.9	28.9
45	RBL 3	95.9	3.9	32.5	0.29	4.0	96	29.3	15.5	4.3	16.3	27.6
46	LRB 99	113.2	4.2	20.3	0.28	3.3	95	27.7	15.0	4.2	16.9	26.2
47	LRB 225	113.3	4.5	43.1	0.25	5.1	95	22.0	13.4	376.0	15.2	29.9
48	LRB 41	141.5	5.0	39.7	0.36	3.8	95	67.3	30.8	8.6	16.5	31.3
49	RBL 98	129.6	4.5	32.6	0.35	3.7	98	46.1	21.4	6.0	16.4	28.5
50	RBL 71	124.1	4.7	39.2	0.34	4.1	98	46.7	22.1	6.2	17.3	28.7
51	LRB 26	121.7	4.9	39.2	0.31	4.2	100	50.5	25.3	7.1	15.3	30.1
52	RBL 61	134.5	4.7	40.2	0.34	4.2	98	48.5	22.7	6.4	14.4	29.3
53	LRB 16	98.9	4.2	21.0	0.24	2.3	95	20.0	12.2	3.4	17.2	26.6
54	LRB 82	104.4	4.4	28.0	0.34	4.0	95	36.2	17.0	4.8	16.5	28.3
55	LRB 12	91.5	3.9	26.9	0.27	3.4	100	38.7	21.5	6.0	16.4	28.6
56	RBL 64	107.0	4.5	25.5	0.34	2.9	103	44.3	20.9	5.9	16.3	29.5
57	LRB 20	119.3	4.9	28.5	0.28	3.3	98	37.5	20.8	5.8	15.5	28.6
58	RBL 118	137.4	3.9	16.1	0.44	2.0	95	18.1	18.4	5.1	16.2	28.5
59	RBL 57	140.1	4.7	32.5	0.28	4.2	95	30.3	21.0	5.9	16.1	26.5
60	RBL 116	113.8	3.5	26.5	0.25	3.4	100	44.8	17.7	5.0	16.3	28.7
$F_{59,59}$		5.50**	3.19**	11.94**	17.58	34.46**		22.83**	14.80**	14.38**	821.76**	2423.53**
SE		9.56	0.34	2.3934	9.79^{E-03}	0.1319		2.39	1.1281	0.316	0.0263	0.046
CD		27.03	0.95	6.7696	2.77^{E-02}	0.373		6.76	3.1907	0.8939	0.0745	0.1301

**Significant at 1% level

Number of branches per plant

The maximum number of branches per plant (5.1) was recorded in LRB 233. LRB 242 recorded the lowest value of 2.7. The CV was 11.8%.

Number of leaves per plant

The mean number of leaves per plant ranged from 16.1 in LRB 118 to 50.3 in LRB 96 with CV 10.5%.

Leaf : stem ratio

LRB 118 recorded the maximum leaf : stem ratio with an average of 0.44. The minimum leaf : stem ratio (0.2) was recorded in RBL 219. The CV was 4.6%.

Leaf area index

The leaf area index ranged from 5.7 in LRB 199 and LRB 242 to 2.0 in LRB 118, with CV 5.2%.

Leaf weight per plant (g)

The mean leaf weight per plant ranged from 18.1g in LRB 118 to 69.3g which was recorded by LRB 29. The CV was 8.5%.

Green fodder yield (t/ha)

LRB 233 recorded the maximum yield of green fodder (31.3 t/ha). The minimum green fodder yield 11.6 t/ha was recorded in LRB 53. The CV was 7.7%.

Dry matter yield (t/ha)

The mean dry matter yield ranged between 3.2 t/ha and 8.7 t/ha. The maximum value was recorded by LRB 233 while LRB 53 showed the minimum dry matter yield. The CV was 7.8 %.

Crude protein content (%)

The maximum crude protein content (18.4%) was recorded by LRB110 while RBL 61 recorded the minimum value (14.4%), with a CV 0.2%.

Crude fibre content (%)

Crude fibre content ranged from 24.0% in LRB 24 to a maximum of 33.4% in LRB 182 with a CV 0.2%.

4.1.2. Variability components and related genetic parameters

Phenotypic, genotypic and environmental components of variance, phenotypic, genotypic and environmental coefficients of variation, heritability and genetic advance (as percentage of mean) were estimated and presented in Tables 3 and 4 respectively.

4.1.2.2. Coefficient of variation

The values of phenotypic, genotypic and environmental coefficient of variation are given in Table 3. Leaf weight per plant recorded the highest phenotypic coefficient of variation (29.6%) followed by number of leaves per plant (26.8%), green fodder yield (21.8%), plant height at harvest (21.7%), dry matter yield (21.5%) and leaf area index (21.5%). The lowest PCV was recorded for crude protein content (4.8%).

Genotypic coefficient of variation (GCV) was high for leaf weight per plant (28.3%), followed by number of leaves per plant (24.6%), leaf area index (20.9%) and green fodder yield (20.7%). GCV was lowest for crude protein content (4.7%).

Number of leaves per plant recorded the maximum environmental coefficient of variation (35.6%), followed by leaf weight per plant (28.9%), green fodder yield (12.3%) and plant height at harvest (12.0%). The least ECV was recorded for crude protein content (0.008%). Crude fibre content recorded an ECV of 0.015%. This indicates that crude protein content and crude fibre content were not influenced by the environment. Number of leaves per plant was more influenced by environment while leaf weight per plant was variable at all levels. Leaf area index was also not much influenced by environment.

At both phenotypic and genotypic levels, leaf weight per plant was the most variable trait while crude protein content was the least variable trait.

4.1.2.3 Heritability and Genetic Advance

The values of heritability coefficient (%) and genetic advance (as percentage of mean) at five per cent selection for different characters are presented in Table 4.

All the characters except number of branches per plant were highly heritable. Number of branches per plant was medium heritable. Branches per plant, leaf area index, crude protein and crude fibre contents were the characters for which one cannot expect much genetic advance. Heritability was maximum for the character crude fibre content (99.9%). Apart from

Table 3. Components of variation of ten characters in fodder rice bean

Sl. No.	Character	Phenotypic variance σp^2	Genotypic variance σg^2	Environ-mental variance σe^2	GCV (%)	PCV (%)	ECV (%)
1	Plant height at harvest(cm)	593.84	411.15	182.69	18.09	21.74	12.06
2	Number of branches per plant	0.47	0.24	0.22	12.46	17.24	5.65
3	Number of leaves per plant	74.11	62.65	11.45	24.64	26.8	35.67
4	Leaf : stem ratio	0.002	0.002	0.0002	13.42	14.21	0.07
5	Leaf area index	0.62	0.58	0.04	20.93	21.54	1.1
6	Leaf weight per plant (g)	136.18	125.75	11.43	28.33	29.6	28.99
7	Green fodder yield (t/ha)	20.11	17.56	2.55	20.37	21.8	12.39
8	Dry matter yield (t/ha)	1.54	1.34	0.2	13.42	21.54	3.47
9	Crude protein content(%)	0.621	0.619	0.0014	4.79	4.8	0.008
10	Crude fibre content 9%)	5.14	5.13	0.0042	8.17	8.17	0.015

Table 4. Heritability and genetic advance of ten characters in fodder rice bean

Sl. No.	Character	Heritability broad sense(%)	Genetic advance at 5% intensity of selection
1	Plant height at harvest	69.24	34.75
2	Number of branches per plant	52.28	0.74
3	Number of leaves per plant	84.54	14.99
4	Leaf: stem ratio	89.24	14.21
5	Leaf area index	94.36	1.53
6	Leaf weight per plant	91.60	22.02
7	Green fodder yield	87.34	21.80
8	Dry matter yield	86.99	21.54
9	Crude protein content	99.77	4.80
10	Crude fibre content	99.92	8.17

this, heritability was high for crude protein content (99.7%), leaf area index (94.3%), leaf weight per plant (91.6%), leaf : stem ratio (89.2%), green fodder yield (87.3%), dry matter yield (86.9%), number of leaves per plant (84.5%) and plant height at harvest (69.2%). Number of branches per plant recorded medium heritability of 52.2%.

Genetic advance as percentage of mean was high for plant height at harvest (34.7%), leaf weight per plant (22.0%), green fodder yield (21.8%) and dry matter yield (21.5%). Number of leaves per plant (14.9%), leaf : stem ratio (14.2%), crude fibre content (8.1%), crude protein content (4.8%), number of branches per plant (0.7%) and leaf area index (1.5%) exhibited low genetic advance.

High value of heritability coupled with high genetic advance was observed for plant height at harvest, leaf weight per plant, green fodder yield and dry matter yield. High heritability and low genetic advance was recorded for number of leaves per plant, leaf : stem ratio, crude fibre content, crude protein content and leaf area index.

4.1.3. Correlation analysis

Phenotypic correlation

Plant height was positively correlated with all the characters except crude protein. Number of branches per plant had correlation with leaf weight per plant and plant height. Number of leaves per plant was uncorrelated with number of branches per plant, leaf : stem ratio and crude protein. Leaf : stem ratio was correlated with leaf weight per plant, green fodder yield and dry matter yield. Leaf area index was correlated with plant height, number of

Table 5. Phenotypic correlation coefficient of ten characters in fodder rice bean

Sl No	Character	Plant height at harvest	Number of branches per plant	Number of leaves per plant	Leaf stem ratio	Leaf area index	Leaf weight per plant	Green fodder yield	Dry matter yield	Crude protein content	Crude fibre content
1	Plant height at harvest	-									
2	Number of branches per plant	0.2795**	-								
3	Number of leaves per plant	0.3490**	0.1173	-							
4	Leaf: stem ratio	0.0154	0.1578	0.0673	-						
5	Leaf area index	0.2756**	0.0346	0.7181**	-0.0748	-					
6	Leaf weight per plant	0.1725	0.2118*	0.5953**	0.3265**	0.3423**	-				
7	Green fodder yield	0.2465**	0.1531	0.4727**	0.2453**	0.2399**	0.8093**	-			
8	Dry matter yield	0.2503**	0.1582	0.4767**	0.2506**	0.2720	0.8139**	0.9962**	-		
9	Crude protein content	-0.099	-0.0344	0.0681	0.1158	0.0541	0.1745*	0.1469	0.1387	-	
10	Crude fibre content	0.2968**	0.1462	0.4981**	0.1358	0.3676**	0.3433**	0.4109**	0.3980**	0.2302**	-

*Significant at 1% level
**Significant at 5% level

Table 6. Genotypic correlation coefficient of ten characters in fodder rice bean

Sl No	Character	Plant height at harvest	Number of branches per plant	Number of leaves per plant	Leaf: stem ratio	Leaf area index	Leaf weight per plant	Green fodder yield	Dry matter yield	Crude protein content	Crude fibre content
1	Plant height at harvest	–									
2	Number of branches per plant	0.3547	–								
3	Number of leaves per plant	0.4052	0.1934	–							
4	Leaf: stem ratio	0.0229	0.2113	0.0582	–						
5	Leaf area index	0.3184	0.0512	0.7953	-0.0885	–					
6	Leaf weight per plant	0.1828	0.2683	0.6121	0.3383	0.3575	–				
7	Green fodder yield	0.2753	0.1942	0.4917	0.3005	0.2555	0.8089	–			
8	Dry matter yield	0.2793	0.2028	0.4967	0.3077	0.291	0.8144	0.9956	–		
9	Crude protein content	-0.1215	-0.0459	0.0747	0.1196	0.0563	0.1847	0.1602	0.1517	–	
10	Crude fibre content	0.3561	0.2058	0.541	0.1464	0.3782	0.358	0.4374	0.4245	0.2302	–

Table 7. Environmental correlation coefficient of ten characters in fodder rice bean

Sl No	Character	Plant height at harvest	Number of branches per plant	Number of leaves per plant	Leaf: stem ratio	Leaf area index	Leaf weight per plant	Green fodder yield	Dry matter yield	Crude protein content	Crude fibre content
1	Plant height at harvest	–									
2	Number of branches per plant	0.1723	–								
3	Number of leaves per plant	0.1788**	-0.0415	–							
4	Leaf: stem ratio	-0.0145	0.0592	0.13	–						
5	Leaf area index	0.1382	-0.0081	0.083	0.0813	–					
6	Leaf weight per plant	0.1673	0.1304	0.4972**	0.2174*	0.1442	–				
7	Green fodder yield	0.1641	0.0891	0.3587**	-0.1713	0.0942	0.8322**	–			
8	Dry matter yield	0.1678	0.086	0.3579**	-0.1735	0.0969	0.8311**	0.9999**	–		
9	Crude protein content	0.0767	-0.0389	-0.0310	0.1905*	-0.0464	-0.1502	-0.1547	-0.1529	–	
10	Crude fibre content	0.0415	-0.1261	0.0739	-0.2595**	0.0627	0.0975	0.2244*	0.2219*	0.2455**	–

*Significant at 1% level
**Significant at 5% level

leaves per plant, leaf weight, green fodder yield and crude fibre content. Leaf weight per plant was correlated with all characters except plant height. Green fodder yield was correlated with all characters except number of branches per plant and crude protein content. Dry matter yield was correlated with all characters except number of branches per plant, leaf area index and crude protein content. Crude protein content was correlated only with leaf weight and crude fibre while crude fibre content was correlated with all characters except number of branches per plant and leaf : stem ratio.

Environmental correlation

For most of characters, pair wise environmental correlation was absent. The only significant correlation observed for x_3, with x_1, x_6, x_7 and x_8; x_4 with x_6, x_9 and x_{10}; x_6 with x_7 and x_8; x_9 with x_4 and x_{10}; x_{10} with x_4, x_7, x_8 and x_9.

Genotypic correlation

Green fodder yield showed high genotypic correlation both dry matter yield, leaf weight per plant, number of leaves per plant, crude fibre content, leaf stem ratio and plant height at harvest.

4.1.4. Path coefficient analysis

Path coefficient analysis was carried out using six characters, *viz.*, plant height at harvest, number of branches per plant, number of leaves per plant, leaf : stem ratio, leaf area index and leaf weight per plant. The direct and indirect effects of these component characters are presented in Table 8.

Leaf weight per plant exhibited maximum direct effect (0.8204) on green fodder yield and its genotypic correlation with green fodder yield was high (0.8090). Indirect effects via other characters were negligible.

Table 8. Direct and indirect effects of component characters on green fodder yield

Sl No	Character	Plant height at harvest	Number of braches per plant	Number of leaves per plant	Leaf stem ratio	Leaf area index	Leaf weight per plant	Total correlation
1	Plant height at harvest (cm)	0.1858	-0.0335	0.0021	0.0007	-0.0298	0.1500	0.2753
2	Number of branches per plant	0.0659	-0.0944	0.0010	0.0064	-0.0048	0.2201	0.1942
3	Number of leaves per plant	0.0753	-0.0183	0.0052	0.0018	-0.0744	0.5021	0.4917
4	Leaf stem ratio	0.0043	-0.0199	0.0003	0.0301	0.0083	0.2775	0.3006
5	Leaf area index	0.0592	-0.0048	0.0041	-0.0027	-0.0936	0.2933	0.2555
6	Leaf weight per plant (g)	0.0340	-0.0253	0.0032	0.0102	-0.0335	0.8204	0.8090

Residual effect = 0.3159 (32 %)
The underlined figures are direct effects

The second highest direct effect on green fodder yield was exhibited by plant height (0.1858) with a genotypic correlation of 0.2753.This increase in the total correlation was mainly due to its positive indirect effect via leaf weight per plant (0.1500).

Other characters exhibited low or negative direct effects on green fodder yield but showed relatively high genotypic correlation due to their high positive indirect effects via leaf weight per plant followed by plant height at harvest.

The two characters *viz.* leaf weight per plant and plant height exhibited maximum positive direct effect and also exhibited high positive indirect effects via other characters. Therefore leaf weight per plant followed by plant height are the main characters responsible for any increase in the production of green fodder yield.

Residual effect was 0.3159, indicating about 68% contribution to green fodder yield through the selected component characters.

4.1.5. Genetic divergence analysis

Sixty accessions of fodder rice bean were subjected to Mahalanobis D^2 analysis based on plant height at harvest, number of branches per plant, number of leaves per plant, leaf : stem ratio, leaf area index, leaf weight per plant, green fodder yield, dry matter yield, crude protein content and crude fibre content.

The significance of these values was tested using Chi-square test of significance. All the D^2 values were significant indicating significant divergence among pair wise genotypes. These accessions were grouped into

Table 9. Group constellations of 60 accessions

Cluster	Number of accessions	Accessions
I	33	1, 2, 4, 5, 6, 8, 9, 10, 12, 14, 15, 17, 19, 20, 22, 23, 25, 26, 27, 28, 30, 31, 33, 34, 36, 37, 45, 50, 51 54, 55, 57, 60
II	11	7, 13, 18, 32, 38, 39, 43, 46, 49, 52, 59
III	6	16, 21, 41, 44, 53, 56
IV	2	3, 11
V	3	24, 35, 48
VI	1	40
VII	1	29
VIII	1	47
IX	1	58
X	1	42

Table 10. Cluster means of ten characters`

Sl. No.	Character	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
1	Plant height at harvest (cm)	104.54	127.21	91.19	108.47	149.02	151.75	58.85	113.27	137.40	202.85
2	Number of branches per plant	3.92	3.92	3.92	4.17	4.84	4.50	3.17	4.50	3.84	4.00
3	Number of leaves per plant	33.06	31.33	23.54	45.22	40.30	38.00	25.15	43.10	16.15	45.65
4	Leaf : stem ratio	0.29	0.32	0.29	0.30	0.33	0.27	0.28	0.24	0.44	0.23
5	Leaf area index	3.60	3.79	3.00	4.27	4.08	3.60	3.60	6.00	2.00	5.00
6	Leaf weight per plant	41.22	35.14	29.50	66.76	61.21	37.75	34.53	22.00	18.16	31.16
7	Green fodder yield	21.36	18.87	15.81	24.95	29.26	20.78	18.55	13.41	18.36	19.79
8	Dry matter yield	6.09	5.82	4.43	6.83	8.19	5.82	5.19	3.75	5.14	5.54
9	Crude protein content	16.37	16.25	16.52	17.30	17.07	16.68	17.56	15.22	16.21	15.27
10	Crude fibre content	27.26	28.13	27.33	29.89	30.09	28.39	25.61	29.92	28.48	28.52

Table 11. Average intra and intercluster distance ($\sqrt{D^2}$)

Sl. No.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	25.07	36.97	35.70	45.23	54.17	57.01	51.14	46.96	61.45	116.69
C_2		24.26	45.26	64.31	49.02	31.38	76.34	33.81	37.26	88.33
C_3			27.98	68.43	76.27	66.64	45.83	40.83	56.74	123.08
C_4				8.80	47.75	76.85	65.45	79.98	94.64	251.81
C_5					21.30	44.35	95.79	71.27	71.88	92.72
C_6						0	100.88	44.39	36.17	61.22
C_7							0	74.44	95.24	161.01
C_8								0	36.96	93.87
C_9									0	75.68
C_{10}										0

Table 12. Average intra and intercluster distance (D^2)

Sl. No.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	628.51	1366.97	1274.47	2045.87	2934.73	3249.64	2615.11	2205.32	3776.35	13615.66
C_2		588.67	2048.17	4135.55	2403.35	984.72	5828.39	1142.78	138.25	7801.91
C_3			783.00	4683.30	5817.88	4440.94	400.27	1667.28	3220.21	15149.86
C_4				77.45	2280.24	5905.89	4283.42	6397.84	8956.85	63409.58
C_5					453.84	1966.83	9177.20	5079.54	5167.33	8596.34
C_6						0	10176.90	1971.04	1308.77	3747.52
C_7							0	5542.02	9069.57	25925.87
C_8								0	1366.27	8812.64
C_9									0	5728.48
C_{10}										0

five clusters using Tocher's method while accessions LRB 235, LRB 221, LRB 225, RBL 118 and LRB 145 remained as single (Table 9). Thirty three accessions come under one group.

The average intra-and inter-cluster D^2 values and distances are given in Tables 11 and 12 respectively. The mean performance of a cluster with respect to various characters is presented in Table 10. The inter-cluster D^2 values indicate the diversification among the groups of accessions resembling each other based on the ten characters studied while intra – cluster D^2 values indicate the magnitude of divergence among accessions within a cluster.

Among the first five clusters, maximum intra – cluster distance was observed in C_3 (27.9) followed by C_1 (25.0), C_2 (24.2) and C_5 (21.3) and minimum in C_4 (8.8). As far as inter-cluster distances are concerned, C_1 had maximum divergence with C_{10} (116.6) and minimum with C_3 (35.7) followed by C_2 (36.9). It ranged from 45.2 (C_4) to 61.4 (C_4) with other clusters. C_2 was more divergent from C_{10} (88.3) followed by C_7 (76.3) and C_4 (64.3) and less divergent with C_6 (31.3) followed by C_8 (33, 8) and C_9 (37.2). C_3, C_4, C_5, C_7, and C_8 also had maximum divergence with C_{10} while C_6 maximum divergence with C_3 and C_7, with C_6 (Table 14).

The average performance of the accessions within clusters with respect to various traits are presented in Table 10. The dwarf plants were in C_6 and tallest in C_{10}. Number of branches ranged from 3.1 in C_9 to 4.8 in C_5. Leaves were less in number in C_9 and maximum in C_{10}. Leaf : stem ratio was minimum in C_{10} and maximum in C_5. Leaf area index was less in C_9 (2.0) and high in C_8 (6.0). Maximum leaf weight per plant was noticed in

Table 13. Pattern of variation in terms of CV at genotypic and intercluster levels

Sl. No.	Character	CV_g (%)	CV_{ic} (%)
1	Plant height at harvest (cm)	12.06 (1)	31.58 (2)
2	Number of branches per plant	11.81 (2)	11.27 (8)
3	Number of leaves per plant	10.52 (3)	29.52 (3)
4	Leaf : stem ratio	4.67 (8)	19.35 (7)
5	Leaf area index	5.20 (7)	23.68 (4)
6	Leaf weight per plant (g)	8.57 (4)	41.09 (1)
7	Green fodder yield (t/ha)	7.78 (6)	22.21 (5)
8	Dry matter yield (t/ha)	7.83 (5)	4.65 (6)
9	Crude protein content (%)	0.24 (9)	4.68 (10)
10	Crude fibre content (%)	0.23 (10)	4.94 (9)

CV_g - Genotypic level coefficient of variation

CV_{ic} - Cluster level coefficient of variation

Figures in parenthesis indicate the rank order of coefficient of variation.

Table 14. Maximum and minimum divergence between clusters

Sl. No.	Cluster	Maximum	Minimum
1	C_1	13615.66 (C_{10})	1274.47 (C_3)
2	C_2	7801.91 (C_{10})	984.72 (C_6)
3	C_3	15149.86 (C_{10})	1274.47 (C_1)
4	C_4	63409.58 (C_{10})	2045.87 (C_1)
5	C_5	9177.20 (C_7)	1966.83 (C_6)
6	C_6	10176.90 (C_7)	984.72 (C_2)
7	C_7	25925.87 (C_{10})	2100.27 (C_3)
8	C_8	8812.64 (C_{10})	1142.78 (C_2)
9	C_9	9069.57 (C_8)	1308.77 (C_6)
10	C_{10}	63409.58 (C_4)	3747.52 (C_6)

the accessions in C_4 (66.7) and minimum in C_9 (18.1). Green fodder yield and dry matter yield were high in C_5 (29.2, 8.1) and low in C_8 (13.4, 3.7). Crude protein content was high in C_7 (17.5) and low in C_8 (15.2) while crude fibre content was high in C_5 (10.0) and low in C_7 (25.6).

Contribution of characters for divergence

The more varying character at genotypic level was plant height with a CV of 12.0% followed by number of branches per plant (11.8%) while at cluster level, leaf weight per plant was found to be the character contributing maximum to divergence (41.0%) followed by plant height (31.5%). Crude protein and crude fibre contents were less variable both at genotypic and cluster levels (Table 13). Hence leaf weight per plant and plant height were considered as the main characters responsible for divergence between clusters.

Discussion

5. DISCUSSION

The primary aim of a plant breeder is to improve yield and quality by evolving superior genotypes. Selection of superior genotypes will be effective only if genetic variability exists in the material chosen for improvement. So the preliminary step in any crop improvement programme is the search for variability in the germplasm.

The performance of a crop is determined partly by its genotype and partly by the environment in which it grows. Hence the phenotypic variance of a character may be partitioned into genotypic and environmental components. When more than one character is considered, the correlation between two characters has to be taken into account.

Heritability and genetic advance are two important genetic parameters. Heritability denotes the proportion of phenotypic variance that is due to the genotype. Selection is generally more effective for characters with high heritability coefficients. Similarly genetic advance measures the magnitude of improvement in the selected individuals over the original population.

Genetic diversity plays an important role in plant breeding because the more diverse the parents within a reasonable range, the more would be the chances for improving the characters in question.

In the present study, 60 accessions of fodder rice bean were evaluated for estimation of genetic divergence so as to group them into clusters based on their genetic distances.

5.1 Variability

Variability is the most important pre requisite in any crop improvement programme. Variability available in a population can be partitioned into phenotypic, genotypic and environmental components. However, gain under selection is achieved only from the genotypic component of variability.

Analysis of variance for 11 characters revealed significant differences among the accessions for 10 characters, viz. plant height at harvest, number of branches per plant, number of leaves per plant, leaf : stem ratio, leaf area index, leaf weight per plant, green fodder yield, dry matter yield, crude protein content and crude fibre content. Duration of the crop did not show any significant difference indicating same duration for the accessions studied. The existence of high variability for several characters in rice bean was reported by Das *et al.* (1997), Kumar *et al.* (1997) and Baisakh (1992). Similar trends of variability for various traits were reported in chickpea (Yadav *et al.*, 1999).

Wide variation was evident for plant height at harvest. The reports by Baisakh (1992) and Das *et al.* (1997) are in conformity with this finding.

Number of branches per plant showed high variability. Baisakh (1992) in rice bean and Borah and Khan (2000) in fodder cowpea reported similar results.

Considerable variability for number of leaves per plant in the present study is in agreement with the findings of Borah and Khan (2000) in fodder cowpea.

In the present study green fodder yield and dry fodder yield showed high variability. Baisakh (1992) in rice bean and Borah and Khan (2000) in fodder cowpea reported similar trends for green forage yield and dry matter yield.

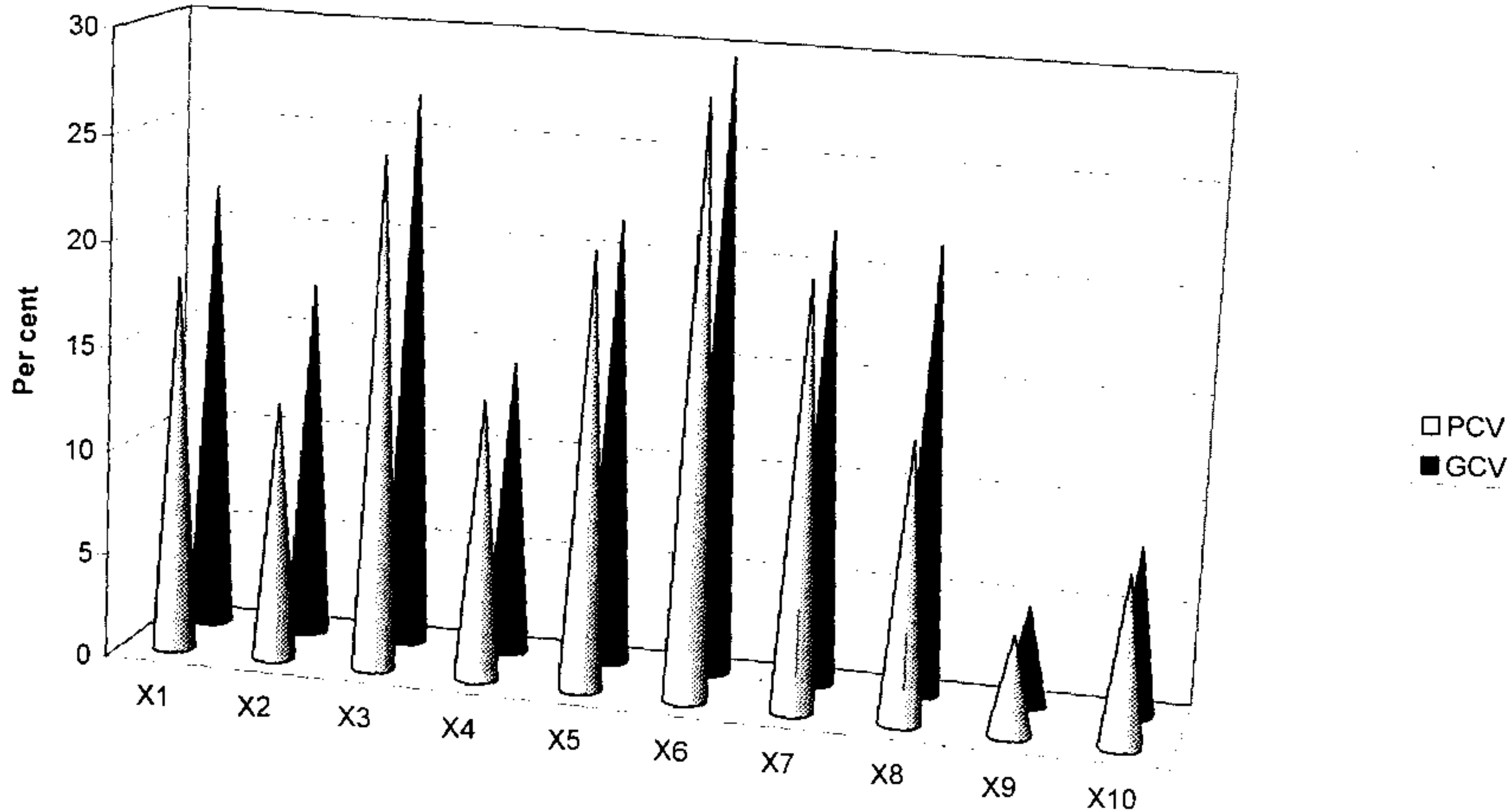
Compared to environmental variance, a higher magnitude of genotypic variance was observed for all the characters studied. This indicates that variability is mostly of genetic contribution.

Coefficient of variation serves as a better criterion for comparison of variability in characters with different units of measurements. Phenotypic coefficient of variation (PCV) measures the extent of total variation while genotypic coefficient of variation (GCV) provides a valid basis for comparing the genetic variability for quantitative characters.

In the present study, the values of PCV and GCV indicate a uniform trend for variability at phenotypic and genotypic levels, for all characters studied. Phenotypic and genotypic coefficients of variation are presented in Fig.1. The high PCV observed for leaf weight per plant, number of leaves per plant and green fodder yield was similar to with the findings of Borah and Khan (2000) in fodder cowpea. The lowest PCV was recorded for crude protein content.

Phenotypic value being the aggregate of genotypic value and environmental deviation, selection based on phenotypic performance could be misleading. The GCV provides a precise measure of genetic variability. High estimate of GCV observed in the present study for number of leaves per plant, leaf area index, green fodder yield and plant height was in accordance with the findings of Borah and Khan (2000) reported in fodder cowpea. High

Fig. 1 Genotypic and phenotypic coefficients of variation for 10 characters in fodder rice bean



X1-Plant height at harvest (cm)
X2-Number of branches per plant
X3-Number of leaves per plant
X4-Leaf:stem ratio
X5-Leaf area index
X6-Leaf weight for plant(g)
X7-Green fodder yield (t/ha)
X8-Dry matter yield (t/ha)
X9-Crude protein content(%)
X10-Crude fibre content(%)

estimates of GCV reported for leaf area index and plant height in the present study were similar to the findings of Ushakumari and Chandrasekharan (1991) reported in fodder lablab. Low estimates of GCV were observed for crude protein content and crude fibre content.

In this study, high values of PCV with corresponding high values of GCV were observed for leaf weight per plant, number of leaves per plant, green fodder yield and plant height. Borah and Khan (2000) in fodder cowpea reported similar results. High GCV values of for plant height was reported by Das *et al.* (1997) in rice bean and Sharma (1999) in cowpea. So for these characters, selection based on the phenotype would be reliable.

5.2 Heritability and genetic advance

The variability existing in a population is the sum total of heritable and non-heritable components. High value of heritability suggests that genetic constitution plays a major role in the expression of that character. Johnson *et al* (1955) suggested that the magnitude of heritability indicates the effectiveness of selection based on phenotypic performance. They further noted that heritability and genetic advance if considered together would make selection more effective. Burton (1952) suggested that GCV along with heritability would provide a clear idea about the amount of genetic advance expected by selection.

In the present study, all the characters except number of branches per plant showed high heritability estimates.

In rice bean, Das *et al.* (1997) and Kumar *et al.* (1997) reported high values of heritability for plant height as obtained in the present study

Similar results were obtained by Ushakumari and Chandrasekharan (1991) in fodder lablab, Mishra *et al.* (1995) in rice bean and Sharma (1999) and Borah and Khan (2000) in fodder cowpea.

High values of heritability was noticed for number of leaves per plant by Ushakumari and Chandrasekharan (1991) in fodder lablab and Borah and Khan (2000) in fodder cowpea, as found in the present study.

Borah and Khan (2000) in fodder cowpea and Ushakumari and Chandrasekharan (1991) in fodder lablab reported high heritability estimates for green fodder yield and dry matter yield. These reports support the findings of the present study.

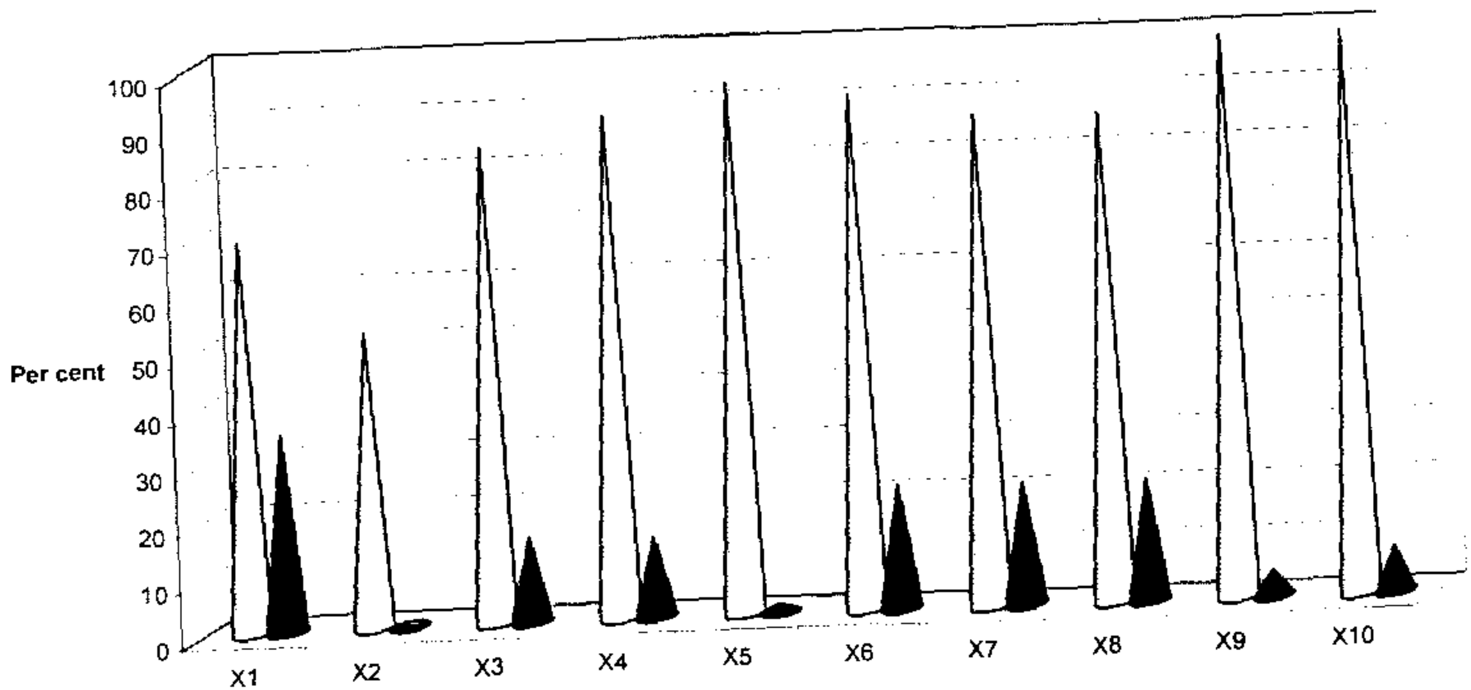
As observed in the present study, high heritability was reported for number of branches per plant by Borah and Khan (2000) in fodder cowpea

Borah and Khan (2000) reported high heritability for crude protein content in fodder cowpea. In the present study also crude protein content recorded high heritability. On the contrary, Ushakumari and Chandrasekharan (1991) reported moderate heritability estimate for crude protein content in fodder lablab.

High values of genetic advance as percentage of mean were recorded for plant height at harvest, leaf weight per plant, green fodder yield and dry fodder yield. Borah and Khan (2000) obtained similar results for the above characters in fodder cowpea. High genetic advance for plant height was also reported by Das *et al.* (1997) and Kumar *et al.* (1997) in rice bean.

Genetic advance recorded for number of branches per plant was low in the present study. But high genetic advance was recorded for number of

Fig. 2 Heritability and genetic advance in fodder rice bean



X1-Plant height at harvest (cm)
X2-Number of branches per plant
X3-Number of leaves per plant
X4-Leaf:stem ratio
X5-Leaf area index
X6-Leaf weight for plant
X7-Green fodder yield (t/ha)
X8-Dry matter yield (t/ha)
X9-Crude protein content(%)
X10-crude fibre content (%)

branches per plant by Borah and Khan (2000) in fodder cowpea Low genetic advance was recorded for crude protein in the present study. Similar results were reported by Borah and Khan (2000) in fodder cowpea.

According to Panse (1957), high heritability coupled with high genetic advance indicates the preponderance of additive gene action suggesting the possibility of genetic improvement of these characters through selection. In the present study, high heritability together with high genetic advance was observed for plant height at harvest, leaf weight per plant, green fodder yield and dry fodder yield. Similar results were obtained for plant height by Das *et al.* (1997) and Kumar *et al.* (1997) in rice bean and Sharma (1999) in cowpea. Similar to the findings of the present study, Borah and Khan (2000) reported high heritability and genetic advance for plant height, green fodder yield and dry fodder yield in fodder cowpea.

The characters number of leaves per plant, leaf stem ratio, crude fibre content, crude protein content and leaf area index recorded high heritability with low genetic advance. This suggests that these characters are governed by non-additive gene action and therefore scope of improvement through selection is very limited.

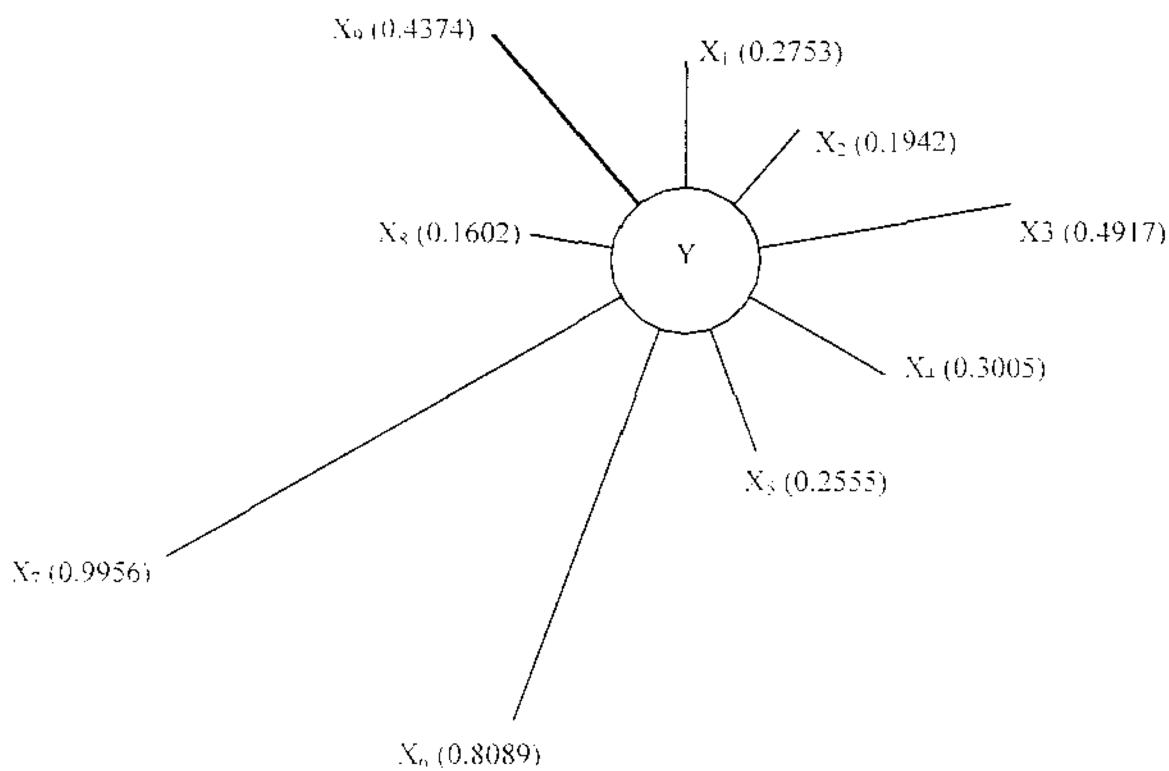
5.3 Correlation

A breeder is always interested to know the inherent association (genotypic correlation) of characters apart from the observable correlation between two characters (phenotypic correlation). Direct selection for yield is often misleading as it is influenced by many component characters both in positive and negative directions. Analysis of yield in terms of phenotypic, genotypic and environmental correlation coefficients of component characters helps to identify the traits on which selection may be based for genetic improvement.

Green fodder yield exhibited positive correlation at phenotypic and genotypic levels with all the other characters. The highest positive genotypic correlation recorded by dry matter yield with green fodder yield indicates that it is the most reliable yield component. Plant height, number of leaves per plant, number of branches per plant, leaf area index, dry matter yield and leaf : stem ratio showed significant positive correlation with green fodder yield. Similar results were reported by Ponmariammal and Das (1996) in fodder cowpea. In fodder cowpea, Jindal (1989) also reported significant positive correlation of green fodder yield with the characters leaf weight, branches per plant, plant height and number of leaves. Sharma *et al.* (1988) reported positive correlation between green forage yield and plant height in cowpea. Vasanthi and Das (1996) reported that in fodder lablab, green fodder yield showed significant positive correlation with all quantitative traits except crude protein content. Ushakumari and Chandrasekharan (1991) also reported positive correlation of green fodder yield with plant height, dry weight of leaves and dry matter production in fodder lablab. In fodder cluster bean, Shanmugam and Balasubramanian (1983) observed positive significant genotypic correlation between green fodder yield and leaf weight. Manonmani *et al.* (2000) reported significant positive correlation between green fodder yield and branches per plant in fodder cowpea.

In general, genotypic correlation with green fodder yield was higher than the corresponding phenotypic correlation for most of the characters.

Fig. 3. Genotypic correlation between green fodder yield and its component characters in fodder rice bean



X1-Plant height at harvest
X2-Number of branches per plant
X3-Number of leaves per plant
X4-Leaf : stem ratio
X5-Leaf area index
X6-Leaf weight per plant
X7-Dry matter yield
X8- Crude protein content
X9- Crude fibre content

This indicates the inherent genetic association between these characters. High heritability obtained for most of the characters further supports this notion, since for highly heritable characters, the phenotypic value of a genotype tend to reflect its genotypic worth. So selection will be effective when based on these characters.

Correlation among yield components

Besides the knowledge of association between fodder yield and its components, inter -- relationships among the yield component characters also provide reliable information for effective selection.

Plant height at harvest recorded positive correlation with number of leaves per plant, number of branches per plant, leaf area index, dry matter yield and crude fibre content at both genotypic and phenotypic levels. Ponmariammal and Das (1996) reported similar results with number of leaves and number branches per plant in fodder cowpea. Similar to the results of the present study, Jindal (1989) reported significant positive correlation between plant height, leaf weight, branches per plant and number of leaves in fodder cowpea.

Number of branches per plant exhibited significant positive correlation with plant height, leaf weight per plant, leaf : stem ratio, dry fodder yield, crude fibre content and number of leaves per plant. Crude protein content showed negative correlation with number of branches per plant. As observed in the present study, Jindal (1989) reported that number of branches per plant exhibited significant positive correlation with plant height, leaf weight and number of leaves in fodder cowpea. Ponmariammal and Das (1996) reported similar results in fodder cowpea.

Phenotypic and genotypic correlation with number of leaves per plant were high for leaf area index, leaf weight per plant, crude fibre content, dry fodder yield and plant height. Ponmariammal and Das (1996) obtained similar results in fodder cowpea for plant height and number of branches per plant. Number of leaves per plant showed significant positive correlation with leaf weight, number of branches per plant and plant height. Similar results were reported by Jindal (1989) in fodder cowpea.

High phenotypic and genotypic correlation was observed for leaf : stem ratio with leaf weight per plant and dry matter yield indicating that an attempt to improve the leaf : stem ratio would result in a simultaneous improvement of these characters. Ponmariammal and Das (1996) reported high positive correlation between leaf : stem ratio and dry matter yield in fodder cowpea.

Leaf area index showed significant positive correlation with number of leaves per plant, crude fibre content, leaf weight per plant, plant height and dry fodder yield.

In the present study, leaf weight per plant exhibited high positive correlation with dry fodder yield, number of leaves per plant, crude fibre content, leaf area index, leaf : stem ratio, number of branches per plant and crude protein content. Similar results were obtained for leaf weight per plant with dry matter yield in forage cluster bean (Shanmugam and Balasubramanian, 1983) and with number of branches per plant, plant height and number of leaves in fodder cowpea (Jindal, 1989).

Dry matter yield showed significant positive correlation with leaf weight per plant. This is supported by the findings of Shanmugam and Balasubramanian (1983) in forage cluster bean. Leaf : stem ratio also showed high positive correlation with dry matter yield, as observed by Ponmariammal and Das (1996) in fodder cowpea. Other characters which exhibited positive correlation with dry matter yield are number of leaves per plant, crude fibre content, leaf area index, plant height and number of branches per plant.

Crude protein content showed significant positive correlation with crude fibre content and leaf weight per plant.

Crude fibre content exhibited significant positive correlation with number of leaves per plant, dry fodder yield, leaf area index, plant height at harvest, leaf weight per plant, number of branches per plant and crude protein content.

The present investigation reveals that green fodder yield is significantly and positively correlated with all the characters studied except crude protein content. It is further observed that the characters, plant height, number of leaves per plant, leaf weight per plant and dry matter yield are highly correlated among themselves. Also, the above mentioned characters exhibit high heritability along with high genetic advance, which indicates that selection for these characters would lead to substantial improvement in fodder yield. Other characters which could be further considered for indirect selection are number of branches per plant, leaf : stem ratio and leaf area index.

5.4 Path coefficient analysis

Although correlation studies between yield and its components are useful, it does not give an exact picture of the relative importance of the various yield attributes. Rate of improvement is expected to be rapid if differential emphasis is laid on the component characters during selection. Path coefficient analysis helps in partitioning the genotypic correlation coefficients into direct and indirect effects of the component characters on yield on the basis of which improvement programmes can be devised effectively.

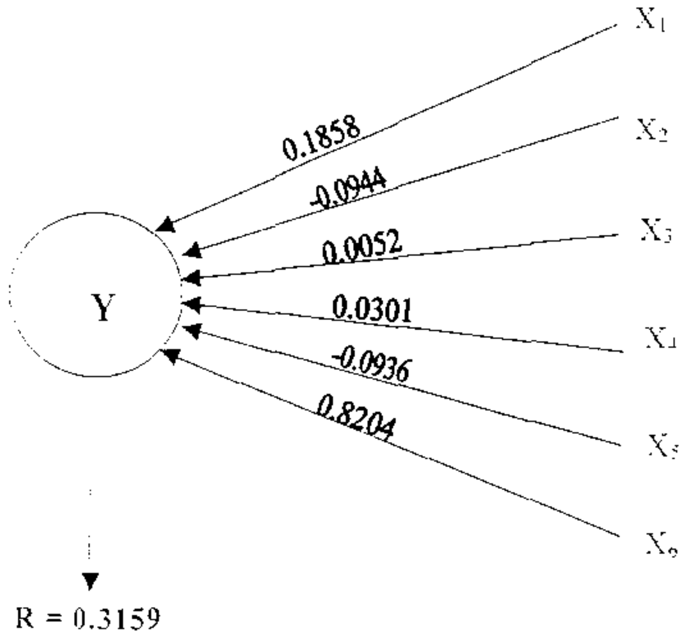
In the present study, the maximum direct effect on yield was exhibited by leaf weight per plant, followed by plant height. Leaf weight per plant also exerted positive indirect effect via plant height, number of leaves per plant and leaf : stem ratio. Plant height exerted high positive indirect effect via leaf weight per plant.

As observed in the present study, Srinivasan and Das (1996) suggested that a desirable plant type for higher forage yield in cowpea would be of tall plant stature and more number of larger leaves.

Similar trends as in the present study was observed by Renganayaki and Sree Rengaswamy (1992) in both blackgram and cowpea and Ponnariammal and Das (1996) in fodder cowpea.

Both leaf weight per plant and plant height had high direct effect along with high genetic correlation. The contribution of other characters via leaf weight per plant and plant height was negligible. The residual effect noticed in the present study was also low

Fig. 4 Path diagram showing direct effects and genotypic correlation in 60 accessions of fodder rice bean



X_2	0.3547				
X_3	0.4052	0.1934			
X_4	0.0229	0.2113	0.0582		
X_5	0.3184	0.0512	0.7953	-0.0885	
X_6	0.1828	0.2683	0.6121	0.3383	0.3575

Y – Green fodder yield

R – Residual effect

X_1 – Plant height at harvest
X_2 – Number of branches per plant
X_3 – Number of leaves per plant

X_4 – Leaf : stem ratio
X_5 – Leaf area index
X_6 - Leaf weight per plant

Hence, leaf weight per plant and plant height can be identified as the major characters contributing towards green fodder yield and selection based on these characters will be effective for developing high yielding varieties of fodder rice bean.

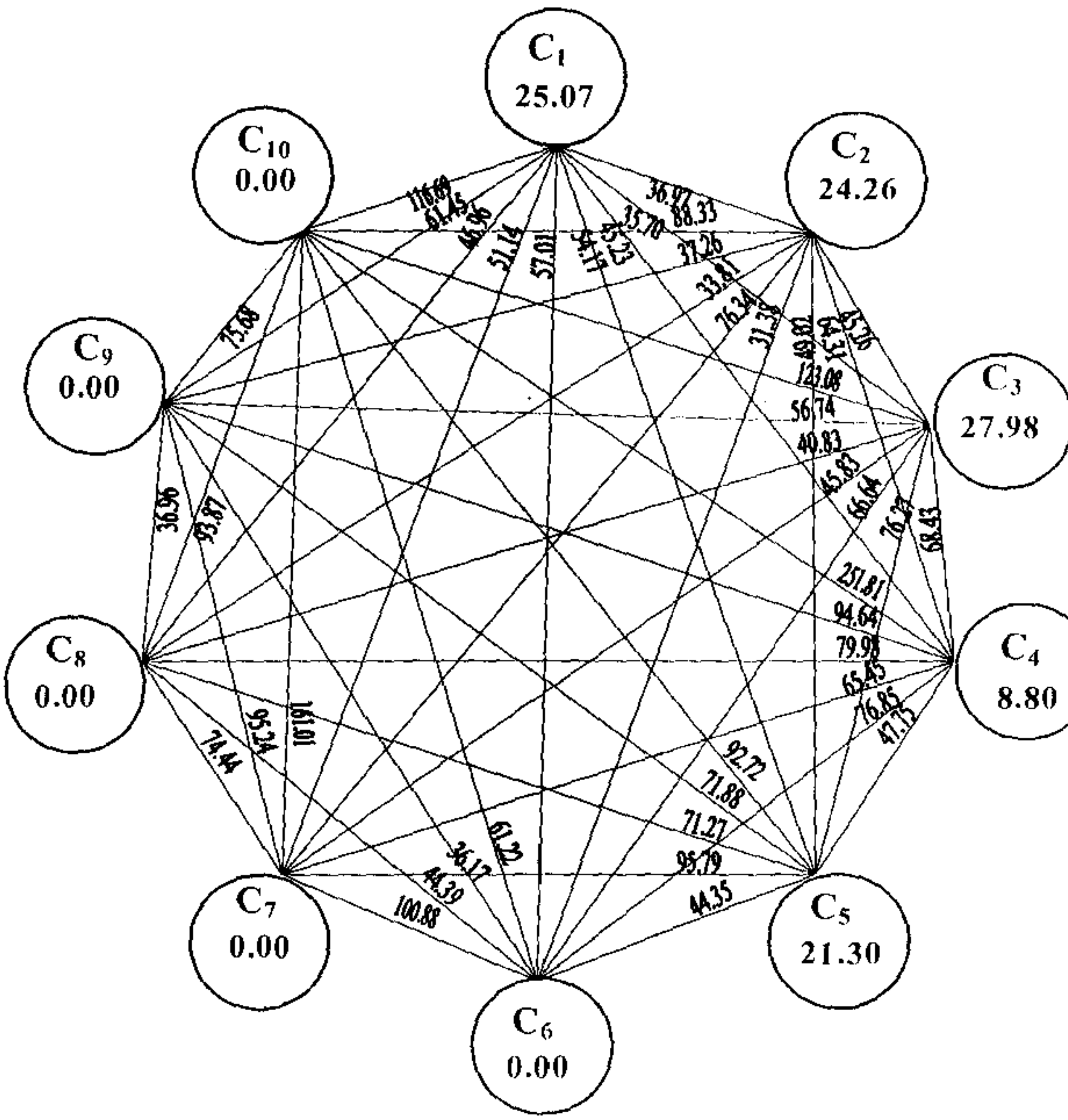
5.5 Genetic divergence analysis

Hybridization is a powerful technique in crop improvement, the main objective being creation of variation. This is achieved when genes from divergent parents are brought together in the F_1. So selection of divergent parents is important. Most rapid improvement in the economic value of a genotype is expected from selection applied simultaneously to several characters which determines the economic value of the crop. Mahalanobis D^2 statistic helps in the selection of genetically divergent parents for the exploitation of hybridization. The relative contribution of each character towards divergence, choice of clusters with maximum D^2 values and selection of accessions from divergent clusters are the criteria to be kept in mind while selecting parents for hybridization.

One of the main objectives of the present investigation was to assess the genetic diversity among the accessions of fodder rice bean and to group them into clusters based on their genetic distances.

The 60 accessions of fodder rice bean were subjected to Mahalanobis D^2 analysis based on the ten characters considered in this study. The 60 accessions were grouped into ten clusters. Fig. 5 shows the genetic diversity at intra and inter cluster levels. The greater the distance between two

Fig. 5. Cluster diagram showing intra and intercluster distances



clusters, greater is the divergence between accessions belonging to the two clusters and vice versa.

Among the ten clusters studied, C_5 showed high mean values for number of branches per plant, green fodder yield, dry matter yield and crude fibre content indicating that this cluster is superior to the others with respect to the above characters. C_{10} was superior for characters like plant height at harvest and number of leaves per plant which were important yield attributes. C_8 exhibited maximum mean value for leaf area index while C_4 showed high mean value for leaf weight per plant. For crude protein content, C_6 was found to be superior to the rest.

C_{10} is found to have maximum inter cluster distance with seven of the ten clusters. C_7 kept maximum divergence between C_5 and C_6. Selection of parents from these divergent clusters will be effective.

Plant height at harvest recorded the maximum coefficient of variation at the genotypic level, followed by number of branches per plant, leaf number per plant and leaf weight per plant. At the inter cluster level, leaf weight per plant registered the maximum coefficient of variation followed by plant height, leaf number per plant and leaf area index. Plant height, leaf number per plant and leaf weight per plant are the characters which contribute maximum towards divergence of the accessions. As mentioned above, C_{10} including LRB 145 recorded high mean values for plant height and number of leaves per plant. Also, C_4 registered maximum mean value for leaf weight per plant. C_{10} and C_4 recorded the maximum divergence between themselves. So selection of parents from these two clusters will be effective for an overall improvement of fodder yield.

Summary

SUMMARY

The present study was conducted at the Department of Plant Breeding Genetics, College of Agriculture, Vellayani from September to November, 1999, to assess the variability in the important economic characters and the genetic divergence among the accessions.

Sixty accessions of fodder rice bean were evaluated in randomized block design with two replications. Data were collected from five randomly selected plants from a population size of 84 plants per entry on ten characters namely plant height at harvest, number of branches per plant, number of leaves per plant, leaf stem ratio, leaf area index, leaf weight per plant, green fodder yield, dry matter yield, crude protein content and crude fibre content. The mean was worked out and subjected to statistical analysis. Salient findings of the study are the following :

Analysis of variance revealed significant differences among the accessions for all the characters studied except duration of the crop.

High phenotypic and genotypic coefficients of variation were observed for leaf weight per plant, number of leaves per plant, leaf area index and green fodder yield indicating high variability for these characters and scope for improvement through selection.

Heritability estimates were high for all the characters studied except number of branches per plant, suggesting very little influence of the environment in the expression of these characters.

High values of genetic advance were recorded for plant height at harvest, leaf weight per plant, green fodder yield and dry fodder yield.

High heritability coupled with high genetic advance was observed for plant height at harvest, leaf weight per plant, green fodder yield and dry fodder yield, indicating additive gene action for these characters. This suggests that permanent improvement could be attained by practicing selection on the above traits.

Green fodder yield exhibited positive correlation with all the characters studied at both phenotypic and genotypic levels. Dry matter yield had the highest positive correlation with green fodder yield followed by leaf weight per plant, number of leaves per plant, crude fibre content, leaf: stem ratio and leaf area index. Hence, yield can be enhanced indirectly by improving these components

Path analysis revealed that leaf weight per plant exhibited maximum positive direct effect on green fodder yield followed by plant height. These characters exerted high positive indirect effect via other characters and also had high genotypic correlation with green fodder yield. The low residual effect obtained indicated that the major portion of variation in yield could be explained by the characters considered in path analysis.

On the basis of genetic distances computed with respect to 10 characters studied, the 60 accessions of fodder rice bean were grouped into 5 clusters while accessions LRB 235, LRB 221, LRB 225, RBL 118 and LRB 145 remained as single. Maximum divergence was obtained between C_4 and C_{13}, while divergence was minimum between C_1 and C_3. Intra cluster distance was maximum in C_3 while it was minimum in C_1. C_{10} showed high mean values for plant height and number of leaves per plant which are important yield attributes and C_4 recorded high values for leaf weight per plant. So selection of parents from the divergent clusters C_4 and C_{10} will be effective in improving green fodder yield.

References

REFERENCES

Aravindan, S. and Das, V.L.D. 1995. Correlation and path analysis for fodder attributes in cowpea. *Madras agric. J.* 82 : 420-422

Backiyarani, S., Nadarajan, N., Rajendran, C. and Shanthi, S. 2000. Genetic divergence for physiological traits in cowpea (*Vigna unguiculata* (L.) Walp). *Legume Res.*, 23 : 114-117

Baisakh, B.1992. Inter relationship between yield and yield attributes in rice bean. *Indian J. Agric. Sci.* 62 : 620-622

Basavarajappa, P.S. and Byregowda, M. 2000. Genetic divergence among field bean (*Lablab purpureus* L. Sweet) cultivars of Southern Karnataka. *Indian J. Genet.* 13 : 134-137

Borah, H.K. and Khan, A.K.F. 2000. Variability, heritability and genetic advance in fodder cowpea. *Madras agric. J.* 87 : 165-166

Burton, G.W.1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassland Congr:* 277-283

Chaudhari, G.B., Patil, J.V. and Barhate, K.K. 2000. Character association in rice bean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi]. *Legume Res.* 23 : 25-28

Das, M., Chathopadhyay, P. and Roquib, M.A. 1997. Genetic variability in grain yield and its components in rice bean. *Environ. Ecol.* 15 : 625 – 628

Das, S., Arora, N.D., Dangi, O.P. and Kaushik, L.S. 1978. Genetic variability and correlation studies in cluster bean (*Cyamopsis tetragonaloba* (L.) Taub.) fodder. *Forage Res.* 4 : 91-94

Das, S.Y. and Chakraborty, S. 1998. Genetic variation for seed yield and its components in green gram. *Adv. Pl. Sci.* 11: 271-273

Deshmukh, R.B. and Patil, J.V. 1998. Genetic divergence in chickpea. *Madras agric. J.* 84 : 664-666

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis components of crested wheat grass seed production. *Agron.J.* 51: 515-518

Dharmalingam, V. and Kadambavanasundaram, M. 1989. Genetic divergence in cowpea[*Vigna unguiculata* (L.) Walp.]. *Madras agric. J.* 76:394-399

Henry, A and Krishna, G.V.S.R. 1990. Genetic divergence in cluster bean. *Madras agric. J.* 77 : 116-120

Jackson, M.L. 1973. *Soil Chemical Analysis*. 2nd edition. Prentice hall of India Pvt. Ltd. New Delhi, p.187

Jain, J.P. 1982. *Statistical Techniques in Quantitative Genetics*. Tata McGraw Hill Co. New Delhi, p. 281

Jindal, S.K. 1989. Path coefficient analysis in fodder cowpea grown under rainfed condition. *Madras agric. J* 76 : 121 124

Jindal, S.K. and Gupta,B.S.1985.Genetic divergence in fodder cowpea. *Indian J. agric. Sci.* 55 : 1-3

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955.Heritability and inter relationship of some quantitative characters in pea (*Pisum sativum* L.). *J. Res. Punjab Agricultural University* 10 : 309-315

Kanwar, J.S. and Chopra, S.L. 1976.*Analytical Agricultural Chemistry*. Kalyani Publishers, Ludhiana, New Delhi, p. 217

Kumar, A., Krishna, R. and Chaturvedi, S.K. 1998. Genetic divergence in chickpea. *Indian J. Genet.* 58 : 337-342

Kumar, A. and Mishra, S.N. 1981. Note on genetic variability for forage yield components in cowpea. *Indian J. agric. Sci.* 51 : 807-809

Kumar, B. M. D., Shambulingappa, K. G. and Kulkarni, R. S. 1996. Genetic divergence in rice bean. *Legume Res.*19 : 15-18

Kumar, B.M.D., Shambulingappa, K.G., Kulkarni, R.S., Swamy, G.S.K. and Lohithaswa, H.S. 1997. Analysis of genetic variability and character associations in rice bean. *Mysore J. agric. Sci.* 31 :23-28

Mandal, N. and Dana, I. 1998. Genetic divergence and nature of heterosis in rice bean. *Ann. agric. Res.* 19 : 18-21

Manonmani, S., Khan, A.K.F., Ravikesavan, R. 2000. Genetic studies in forage cowpea. *Madras agric. J.* 86 : 500-501

Mendoza, E.M.T., Rodriguez, F.M. and Revilleza, M.J.R. 1990. Proximate chemical composition of several Philippine indigenous food legumes. *Philippine Agriculturist.* 73 : 69-74

Miller, P.A., Williams, V.C., Robinson, H.P. and Comstock, R.E. 1958. Estimation of genotypic and environmental variances and covariance in upland cotton and their implications in selection. *Agron. J.* 5 :126-131

Mishra, A., Muduli, K.C., Mishra, B.K. and Patra, A.K. 1995. Inter-relationship between yield and its components in rice bean. *Environ. Ecol.* 13 : 430-432

Mitra, J., Natarajan, S., Jain, R.K. and Singh, U.P. 2000. Genetic diversity for seed yield in a large collection of cluster bean (*Cyamopsis tetragonaloba* (L.) Taub.) *Indian J. Genet.* 13 : 230-233

Murthy, K.G. and Dorairaj, M.S. 1990. Genetic divergence in pigeonpea. *Indian J. Genet.* 50 : 279-282

Nandi, A., Tripathy, P. and Lenka, D. 1998. Divergence analysis in dolichos bean (*Lablab purpureus* (L.) Sweet). ACIAR *Food Legume Newsletter* 28 : 89-10

Nandi, A., Tripathy, P. and Lenka, D. 2000. Genetic divergence in hyacinth bean (*Dolichos lablab*). *Indian J. agric. Sci.* 70 : 450-451

Panse, V.G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.* 17 : 318-328

Ponmariammal, T. and Das, V.L.D. 1996. Correlation and path analysis for fodder yield in cowpea. *Madras agric. J.* 83 : 660-661

Raje, R.S. and Rao, S.K. 2001. Genetic diversity in a germplasm collection of mung bean (*Vigna radiata* L. Wilczek.). *Indian J. Genet.* 61 : 50-52

Rao, C. R. 1952. *Advanced Statistical Methods in Biometrical Research.* John Wiley and Sons, New York, p. 390

Renganayaki, K. and Sree Rengaswamy, S.R. 1992 a. Path coefficient analysis in cowpea [*Vigna unguiculata* (L.) Walp.].*Madras agric. J.* 79:476-481

Renganayaki, K. and Sree Rengaswamy, S.R. 1992 b. Path coefficient analysis in black gram. *Madras agric. J.* 79:634-639

Rewale, A.P., Birari, S.P., and Apte, U.B. 1996 Genetic divergence in cowpea. *Indian J. agric. Res.* 30 : 73-79

Roquib, M.A. and Das, M. 1995.Genetic divergence in rice bean (*Vigna umbellata*). *Adv. Pl. Sci.* 8 : 312-318

Samal, K.M., Senapathy, N., Patnaik, H.P. and Nandi, A. 2001. Genetic divergence in mutant lines of pigeonpea (*Cajanus cajan* (L.) Mill. Sp). *Legume Res.* 24 : 186-189

Shanmugam, A.S. and Balasubramanian, M. 1983. Studies on character association in forage cluster bean (*Cyamopsis tetragonaloba* (L.) Taub.). *Madras agric. J.* 70 : 567-571

Sharma, B.D., Hore, D.K. and Dobhal, V.K. 1996. Classificatory analysis in rice bean (*Vigna umbellata*). *J. Hill Res.*. 9 : 79-81

Sharma, P.C., Mishra, S.N., Singh, A. and Verma, J.S.1988. Genetic variability and correlation in cowpea. *Ann. agric. Res.* 9 : 101-105

Sharma, T.R. 1999. Genetic variability studies in cowpea. *Legume. Res.* 22 : 65-66

Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.N., Debald, H.A., Kester, E.B. and Klick, J.T. 1965. Quality evaluation studies of foreign and domestic races. *Tech. Bull.* 1331. Services, U.S.A., p.1-86

Singh, G., Singh, S.P. and Chaudhary, B.S. 1998. Genetic divergence analysis in rice bean. *Indian J. Genet.* 58 : 101-105

Singh, M.R.K., Sharma, P.R. and Singh, L.I. 1999. Genetic divergence among rice bean cultivars of Manipur Hills. *Indian J. Genet.* 59 : 221-225

Sivakumar, S. and Muthiah, A.R. 2000. Genetic divergence in chickpea germplasm. *Madras agric. J.* 87 : 48-50

Sonone, A.H., Jadhav, S.J., Dahat, D.V. and Aher, R.P. 1999. Path analysis in rice bean. *Legume Res.* 22 : 195-197

Srinivasan, C. and Das, V.L.D. 1996. Correlation and path analysis for fodder yield in cowpea. *Madras agric. J.* 83 : 660-661

Tawar, M.L., Mishra, A.K., Rao, S.K. and Sharma, S.M. 1988. Genetic divergence in mung bean. *Legume Res.* 11 : 109-113

Thaware, B.L., Birari, S.P., Dhonukshe, B.L. and Jamadagni, B.M. 2000. Correlation between yield and yield attributes under different environments in rice bean. *Indian J. agric. Res.* 34 : 47-50

Thaware, B.L., Toro, V.A. and Birari, S.P. 1992. Variability in yield and chemical composition of fodder varieties of cowpea. *Legume Res.* 15 : 65-68

Thombre, B.B., Aher, R.P. and Dahat, D.V. 2000. Genetic divergence in pigeonpea. *Indian J. agric. Res.* 34 : 126-129

Ushakumari, R., Backiyarani, S. and Dhanakodi, C.V. 2000. Character contribution to diversity in cowpea. *Legume Res.* 23 : 122-125

Ushakumari, R. and Chandrasekharan, P. 1991. Genetic variability and correlation studies in fodder lablab (*Lablab purpureus* L.). *Forage Res.* 17 : 1-5

Vasanthi, S. and Das, V.L.D. 1996. Correlation and path analysis in fodder lablab. *Madras agric. J.* 83 : 147-149

Watson, D.J. 1962. The physiological basis of variation for yield. *Ann. Bot.* 4 : 101-145

Yadav, V.S., Singh, D., Yadav, S.S. and Kumar, J. 1999. Genetic parameters of variability under different environments in chickpea. *Ann. agric. Res.* 20 : 99-102

QUANTITATIVE VARIATION AND GENETIC DIVERGENCE IN FODDER RICE BEAN
[*Vigna umbellata* (Thunb.) Ohwi and Ohashi]

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ABSTRACT OF THE THESIS
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ABSTRACT

A research programme was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 1999-2000 with the objective of estimating the variability in the important economic characters and the genetic divergence among the accessions in order to group them into clusters based on the magnitude of genetic distance using Mahalanobis D^2 statistic. The experiment was conducted using 60 accessions adopting a randomised block design with two replications. Data collected on eleven characters were subjected to statistical analysis. Coefficient of variation, heritability, genetic advance, correlation among the characters, path coefficient and genetic divergence were estimated.

Analysis of variance revealed significant differences among the accessions for all the characters except duration of the crop. Phenotypic and genotypic coefficient of variation were high for leaf weight per plant, number of leaves per plant and green fodder yield. High heritability coupled with high genetic advance was observed for plant height, leaf weight per plant, green fodder yield and dry fodder yield.

Correlation studies indicated that plant height, number of leaves per plant, leaf area index, leaf weight per plant, dry fodder yield and crude fibre content exhibited significant positive correlation with green fodder yield.

Leaf weight per plant exhibited the highest positive direct effect on green fodder yield followed by plant height. Number of branches per plant and leaf area index recorded negative direct effect on green fodder yield.

Based on the genetic distances computed with respect to ten characters studied, the 60 accessions of fodder rice bean were grouped into five clusters while accessions LRB 235, LRB 221, LRB 225, RBL 118 and LRB 145 remained as single. Maximum divergence was obtained between C_4 and C_{10} while divergence was minimum between C_1 and C_3. Hence, selection of parents from C_4 and C_{10} will be effective for an overall improvement of fodder yield.