# GENETIC VARIABILITY FOR YIELD AND FUSARIUM WILT RESISTANCE IN YARD LONG BEAN

(*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)

Madhu Kumar, K.

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Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695 522

## DECLARATION

I hereby declare that this thesis entitled "**Genetic variability for yield and Fusarium wilt resistance in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)**" 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,
7-1-2006.

K. Madhu Kumar
**Madhu Kumar, K**
(2003-11-31)

# CERTIFICATE

Certified that this thesis entitled "**Genetic variability for yield and Fusarium wilt resistance in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)**" is a record of research work done independently by Mr. Madhu Kumar, K. (2003-11-31) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Radhadevi

Vellayani,
7-1-2006.

**Dr. (Mrs.) D.S. RADHADEVI**
(Chairperson, Advisory Committee)
Associate Professor,
Department of Plant Breeding and Genetics.
College of Agriculture, Vellayani.
Thiruvananthapuram-695 522.

**Approved by**

*Chairperson:*

**Dr. (Mrs.) D.S. RADHA DEVI**
Associate Professor,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

*Members :*

**Dr. P. MANJU**
Associate Professor and Head,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

**Dr. P. SANTHA KUMARI**
Associate Professor,
Department of Plant Pathology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

**Dr. VIJAYARAGHAVAKUMAR**
Associate Professor,
Department of Agricultural Statistics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

*External Examiner :*

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# *Introduction*

# 1. INTRODUCTION

The yard long bean, *Vigna unguiculata* sub sp. *sesquipedalis* (L.) Verdc. (Syn. String bean, asparagus bean, sitao and snake bean) is a vegetable crop widely cultivated in India, Indonesia, Philippines and Sri Lanka. Green pods are highly nutritious and 100 gram contains protein 4.3 g, fat 0.2 g, minerals 0.9 g, fibre 2.0 g, carbohydrate 8.0 g, calcium 80 mg, phosphorus 75 mg, iron 2.5 mg, vitamin A 941 I.U., riboflavin 0.09 mg, Thiamine 0.07 mg, nicotinic acid 0.9 mg and vitamin C 13 mg (Chakraborty, 1986).

The typical vegetable cowpea is characterized by long pods (more than 30 cm), stringless pods, fleshy pod pericarp, thin and long seeds and higher monosaccharide to polysaccharide ratio. It is a true diploid with 2n = 22 and Africa is considered as the primary centre of origin (Peter, 1998). Cowpea is an important tropical Indian pulse and vegetable crop covering an area of about 7.7 million ha. The productivity of this crop is low (3q/ha) which needs improvement through systemic breeding programmes (Yadav *et al.*, 2004).

Incidence of pests and diseases is considered to be a major limiting factor affecting the production of yard long bean. Off late Fusarium wilt has emerged as one of the serious disease problems. Most of the yard long bean cultivars are susceptible to this disease. Scanning of the literature suggested the presence of varying degrees of resistance to this disease among the cowpea genotypes. In this respect, breeding for disease resistance assumes utmost importance. Hence this work was intended to identify the source of resistance for developing high yielding Fusarium wilt resistant variety of yard long bean.

Crop improvement works in yard long bean are considerably less. Several local and improved yard long bean varieties are available. An

understanding of the variability in green pod yield and yield contributing characters among such varieties is essential for crop improvement efforts. Keeping in view the above mentioned aspects, the present investigation was undertaken with the following objectives.

- To study the genetic variability for different traits by estimating genetic parameters
- To measure the degree and pattern of association between yield and its components by estimating correlation coefficient
- To understand the direct and indirect effects of yield contributing characters by path coefficient analysis
- Estimation of selection index and clustering of genotypes to facilitate selection of parents for hybridization.
- To identify the sources of Fusarium wilt resistance in yard long bean through screening of germplasm.

# *Review of Literature*

# 2. REVIEW OF LITERATURE

The present study involved evaluation of domestic germplasm of yard long bean for vegetable pod yield and Fusarium wilt resistance. Despite its wide genetic variability, nutritional and economic importance, very little attention has been paid to the improvement of this crop. Crop improvement works appear to be scanty in yard long bean. However relevant literature available on crop improvement in cowpea in general is reviewed here under

## 2.1 VARIABILITY STUDIES

Genetic variability for yield and yield contributing traits in the base population is essential for successful crop improvement (Allard, 1960). The larger the variability, the better is the chance of identifying superior genotypes. Study of variability enables the breeder to determine the crop breeding strategies.

A study on genetic variability with 16 varieties of cowpea by Radhakrishnan and Jebaraj (1982) revealed highly significant differences for characters like plant height, number of branches, clusters and pods per plant, pod length, number of grains per pod, days to maturity and 100 grain weight. Patil and Baviskar (1987) studied variability studies with 49 cultivars of cowpea and reported that the extent of variability was maximum for seed yield per plant followed by pods per plant, pod clusters per plant and days to maturity.

The performance of 10 cowpea cultivars in six different environments carried out by Kandasamy *et al.* (1989) showed wide variability for days to 50 per cent flowering, days to maturity, pods per plant, pod clusters per plant, pod length, seeds per pod, 100 grain weight and seed yield per plant. The maximum range of variation was observed for number of pods per plant, clusters per plant and seed yield per plant.

Siddique and Gupta (1991) reported high variability for days to first flowering, plant height, pods per plant, pod length, 100 seed weight, seeds per pod

and seed yield in cowpea. High variability among different genotypes for days to flowering, number of pods per cluster, pod length and number of seeds per pod in cowpea was reported by Rejatha (1992). High genotypic variance was observed by Savithramma (1992) for all the characters except seeds per pod in cowpea

Aghora *et al.* (1994) studied 19 diverse vegetable cowpea lines and found that wide variability existed among the genotypes with respect to the protein content. Broad spectrum genetic variability was observed by Sobha (1994) for pod length and seed yield among 31 different cultivars of cowpea. Wide variation for plant height, pods per plant, pod length, pod width, seeds per pod and grain yield in cowpea were observed by Mathur (1995).

In a study with 30 different genotypes of yard long bean, Resmi (1998) observed significant differences among the genotypes for vine length, number of primary branches, days to flowering, days to harvest, pod length, pod girth, pod weight , seeds per pod, inflorescences per plant , pods per inflorescence, pods per plant, pod yield per plant, 100 seed weight, fibre content of pods and protein content of pods .

Significant variability was noticed for days to 50 per cent flowering, plant height, number of primary branches per plant, pod length, number of pods per plant, number of seeds per pod, 100 seed weight and yield per plant in cowpea (Sobha and Vahab, 1998).

Vardhan and Savithramma (1998a) in a study with 102 accessions of cowpea found high variability for all the characters studied except for dry pod yield.

Dwivedi *et al.* (1999) noticed a wide range of variability in number of branches, days to flowering, days to maturity, clusters per plant, pods per cluster, pods per plant, seeds per pod, size, shape and colour of pods and seeds, pod weight, seed weight per plant and 100 seed weight in 345 cowpea accessions.

Anbuselvam *et al.* (2000) observed significant variability for the characters days to 50 percent flowering, plant height, number of primary branches, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, 100-seed weight and yield per plant in 50 cowpea genotypes.

Pournami (2000) observed significant differences among the 51 yard long bean genotypes for days to flowering, inflorescences per plant, pods per inflorescence, pods per plant and pod length.

Vidya (2000) in a study with 50 cultivars of yard long bean, reported significant difference among the varieties for days to first flowering, length of harvesting period, number of inflorescences per plant, number of pods per inflorescence, length of main stem, number of primary branches, number of pods per plant, yield of vegetable pods per plant, pod length, pod girth, pod weight and seeds per pod.

In a study with 20 different genotypes of bush type vegetable cowpea, Ajith (2001) noticed significant difference for days to 50 percent flowering, number of days to first harvest, length of harvest period ,duration of crop, length of main stem , number of primary branches , number of pod clusters per plant , number of pods per plant, pod length, pod girth, pod weight ,number of seeds per pod and yield of green pods per plant.

Significant variability existed among 50 cowpea genotypes for days to 50 percent flowering, pods per plant, inflorescences per plant, pods per inflorescence, plant height, primary branches, pod length, seeds per pod, grain yield per plant and 100-seed weight (Philip, 2004).

## 2.2 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Genetically determined variation can be successfully selected only when the major part of the variability of the trait is genetic. The genetic parameters like coefficient of variation, heritability and genetic advance provide an exact picture of variability in a population.

Angadi *et al.* (1978) studied 50 genotypes of cowpea and found that the genotypic coefficient of variation ranged from 30.48 for seeds per pod to 81.58 for pod number. High values of genotypic coefficient of variation were also recorded for number of pod clusters and 100 seed weight. Heritability values ranged from 68.35 per cent for number of branches to 98.92 per cent for 100 seed weight. Pod number, pod cluster number, pod yield, seed yield and 100-seed weight had high heritability estimates coupled with high genetic advance where as number of branches and seeds per pod exhibited high heritability with low genetic advance.

Working on eleven cowpea varieties Jana *et al.* (1982) revealed high genotypic coefficient of variation for vegetable yield and pods per plant. Heritability and genetic advance were high for characters 1000 grain weight and days to flower.

Radhakrishnan and Jebaraj (1982) reported high heritability for plant height, number of branches, clusters and pods per plant, pod length, number of grains per pod, days to maturity and 100 grain weight. Number of pods per plant showed high genotypic coefficient of variation. Genetic gain was highest for number of pods and clusters per plant and least for days to maturity and plant height in 16 varieties of cowpea.

In a study of genetic variability with 40 genotypes of cowpea Dharmalingam and Kadambavanasundaram (1984) obtained high heritability for pod length and 100 seed weight. Apte *et al.* (1987) noticed high heritability for 100-seed weight, seeds per pod and days to maturity in a study with 50 cowpea genotypes. Percentage genetic gain was greatest for 100 seed weight followed by plant weight, branches per plant and seeds per pod.

Working with 49 cultivars of cowpea, Patil and Baviskar (1987) revealed that the genotypic and phenotypic coefficients of variation were high for pod clusters per plant, pods per plant, seed yield per plant and 100 seed weight. Heritability was highest for 100 seed weight followed by days to maturity and pod length.

In a study of 35 genotypes of cowpea conducted by Sharma *et al.* (1988), the maximum genotypic coefficient of variation was found for dry matter yield followed by plant height, pods per plant, seed weight and green pod yield. Heritability values ranged from 46.9 per cent for green pod yield to 98 per cent for days to 50 per cent maturity.

Kandasamy *et al.* (1989) studied the performance of 10 cowpea cultivars in six different environments and reported high phenotypic and genotypic coefficients of variation for pods per plant, clusters per plant and seed yield per plant. High heritability coupled with high genetic advance was noticed for pods per plant, clusters per plant, 100 seed weight and seed yield per plant.

Genetic variability studies by Thiyagarajan (1989) in cowpea showed that days to 50 per cent flowering, days to maturity, plant height, pod length, number of seeds per pod and 100 grain weight recorded high heritability estimates. Estimates of heritability and genetic advance were high for plant height, number of seeds per pod and 100 grain weight.

Thiyagarajan *et al.* (1989) in 36 Nigerian cowpea genotypes from IITA (International Institute of Tropical Agriculture, Nigeria) reported that plant height and seed yield per plant recorded high values for heritability and genotypic coefficient of variation. High estimates of heritability and genetic advance as percentage of mean were observed for plant height, clusters per plant, pods per plant, seeds per pod and seed yield per plant.

High heritability and high genetic advance was reported for characters like plant height, seed number per plant, pods per primary branch, pod length and breadth, days to 50 per cent flowering and maturity and seed yield per plant in cowpea (Roquib and Patnaik, 1990).

Siddique and Gupta (1991) reported high phenotypic and genotypic coefficients of variation for pods per plant, plant height, 100 seed weight and seed yield. High heritability estimates were reported for pods per plant, plant height, 100 seed weight, days to first flowering, pod length and seeds per pod. High

genetic gain was reported for days to first flowering, plant height and seed yield in cowpea.

High genotypic coefficient of variation was reported for characters like plant height, seed weight per plant, seeds per pod and 100 seed weight by Savithramma (1992). High heritability values were observed for plant height, pod length and 100 seed weight. High genetic advance was recorded in respect of plant height, seed weight per plant and 100 seed weight in cowpea.

Sudhakumari (1993) in a study with 59 varieties of cowpea reported high values of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance for pod length, number of primary branches per plant and 100 seed weight.

Sawant (1994) studied seed yield and 11 component traits in cowpea and reported high phenotypic and genotypic coefficients of variation for plant height, pods per plant, inflorescences per plant and 100 seed weight. High heritability and high genetic advance were observed for plant height, seed yield per plant, pods per plant, 100 seed weight, inflorescences per plant, branches per plant and pod length.

Working on 31 genotypes of bush type vegetable cowpea, Sobha (1994) observed that pod weight and pod yield had high genotypic coefficient of variation. High heritability and high genetic advance were observed for pod weight, pod yield per plant, days to harvest, pod length and girth.

In cowpea the high genotypic coefficient of variation was recorded for grain yield per plant. Plant height, pods per plant, pod length, pod width, seeds per pod and grain yield showed high heritability estimates. High genetic gain was reported for pods per plant and grain yield per plant (Mathur, 1995).

Rewale *et al.* (1995) studied heritability in 70 diverse cowpea genotypes on days to 50 per cent flowering, plant height, number of inflorescences per plant ,number of pods per plant ,pod length ,100-grain weight and seed yield per plant

and found that the estimates of heritability and genetic advance were high for 100 seed weight and plant height.

Sreekumar (1995) observed high heritability for days to 50 per cent flowering, total nodule weight, weight of 100 seeds and seed protein content and medium heritability for total number of nodules, length of pods and number of pods per plant. Genetic advance as percentage of mean was high for characters like total nodule weight, number of pods per plant and 100 seed weight. Moderate genetic advance was observed for total number of nodules and grain yield and low genetic advance for number of days to flower, plant dry weight, length of pod and seed protein content.

Backiyarani and Nadarajan (1996) studied 34 genotypes of cowpea and observed high phenotypic and genotypic coefficients of variation for pods per plant, clusters per plant and 100 seed weight. Heritability and genetic advance were high for 100 seed weight and single plant yield.

Sreekumar *et al.* (1996) studied 18 yard long bean genotypes and reported high values of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance for pod length and seeds per pod. High heritability with low genetic advance was observed for number of days to flowering and days to harvest.

Working with seven cowpea genotypes Rajaravindran and Das (1997) observed very low genotypic coefficients of variation for all the characters except for green pod yield. Days to maturity recorded the lowest genotypic and phenotypic coefficients of variation. Heritability was highest for pod length followed by days to 50 per cent flowering, days to maturity and green pod yield while it was the lowest for pods per plant. Genetic advance was high for green pod yield and pods per plant.

Resmi (1998) reported high phenotypic coefficient of variation for pod yield per plant followed by number of pods per kilogram and number of inflorescences per plant in yard long bean. High genotypic coefficient of variation

was recorded for pod yield per plant followed by number of pods per kilogram. Heritability was high for number of pods per kilogram and 100 seed weight followed by pod weight and pod length. High heritability along with high genetic advance was reported for pod yield per plant, number of pods per kilogram, number of inflorescences per plant and weight of pods.

Vardhan and Savithramma (1998a) in a study with 102 accessions of cowpea found high values of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance for plant height, number of primary branches, seed yield per plant and green pod yield.

In cowpea, Hazra *et al.* (1999) reported high phenotypic and genotypic coefficients of variation along with high heritability and high genetic advance for plant height, pod weight, pod length, and pod yield per plant.

In 11 cultivars of cowpea, Mandal *et al.* (1999) observed that nodule number per plant had high genotypic coefficient of variation, high heritability and high genetic advance and nodule weight per plant with moderately high heritability and genetic advance.

Rangaiah and Mahadevu (1999) in cowpea observed wide range of variability and high estimates of genotypic coefficient of variation for plant height, number of branches per plant, number of seeds per plant, pod weight and total seed weight per plant. All these characters showed high heritability and high genetic advance.

High estimates of phenotypic coefficient of variation along with high to moderate heritability as well as genetic advance for number of clusters per plant, number of pods per plant, number of seeds per plant and pod weight was reported in cowpea (Rangaiah *et al.*, 1999).

Kalaiyarasi and Palanisamy (2000) reported that seed yield per plant and number of pods per plant had high estimates of genotypic coefficient of variation followed by 100 seed weight, number of seeds per pod and plant height. High heritability coupled with high genetic advance were observed for seed yield per

plant, number of pods per plant, 100 seed weight and number of seeds per pod in cowpea.

In a variability study conducted by Pournami (2000), significant differences were observed among the 51 yard long bean genotypes for eleven characters out of fourteen characters. Maximum genotypic coefficient of variation was observed for number of pods per plant followed by yield of vegetable pods per plant. Heritability was high for number of pods per plant followed by yield of vegetable pods per plant. High estimates of heritability coupled with high genetic advance were recorded for number of pods per plant, pod yield per plant and pod weight.

In a study with 50 cowpea genotypes Selvam *et al.* (2000) observed high genotypic coefficient of variation and phenotypic coefficient of variation for plant height, number of pods, seed yield and number of branches per plant. Genotypic coefficient of variation, heritability and genetic advance were high for plant height and days to 50 per cent flowering.

Tyagi *et al.* (2000) in a study with 24 genotypes of cowpea found high estimates of heritability (>50 %), genotypic coefficient of variation and genetic advance for days to 50 per cent flowering, plant height, seed yield per plant and days to maturity.

Working with 50 cultivars of yard long bean Vidya (2000) reported that yield of vegetable pods per plant, number of pods per inflorescence, main stem length, and pod weight recorded high phenotypic and genotypic coefficients of variation while it was low for days to first flowering. High heritability coupled with high genetic advance was observed for number of pods per inflorescence, yield of vegetable pods per plant, number of pods per plant, pod weight, length of main stem and number of inflorescences per plant.

In bush type vegetable cowpea, Ajith (2001) observed high phenotypic and genotypic coefficients of variation for main stem length, number of primary branches, pod weight, pod clusters per plant, pod length and seeds per pod and

high heritability coupled with high genetic advance for main stem length, number of primary branches, pod weight, pod clusters per plant, pod length and seeds per pod.

Nehru and Manjunath (2001) in a study with 14 cultivars of cowpea reported that phenotypic coefficient of variation was highest for pods per plant followed by cluster, primary branches and yield per plant. High heritability and high genetic advance were noted for pods per plant and moderate for plant height, 100 seed weight and yield per plant.

In a study with 34 cowpea genotypes Rameshkumar *et al.* (2002) observed high estimates of genotypic coefficient of variation, heritability and genetic advance for total phenols.

In a study with 50 cowpea genotypes by Vineetakumari *et al.* (2003) observed high genotypic and phenotypic coefficients of variation for days to flowering, days to maturity, number of clusters per plant, number of pods per plant, 100 seed weight and seed yield per plant. High heritability and genetic gain were recorded for seed yield per plant, number of pods per plant and number of clusters per plant.

Narayanankutty *et al.* (2003) observed high phenotypic coefficient of variation and genotypic coefficient of variation for fruit yield, pods per plant and weight of pod. High heritability coupled with high genetic advance was observed for fruit yield, pods per plant and weight of pod in cowpea.

Relatively high genotypic and phenotypic coefficients of variation were recorded for plant height, number of pods per plant and green pod yield per plant in cowpea by Pal *et al.* (2003). High heritability with moderate to high genetic advance were observed for plant height, primary branches per plant, peduncles per plant and green pods per plant. Days to 50 per cent flowering, days to first green pod picking, pod diameter, seeds per plant and 100 seed weight manifested high heritability with low genetic advance.

Venkatesan *et al.* (2003b) evaluated twenty genotypes of cowpea and observed high genotypic coefficient of variation, phenotypic coefficient of variation and heritability coupled with genetic advance for plant height and dry matter production. Moderate values of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were recorded for seed yield, 100 seed weight, pods per plant, pod length and clusters per plant.

Philip (2004) reported that high phenotypic and genotypic coefficients of variation for grain yield per plant followed by 100 seed weight and number of pods per plant in cowpea. High heritability was observed for number of pods per plant, number of inflorescences per plant, plant height, number of primary branches per plant, pod length, number of seeds per pod, 100-seed weight and grain yield per plant while days to 50 per cent flowering and number of inflorescences per plant exhibited moderate heritability. Grain yield, pods per plant and 100 seed weight recorded high genetic advance. Genetic advance was moderate for days to 50 per cent flowering and plant height, while for number of inflorescences per plant it was low.

## 2.3 CORRELATION STUDIES

Yield is complex character determined by several component characters. Improvement in yield is possible only through selection for the desirable component characters. The relationship of yield with other traits is of great importance while formulating any selection programme for crop improvement. Research work done in cowpea to bring out the relationship of different traits with pod yield and among the yield contributing factors is briefly reviewed.

Jana *et al.* (1982) reported positive and significant correlation of primary branches per plant with pod yield and it was negatively correlated with pod length in cowpea. Correlation studies in cowpea by Patil and Bhapkar (1987a) revealed that yield was positively and significantly correlated with pods per plant and seeds per pod, which were negatively correlated with each other.

Ye and Zhang (1987) observed the existence of positive correlation between pod yield, protein yield, dry matter yield and their components in yard long bean. The green pod yield was highly and positively correlated with pods per plant, days to first flowering, seeds per pod and plant height in cowpea (Sharma *et al.*, 1988).

Mareena (1989) reported high positive correlation of yield per plant with number of pods per plant and plant height in cowpea. Grain yield was significantly and positively correlated with days to 50 per cent flowering, number of pods per plant, number of clusters per plant, pod length and 100-grain weight in cowpea (Patil *et al.*, 1989).

High positive correlation was observed by Tewari and Gautam (1989) for green pod yield per plant in cowpea with number of primary branches per plant, number of pods per cluster, clusters per plant, 100 seed weight and seeds per pod.

Apte *et al.* (1991) found significant positive correlation of days to 50 per cent flowering with number of branches, pod number, pod length and seeds per pod in cowpea. Plant height showed significant positive correlation with pod number and seeds per pod and a negative correlation with number of branches. Number of branches exhibited significant positive correlation with pod number and seeds per pod. Pod number and pod length had positive correlation with seeds per pod.

Sudhakumari (1993) reported positive significant correlation of seed yield per plant with number of seeds per pod, length of pod and 100-seed weight in cowpea. In cowpea, green pod yield per plant was positively correlated with pod length and pod weight in cowpea (Misra *et al.* 1994).

Sawant (1994) reported that seed yield was significantly and positively correlated with branches per plant, inflorescences per plant, pods per plant, pod length, seeds per pod and 100-seed weight in cowpea.

In vegetable cowpea, high and positive correlation between pod yield and days to harvest, pod length, pod girth, pod weight, seeds per pod and 100 seed weight was reported by Sobha (1994).

Tamilselvam and Das (1994) reported positive correlation of seed yield per plant with plant height, number of branches per plant, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod and 100-seed weight. Plant height was positively correlated with days to 50 per cent flowering, number of cluster per plant, pod length and 100 seed weight. Number of seeds per pod was positively correlated with 100 seed weight. Number of clusters and pods per plant were negatively correlated with pod length and 100 seed weight in cowpea.

In cowpea, Hussein and Farghali (1995) reported significant phenotypic correlation between pod length and 100 seed weight and significant genotypic correlation between days to flowering and pod length as well as number of seeds per pod and seed yield.

Kar *et al.* (1995) observed strong association of pod yield with fibre percentage and seeds per pod in cowpea.

In cowpea, Mathur (1995) reported that pods per plant showed negative correlation with seeds per pod and positive correlation with plant height, pod length and pod width. Pod length had positive correlation with seeds per pod and negative correlation with plant height. Pod width had negative correlation with seeds per pod.

Pod length and 100 seed weight had significant positive phenotypic correlation in cowpea (Shakarad *et al.*, 1995). Days to flowering recorded significant genotypic correlation with pod length, number of seeds per pod and seed yield. Naidu *et al.* (1996) reported positive correlation between number of clusters per plant and number of pods per plant in cowpea.

Sreekumar *et al.* (1996) reported significant positive correlation in yard long bean between yield of green pods with number of fruiting points per plant,

number of pods per plant, pod length and number of seeds per pod, both at phenotypic and genotypic levels. Number of pods per plant was correlated positively with number of fruiting points per plant and negatively with number of days to first flowering as well as first picking. Number of seeds per pod had significant positive correlation with pod length and number of days to flower.

Chattopadhyay *et al.* (1997) reported that pod length, green pod weight, seeds per pod and 100 seed weight exhibited significant positive genotypic correlations with green pod yield. Days to flowering registered high and negative association with green pod yield both at genotypic and phenotypic level. Pod number showed significant negative relationship with green pod weight and pod length.

Grain yield per plant was positively and significantly associated with clusters per plant, pods per plant and total biomass per plant (Singh *et al.*, 1998).Correlation studies by Resmi (1998) with 30 genotypes of yard long bean indicated high positive correlation of pod yield with pod weight, pod length and number of pods per plant.

Vardhan and Savithramma (1998b) reported that green pod yield per plant in cowpea was significantly and positively correlated with pod length, pod width, pods per plant and biomass.

In cowpea Kalaiyarasi and Palanisamy (2000) reported that pod length, seeds per pod, 100 seed weight and crude protein content had a strong positive correlation with seed yield. In yard long bean positive genotypic correlation of pod yield per plant with number of seeds per pod, number of pods per plant, length of harvest period, number of pods per inflorescence, pod weight and pod length was reported by Pournami (2000).

Vidya (2000) studied 50 genotypes of yard long bean and found that number of pods per plant had the highest genotypic positive correlation with pod yield per plant followed by number of pods per inflorescence, pod weight, length of harvest period, pod girth, pod length and number and primary branches. In

vegetable cowpea, pod yield per plant showed high genotypic correlation with number of pods per plant, pod weight, pods per cluster, pod clusters per plant and pod girth (Ajith, 2001). Yield per plant was significantly and positively correlated with number of primary branches and plant height in cowpea was reported by Kohli and Agarwal (2002).

Singh and Verma (2002) observed that seed yield in cowpea was positively correlated with 100 seed weight and pod length, Pod length and plant height were positively correlated with 100 seed weight. A negative correlation was noticed between 100 seed weight and number of pods per peduncle, and number of days to 50 per cent flowering.

Correlation studies by Ushakumari *et al.* (2001) with 50 genotypes of cowpea noticed that yield per plant was significantly and positively associated with pod length, plant height and number of pods per plant but negatively correlated with number of branches per plant, clusters per plant and seeds per pod. Significant and positive association was observed between branches per plant and pod length and between clusters per plant and pods per plant.

Seed yield per plant in cowpea was positively correlated with number of clusters per plant, pods per plant and 100-seed weight, but it was negatively correlated with days to maturity (Vineetakumari *et al.*, 2003).

In cowpea, Kutty *et al.* (2003) observed that number of pods per plant, pod weight and pod length were positively and significantly correlated with yield per plant both at genotypic and phenotypic level. Number of days to first picking showed significant negative correlation with yield per plant and number of pods per plant.

Plant height, pod yield and pod length had significant positive correlation with grain yield in cowpea at genotypic and phenotypic levels (Neema and Palanisamy, 2003). Pod yield had significant positive association with number of pods, pod length and number of grains per plant at the genotypic level while pod length had significant association at phenotypic level.

Parmar *et al.*, (2003) observed that grain yield in cowpea showed significant positive association with clusters per plant and pods per plant at phenotypic and genotypic levels. Significant positive genotypic correlations were noticed between days to flowering with days to maturity and plant height, days to maturity with plant height, pod length with seeds per pod, plant height with test weight, branches per plant with clusters per plant, clusters per plant with pods per plant and pods per cluster with pods per plant.

Venkatesan *et al.* (2003a) observed that branches per plant, clusters per plant, pods per plant, pods per cluster and pod yield had positive correlations with seed yield both at phenotypic and genotypic level in cowpea.

Fresh pod yield per plant in cowpea was significantly and positively correlated with fresh pod harvest period, number of pods per plant, average pod weight, pod length and pod width (Peksen, 2004). There were positive and significant correlation between fresh pod yield per plant, number of branches per plant and pod thickness.

Grain yield per plant in cowpea exhibited highly significant positive correlation with number of pods per plant, inflorescences per plant, seeds per pod and 100 seed weight both at genotypic and phenotypic levels (Philip, 2004).

In cowpea, Xiao-Jie *et al.* (2004) observed positive correlation between the number of peduncles per plant and branches per plant and between pod length and pod width.

## 2.4 PATH ANALYSIS

Path coefficient is a standardised partial regression coefficient which measures the direct influence of one variable (cause) upon another (effect) and permits the separation of correlation coefficients into components of direct and indirect effects (Dewey and Lu, 1959). The information obtained from path analysis helps in indirect selection for genetic improvement of yield.

Murthy (1982) observed that the number of pods per plant was the major contributor to yield followed by pod length, seeds per pod and pod weight in cowpea.

Jana *et al.* (1983) reported that pod number per plant had the highest direct effect on pod yield per plant in yard long bean, while Ye and Zhang (1987) identified pods per inflorescence as the character with the greatest direct effect on pod yield in yard long bean. High negative direct effect on yield was obtained through days to flowering and pod length in cowpea by Tewari and Gautam (1989).

Biradar *et al.* (1991) found that pod weight had the highest positive direct effect on yield in cowpea followed by plant height and clusters per plant. Pod length, pods per plant and seeds per pod showed negative direct effect on yield.

In cowpea, Misra *et al.* (1994) found that pod length had the greatest direct effect on pod yield followed by pod diameter while direct negative effects was observed for average pod weight.

Sawant (1994) reported that in cowpea pods per plant had the highest positive direct effect on seed yield followed by 100-seed weight, seeds per pod, days to 50 percent flowering, inflorescences per plant, plant height and pod length. Pod weight showed the maximum positive direct effect on yield followed by pod girth and 100 seed weight in bush type vegetable cowpea (Sobha, 1994).

Kar *et al.* (1995) observed that in vegetable cowpea, pod length and fibre content were found to be the main determinants of pod yield. The green pod weight, dry pod weight, pod number and seeds per pod were the most important components of yield because of their high positive direct effects Chattopadhyay *et al.* (1997)

In cowpea Singh and Singh (1997) reported that number of clusters per plant, number of seeds per pod and total biomass made the greatest direct contribution to seed yield.

Singh *et al.* (1998) reported that pods per plant and total biomass per plant were the most important component characters on grain yield per plant in cowpea.

Resmi (1998) reported that number of pods per plant exerted the maximum positive direct effect on pod yield followed by pod weight in vegetable cowpea. Pod length exerted positive indirect effect on pod yield through pod weight

Vardhan and Savithramma (1998b) revealed that green pods per plant, pod length, pod width and number of primary branches were the major traits contributing to green pod yield per plant in cowpea.

Kapoor *et al.* (2000b) reported that number of seeds per pod and 100-seed weight were the main contributing characters towards seed yield in cowpea. Pod length contributed indirectly towards seed yield via number of seeds per pod and 100-seed weight.

In yard long bean, Pournami (2000) reported that days to first flowering exerted the maximum direct effect on pod yield followed by number of pods per plant. Days to first harvest, length of harvesting period and number of inflorescences per plant exerted negative direct effect on pod yield.

Path analysis in cowpea revealed that pod weight per plant had the highest positive direct effect on total seed weight, followed by 100 seed weight and seeds per plant (Rangaiah, 2000).

Tyagi *et al.* (2000) reported that the highest and lowest positive direct effects on seed yield in cowpea were observed for seed weight per pod and plant height respectively. Days to 50 per cent flowering recorded a negative direct effect on seed yield per plant.

Path analysis in yard long bean by Vidya (2000) reported that maximum direct effect on yield was shown by number of pods per plant followed by pod weight Number of pods per inflorescence had high indirect effect via number of pods per plant.

Ajith (2001) reported that pods per plant and pod weight had the highest direct effects on pod yield in vegetable cowpea. Pods per plant exerted positive indirect effect via pod weight.

Bastian *et al*., (2001) reported that dry matter production had high positive direct effect on seed yield followed by pod length in cowpea. The direct effects exhibited by seeds per pod and pod number were negligible. Days to flowering, plant height, branch number, cluster number, pod number, seeds per pod, test weight and seed protein content exhibited negative direct effects on seed yield. The indirect effects of dry matter production and pod length through other characters on seed yield was either low or negligible. The high direct effects of pod number and seeds per pod on seed yield were diluted to negligible amounts due to the impact of days to flowering, plant height, branch number and cluster number on these two traits.

Neema and Palanisamy (2001) observed that plant height, number of branches per plant, pod yield, number of pods and pod length had positive direct effect on grain yield in cowpea. The highest positive direct effect on grain yield was recorded by pod yield and the lowest by pod length. The indirect effect was maximum for pod length via pod yield.

In cowpea path analysis indicated that number of seeds per pod, number of pods per plant and crude protein content had high positive direct effect on seed yield while pod length, 100 seed weight, number of branches per plant and crude fibre content had negative direct effect (Kalaiyarasi and Palanisamy, 2002). Pod length and 100 seed weight had positive indirect effect on seed yield through number of pods per plant, number of seeds per pod and crude protein content.

Ushakumari *et al*. (2002) reported that pod length, plant height and pods per plant were the major yield contributing components of grain yield in cowpea. The maximum positive indirect effect of seeds per plant on grain yield was observed through pod length. Branches per plant showed positive indirect effect on yield per plant through pod length and cluster per plant, its negative indirect effect was observed through plant height, pods per plant and seeds per pod.

Clusters per plant had positive indirect effect on yield per plant through pods per plant, pod length and branches per plant.

In cowpea, path analysis revealed that the number of clusters, pods per plant, seeds per plant and 100-seed weight showed the greatest positive direct effect on seed yield where as number of days to maturity and flowering exhibited the negative direct effects on seed yield per plant (Vineetakumari, 2003).

Kutty *et al.* (2003) indicated that the pods per plant, followed by pod weight had the greatest positive direct effect on yield,. The direct effects of pod length and number of days to first picking were low mainly due to high indirect effect via average weight of pods and number of pods per plant.

In cowpea, Parmer *et al.* (2003) reported that pods per plant registered the highest direct effect on seed yield followed by cluster per plant and seeds per pod. Where as test weight, days to flower and pods per cluster exhibited moderate positive direct effect. The indirect effect of branches per plant via seeds per pod was also positive and high.

Subbiah *et al.* (2003) reported that number of pods per plant, number of branches per plant, pod length, pod weight and number of seeds per pod had positive direct effect on green pod yield. Crude fibre content of the pods had negative direct effect on green pod yield. Number of pods per plant had positive indirect effect on yield per plant through days to flowering, number of branches per plant, pod length, pod weight, number of seeds per pod, test weight and crude fibre content of the pods.

Venkatesan *et al.* (2003a) revealed positive direct effect on number of pods per plant, pod length, number of clusters per plant, number of seeds per pod and 100 seed weight on seed yield.

Philip (2004) reported that number of pods per plant followed by 100 seed weight and seeds per pod exerted the maximum positive direct effect on grain yield in cowpea. Pod length contributed to yield through positive indirect effect

through number of seeds per pod, number of pods per plant, number of inflorescences per plant, number of pods per inflorescence and 100 seed weight.

## 2.5 GENETIC DIVERGENCE

A knowledge of genetic divergence among the different genotypes is very essential in selection of parents for hybridization programme. According to Singh and Gupta (1968), the more divergent the parents with a reasonable range, the more would be the chance of improving a character in question through hybridization programme.

In cowpea, Kumar *et al.* (1982) grouped 50 genotypes into seven clusters using Mahalanobis $D^2$ statistic and found that days to 50 per cent maturity, pod length, pod width and 100 grain weight were the characters which contributed maximum to genetic divergence.

Chikkadyavaiah (1985) studied genetic divergence among 207 indigenous and 117 exotic genotypes of cowpea and grouped 23 stable genotypes to one cluster using cluster analysis.

Jindal (1985) used Mahalanobis $D^2$ statistic to cluster 52 cowpea varieties from India and other countries for ten characters and grouped them into eight clusters. The clustering did not reflect the geographical origin of the varieties.

Patil and Bhapkar (1987b) studied genetic divergence among 18 indigenous and 21 exotic genotypes of cowpea and grouped them into 16 clusters using Mahalanobis $D^2$ statistic.

In cowpea, Thiyagrajan *et al.* (1988) reported that days to 50 per cent flowering, 100 seed weight and plant height were the characters which contributed maximum to genetic divergence.

Dharmalingam and Kadambavanasundaram (1989) observed wide genetic diversity among the 13 clusters formed from 40 genotypes of cowpea. The genotypes CO-2 and G 5 belonging to the two most divergent clusters were recommended as suitable for inclusion in heterosis breeding programmes.

Renganayaki and Rengaswamy (1991) used Mahalanobis $D^2$ statistic to cluster six genotypes of cowpea into four clusters. 100 seed weight, pod length and seed yield per plant were the characters which contributed most towards genetic divergence in cowpea.

Sobha (1994) studied genetic divergence in 31 cowpea genotypes and grouped them into six clusters. Strict parallelism was observed between genetic diversity and geographic distribution.

Sudhakumari and Gopimony (1994) used Mahalanobis $D^2$ technique to estimate genetic divergence of 59 cowpea varieties and grouped them into eight clusters.

In cowpea, Hazra *et al.* (1996) grouped 45 genotypes into four clusters using Mahalanobis $D^2$ statistic. Intercluster distance was maximum between clusters I and IV.

Rewale *et al.* (1996) studied genetic divergence of 70 genotypes of cowpea and grouped them into 19 clusters using Mahalanobis $D^2$ statistic. There was no relationship between geographical origin and genetic diversity. Days to initiation of flowering, 50 per cent flowering and maturity, number of inflorescences, pod per plant, pod length, 100 seed weight, and seed yield per plant made major contribution to total divergence.

Mahalanobis $D^2$ statistic was used to estimate genetic divergence of ten yield related characters in 50 cowpea genotypes by Santos *et al.* (1997). Length of the main branch, 100 seed weight and pod length were the most important characters to affect divergence.

Sharma and Mishra (1997) measured the genetic divergence in 42 indigenous and exotic strains of cowpea and grouped them into six different clusters. Days to 50 per cent flowering, plant height and pods per peduncle contributed the most towards genetic divergence.

Resmi (1998) grouped 30 yard long bean varieties into four clusters based on $D^2$ analysis. Cluster IV the largest cluster had 18 genotypes. Inter cluster

distance was maximum between clusters I and III and least between clusters I and II.

Viswanathan *et al.* (1998) assessed the genetic divergence in 72 genotypes of cowpea and observed high genetic diversity among them. Information on nine characters from 24 early maturing genotypes of cowpea from different geographical regions were subjected to Mahalanobis $D^2$ analysis by Tyagi *et al.* (1999) and grouped them into three clusters. Genetic diversity was independent of geographical origin.

Backiyarani *et al.* (2000) used Mahalanobis $D^2$ analysis to cluster 32 genotypes of cowpea into six clusters of which cluster IV was the largest with 18 genotypes. Geographical diversity was not related to genetic diversity. Single plant yield, harvest index and earliness in flowering together accounted for 80 per cent of the total genetic divergence

Kapoor *et al.* (2000a) studied the genetic divergence of 60 cowpea genotypes and grouped them into 15 clusters depending upon their genetic distance.

Ushakumari *et al.* (2000) grouped 50 genotypes of cowpea into 13 clusters using Mahalanobis $D^2$ analysis. Plant height, number of seeds per pod, number of branches per plant, number of pods per cluster and pod length contributed maximum towards genetic divergence.

In yard long bean, Vidya (2000) grouped 50 genotypes into four clusters using Mahalanobis $D^2$ statistics. Cluster I formed the largest cluster with 28 genotypes while cluster IV had only a single cultivar.

Anbuselvam *et al.* (2000) grouped 50 genotypes of cowpea into four clusters based on genetic divergence using Multivariate analysis of $D^2$ statistics. High $D^2$ value in cluster I included 45 genotypes.

Narayanankutty *et al.* (2003) studied genetic divergence in 37 genotypes of vegetable cowpea and grouped them into 11 clusters using Mahalanobis $D^2$

statistics. The maximum inter cluster distance observed between clusters VIII and X followed by clusters VI and X and clusters VIII and IX respectively.

In cowpea, Philip (2004) studied genetic divergence in 50 genotypes and grouped them into ten clusters. Wide range of genetic divergence was noticed among the genotypes.

The nature and magnitude of genetic divergence were assessed in 20 cowpea genotypes using Mahalanobis $D^2$ statistic (Venkatesan *et al.*, 2004). The population was grouped into six clusters, of which clusters II and III had the maximum number of genotypes. Analysis corroborated the absence of parellism between geographic origin and genetic diversity. The maximum inter cluster distance was between clusters II and IV. Clusters per plant, pods per cluster, pods per plant and seed yield per plant contributed maximum towards the total divergence.

## 2.6 SELECTION INDEX

The economic worth of plant depends upon several characters. So while selecting a desirable plant from a segregating population the plant breeder has to give due consideration to characters of economic importance. Selection index is one such method of selecting plants for crop improvement based on several characters of importance. This method was proposed by Smith (1947) using discriminant function (Fisher, 1936).

Resmi (1998) worked out the selection indices for 30 yard long bean genotypes on the basis of 13 characters which showed high correlation with yield *viz.*, length of vine, number of primary branches, petiole length, days to first flowering, pod length, pod girth, pod weight, pods per inflorescence, pods per kg, pods per plant and pod yield per plant. Based on the analysis genotype VS-6 attained the maximum selection index value followed by VS-11, VS-19 and VS-3 and the least score was obtained for VS-16, VS-10 and VS-2.

Selection indices were worked out on the basis of yield and six component characters *viz.*, number of pods per plant, number of inflorescences per plant,

number of pods per inflorescence, pod length, seeds per pod and 100 seed weight by Philip (2004). Among the 50 genotypes, $T_2$ ranked first with highest index value followed by $T_8$, $T_6$ and $T_4$. The genotypes with least index value was VS 47.

## 2.7 FUSARIUM WILT

Fusarium wilt was first reported in cowpea from USA (Orton, 1902). In India, this disease was first recorded in cowpea by Singh and Sinha (1955). Allen (1983) reported involvement of *Fusarium solani* in dry root rot of cowpea.

Wilt caused by *Fusarium oxysporum* Schlecht. ex Fries f. sp. *tracheiphilum* (E.F. Smith) Snyder & Hansen was also reported. Three races of the pathogen have been distinguished, *i.e.*, race 1 has been isolated from both cowpea and soybean; race 2 from some cowpea cultivars only; and race 3 from cowpea cv. Arlington, which is resistant to the other 2 races. Infected plants are more frequently noted because the leaves become flaccid and chlorotic before falling prematurely. Closer examination reveals that the lower stem may be swollen before chlorosis appears, and necrotic vascular tissue in the stems and roots often in more extensive form than might be expected from foliar symptoms. A rapid wilt develops in young plants, which are usually killed, but plants infected at a later stage in development may be stunted with slower progression of foliar chlorosis and wilt. Some infected plants may never show external symptoms, yet the vascular tissue may be severely disrupted and discoloured (Cook, 1978).

A study was conducted by Sajise (1988) to identify influence of cultivar, inoculum density and plant age on the incidence of Fusarium rot and stem rot in cowpea. Different levels of *F. solani* inoculum were inoculated to five, 17 and 22 days old seedlings of TVX 289-4G, VCS 6-1 and CES 42-2 cowpea cultivars. Among the cultivars tested, CES 42-2 was the most resistant. The degree of infection was not significantly effected by the different levels of inoculum used. However plant age significantly affected the percentage of infected plants. The infection was higher in 22 than in 17 days old plants and was completely suppressed in five day old seedlings.

Xylem extracts from healthy wilt-resistant plants of TVu 1560 were more toxic to the pathogen than extracts from healthy susceptible Blackeye plants. In the susceptible cultivar the pathogen grew extensively in the xylem vessels, causing plugging and leading to severe disease symptoms. The population of *F. oxysporum* increased while the dry wt of the plant decreased in proportion to plant age. Younger plants were more susceptible to infection than older ones (Shihata *et al.*, 1989b).

A bioassay of 22 cowpea cultivars showed the presence of seed borne fungi in eight countries of Brazil which include *Fusarium pallidoroseum* (26.9 %) and *F. oxysporum* (15.6 %). Cultivar Sempre-verde, Costela-de-vace and moita had 90-100 per cent germination. A direct correlation was found between the total number of seed borne fungi and germination (Barros *et. al.*, 1990).

The wilt of cowpea was noticed in farmers' field in Thiruvananthapuram district of Kerala (Reghunath *et al.*, 1995). Fusarium wilt is characterized by yellowing of leaves followed by defoliation, drying of vines and root decay. Sometimes there is also swelling of the basal part of the plant including the lower part of the stem and upper part of the tap root forming a tuber like structure which later gets disintegrated.

Schneider and Kelley (2000) studied Fusarium root rot in bean. The genetic resistance to the pathogen (*Fusarium oxysporum* f. sp. *phaseoli*) is considered quantitative and strongly influenced by environmental factors. They observed correlation coefficient between the greenhouse and field ratings were significant for the screening of Fusarium root rot resistance.

The intensity of cowpea Fusarium wilt (*Fusarium oxysporum* f.sp. *tracheiphilum*) in 10 soil types in Pernambuco, Brazil was investigated by Assuncao *et al.* (2003) and verified significant correlations between disease associated variables and relative spore production of the pathogens in the different soils.

Eloy and Michereff (2003) reported that Fusarium wilt caused by *Fusarium oxysporum* f. sp. *tracheiphilum*, is an important cowpea disease in the Brazilian Northeast. Aiming to determine the correlation between disease severity and reduction of cowpea seed yield, cultivated during two different period of time, an assay was carried out using plots artificially inoculated with the pathogen. At harvest, yield of each plot was determined from the total weight of seeds per plant. After harvest, the severity of Fusarium wilt was evaluated in all plants. No significant correlation was found between inoculum density of the pathogen that was present in the soil before planting and disease severity. Fusarium severity ranged between 3.2 and 93.3 per cent, while the yield loss ranged between 2.2 and 98.1 per cent. The model of simple linear regression, without data transformation, fitted the data in relation to Fusarium wilt severity and yield losses of both planting times, which proved the significant influence of the severity on yield loss levels.

Fusarium wilt is considered to be one of the most destructive soil borne disease of pulses. The yield loss due to Fusarium wilt vary with the stage at which the diseases occurs. Severe incidence of the disease during early reproductive stage induce flower and pod abortion which drastically decrease the seed number and yield. Fusarium causing wilt was assessed by inoculating them on two week old cowpea seedlings. Among the different species of Fusarium, *Fusarium pallidoroseum* was found to be most virulent in causing cowpea Fusarium wilt (Senthilkumar, 2003).

### 2.7.1 Source for Resistance

The original sources of resistance to Fusarium wilt of cowpea were obtained by selecting surviving plants from susceptible cultivars that were grown in the field plots with high inoculum density (Orton, 1902) since these field plots were infested with organisms in addition to Fusarium. Often surviving plants had resistance to other soil borne pathogens such as charcol rot and root rot nematodes. In such tests all cultivars except 'Iron', 'Victor' and 'Brabham' were eliminated as possible breeding stocks. When wilt resistant plants of these

crossed with susceptible plants their progenies segregated in such a manner as to indicate that the resistance was dominant.

Three races of *Fusarium oxysporum* f. sp. tracheiphilum have been reported. The race were differentiated as follows: Race 1 is pathogenic to plants of the cowpea cultivar Groit, but not plants of cultivars of Epoit and Arlington; race 3 is pathogenic to plants of 'Red Chinese and Arlington but not to 'Groit' (Armstrong and Armstrong, 1950; Hare, 1953).

Genetic studies were done using M455 (a probable derivative of the cultivar Iron, which is resistant to three races of cowpea wilt) and the cultivar brown sugar crowder (susceptible to all races) showed that resistance is conditioned by two dominant genes for each race 1, 2 and 3 (Hare, 1957).

Races of the fungus also have been distinguished on the basis of varietal susceptibility with cv. iron resistant to all three races, Arlington resistant to races 1 and 2 but killed by race 3 (also isolated from infected soybean), Groit killed by race 1 but not race 2 and Extra Early Black eye killed by race 2 but not by race 1. Genetic resistance from cv. Iron has been found to result from a single dominant factor for race 1 of the causal fungus and two dominant factors each for races 2 and 3. Satisfactory control has been achieved (in the United States) through use of resistant varieties, viz. Brown sugar Crowder S-1, Grant and Missisippi Crowder (Cook, 1978).

Four varieties of cowpea evaluated for susceptibility to *F. oxysporum* which was isolated from naturally diseased cowpea varieties by Shihata *et al.* (1988) indicated that varieties Black eye. TVu 1330 and TVx 3236-01G were susceptible whereas the TVu 1560 was resistant.

Shihata *et al.* (1989a) observed that *Fusarium oxysporum* was the most frequent isolate from diseased plants in all the cowpea fields examined, while *F. solani* and *F. moniliforme* were also present. Each fungus showed considerable pathogenic variation among different isolates and the various cultivars differed in their reaction to a highly virulent isolate of each pathogen. TVu 1560 was the

most resistant to all three Fusarium spp. In a field trial seed yield was significantly affected by inoculum with *F. oxysporum*. California Black eye 5 and TVu 1560 gave the highest and lowest yield reductions respectively in both seasons.

The population of *F. oxysporum* in the susceptible cultivar Black eye increased and reached a peak by the 50$^{th}$ day after sowing, however in the resistant cultivar TVu 1560 the population remained low and plants failed to develop symptoms Shihata *et al.* (1989b). Younger plants were more susceptible to infection than older ones.

The *Vigna unguiculata* cv. California Black eye (CB) 46 (PI548784), released in 1987, was derived as a single-plant selection from a 300-plant BC1 F7 family from the cross CB5 X PI166146. Field and greenhouse testing confirmed that CB46 is resistant to *Fusarium oxysporum* f.sp. *tracheiphilum* race 3 (isolate 793) which is common throughout the growing region(Helms *et al.*,1991a).

California Black eye (CB) 88 released in 1989, the *Vigna unguiculata* cv. California Black eye (CB) 88 (PI548785) originated as a mass-selected F4 family from the cross CB5 X 7977, where 7977 is a breeding line from the cross CB5 X PI166146. Resistance to *Fusarium oxysporum* f.sp. *tracheiphilum* race 3, common throughout the California Black eye growing region, was confirmed by field and greenhouse testing (Helms *et al.*,1991b).

Seventy three *Phaseolus vulgaris* genotypes were screened for resistance to the *Fusarium oxysporum* f.sp. *phaseoli* using artificial inoculum by Buruchara and Camacho (2000). They observed that by increasing inoculum from $10^2$ to $10^7$ conidia per ml did not affect the resistance of cultivars RWR 950 and G 685 but in the susceptible varieties G 2333 and MLB-48-49A it resulted in early appearance with high incidence and severity of the disease.

The response of 23 bean cultivars to four physiological races of Fusarium wilt (caused by *Fusarium oxysporum* f.sp. *phaseoli*) was evaluated by Sala *et al.* (2001). The roots of seven day old seedlings grown in sterilized sand were immersed for ten minutes in an inoculum suspension of $10^6$ spores per ml.

Evaluation was performed 25-30 days after inoculation using the scale from 0 (without symptoms) to 4 (wilted or died). Plants with ratings 0 to 2 were considered resistant and those with ratings of 3 to 4 were susceptible. Among the cultivars, IAC-Maravilha was susceptible to all the races of *F. oxysporum* f.sp. *phaseoli*, while Apore, FT 120, Carioca-MG, IAC-Carioca, IAC-Una, IAPAR 14, IAPAR 31, IAPAR 44, Perola, Ruda, Jalo Precoce and FT Bonito were resistant to all physiological races of the pathogen.

Cavalcanti *et al.* (2002) studied that efficiency of two inoculation methods in the assessment of resistance of 16 cultivars and lines of common bean to *Fusarium oxysporum* f. sp. *phaseoli*. They revealed that the root immersion method was more effective than the soil perforation method in assessing common bean resistance to Fusarium wilt. In the study, the cultivars Goiano Precoce, RH 3104 and IPA-9 were the most resistant genotypes, whereas LM 93204247, LM 93204296 and IPA-1 were the most susceptible ones.

# 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 the period 2004-2005.The present study aimed at evaluating a collection of yard long bean genotypes for yield and Fusarium wilt resistance. The field study was conducted in two experiments *viz.*, Experiment-I for evaluation and screening of genotypes for yield and yield components and Experiment-II for screening of genotypes for Fusarium wilt disease resistance. The details of the field experiment conducted and the statistical analysis carried out are provided here under.

## 3.1 MATERIALS

### 3.1.1 Experiment-I and Experiment-II

The basic material for the study included 30 genotypes of yard long bean collected from different agro climatic regions of Kerala including released varieties of Kerala Agricultural University. The details of the accessions collected are given in the Table 1. Plate 1 shows the variations in pod characters of the varieties.

## 3.2 METHODS

Layout and conduct of the experiment.

### 3.2.1 Experiment-I

The seeds of the 30 genotypes were laid out in Randomised Block Design with three replications during July 2004 in Experiment-I. In each replication 10 plants per genotype were taken. Normal cultural practices as per the Package of Practices recommendations of the Kerala Agricultural University (KAU, 2002) were adopted. Seeds were sown in rows 1m apart with spacing of 0.3 m between plants (Plate 2).

Table 1. Particulars of yard long bean genotypes used in the study

| Sl. No. | Treatments | Varieties | Source |
|---|---|---|---|
| 1 | Vu1 | Kayamkulam local | Kayamkulam |
| 2 | Vu2 | Malapuram local-2 | Malappuram |
| 3 | Vu3 | Ookodu local-1 | Ookodu |
| 4 | Vu4 | Thiruvananthapuram local-1 | Thiruvananthapuram |
| 5 | Vu5 | Sarika | Instructional Farm, Vellayani |
| 6 | Vu6 | Thiruvananthapuram local-4 | Thiruvananthapuram |
| 7 | Vu7 | Kollengode local | Kollengode |
| 8 | Vu8 | Vaijayanthi | Instructional Farm, Vellayani |
| 9 | Vu9 | KMV-1 | R.A.R.S, Mannuthy |
| 10 | Vu10 | Thiruvananthapuram local-3 | Thiruvananthapuram |
| 11 | Vu11 | Malappuram local-1 | Malappuram |
| 12 | Vu12 | Kalliyoor local | Kalliyoor |
| 13 | Vu13 | Kuttichal local | Kuttichal |
| 14 | Vu14 | VS27 | R.A.R.S, Mannuthy |
| 15 | Vu15 | Palapoor local-3 | Palapoor |
| 16 | Vu16 | VS86 | R.A.R.S, Mannuthy |
| 17 | Vu17 | Vellayani local | Instructional Farm, Vellayani |
| 18 | Vu18 | CPCH-1 | R.A.R.S, Mannuthy |
| 19 | Vu19 | Vella valli payar | Thiruvananthapuram |
| 20 | Vu20 | Palapoor local-2 | Palapoor |
| 21 | Vu21 | Varuvila local-1 | Varuvila |
| 22 | Vu22 | Thiruvananthapuram local-2 | Thiruvananthapuram |
| 23 | Vu23 | Ookodu local-2 | Ookodu |
| 24 | Vu24 | Malika | Instructional Farm, Vellayani |
| 25 | Vu25 | Palakkad local | Palakkad |
| 26 | Vu26 | Varuvila local-2 | Varuvila |
| 27 | Vu27 | Thrissur local | Thrissur |
| 28 | Vu28 | Kasargode local | Kasargode |
| 29 | Vu29 | Palapoor local-1 | Palapoor |
| 30 | Vu30 | Lola | Instructional Farm, Vellayani |

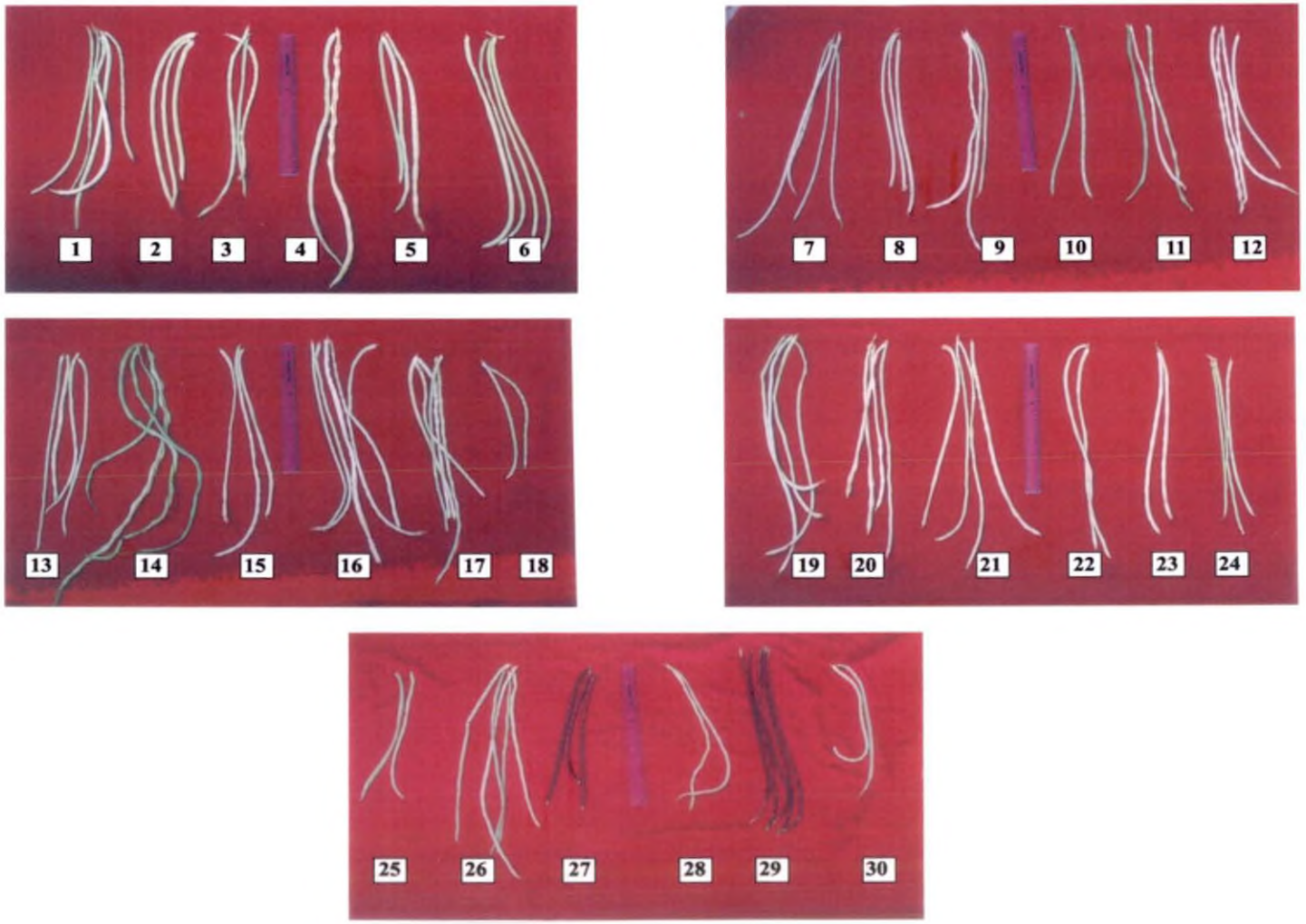



**Plate 1. Variation in pod characters**

**Plate 2. Field view - evaluation and screening of genotypes for yield and yield components**

### 3.2.2 Experiment-II

The seeds of the 30 genotypes were laid out in Randomised Block Design with three replications during July 2004 in Experiment–II (Plate 3). In each replication 10 plants per genotype were taken. Seeds were sown in rows 1m apart with spacing of 0.3 m between plants. On the seedlings symptoms were observed as damping off. On mature plants yellowing of the leaves were initial symptom, the plants showed wilting at advanced stage (Plate 4 and 5). On set of wilt symptoms were recorded.

#### *3.2.2.1 Isolation of the Pathogen*

Cowpea plants showing typical yellowing and wilting symptoms were collected from the cowpea fields of College of Agriculture, Vellayani, Thiruvananthapuram District of Kerala. Pathogen was isolated following the standard tissue isolation technique. The root along with collar portion of the wilted cowpea plants were washed in tap water and cut into small bits. The bits were then surface sterilized in 0.1 per cent mercuric chloride solution for one minute followed by washing in sterile water 2-3 times. The sterilized pieces were then transferred into sterile petridishes containing Potato Dextrose Agar (PDA) medium under aseptic conditions .The plates were then incubated at room temperature. On the third day onwards whitish fungal growth was visible from the bits, mycelial bits were transferred to PDA slants under aseptic conditions and slants were kept under room temperature. When full growth of the pathogen was visible the slants were transferred to refrigerator for further studies. Thus the culture of the pathogen was maintained (Plate 6).

#### *3.2.2.2 Preparation of Pathogen Inoculum:*

The culture was mass multiplied in PDA in petridishes for inoculation in the rice bran. Fusarium was mass multiplied in rice bran. The materials required for mass multiplication were

**Plate 3. Field view - screening of genotypes for Fusarium wilt resistance**

**Plate 4. Yard long bean genotypes exhibiting yellowing symptoms**

**Plate 5. Yard long bean genotypes exhibiting wilting symptoms**

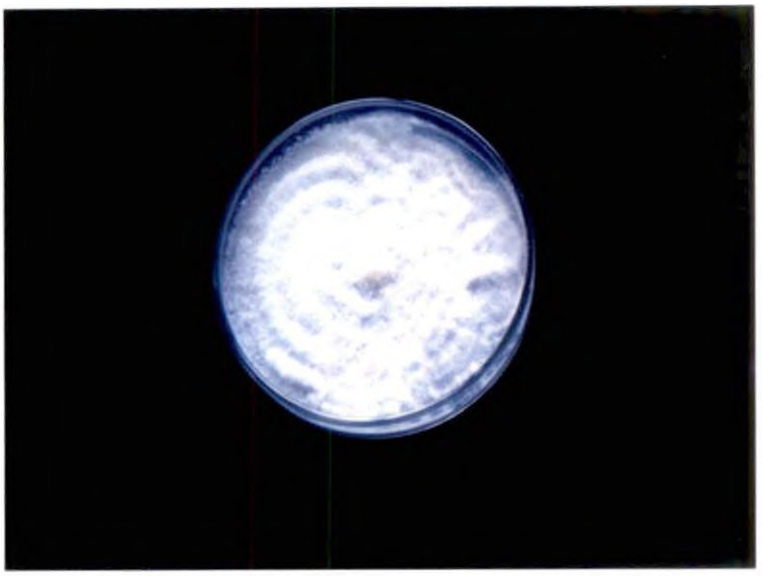


**Plate 6. Fusarium oxysporum culture**

**Plate 7. Mass multiplication of Fusarium oxysporum in rice bran**

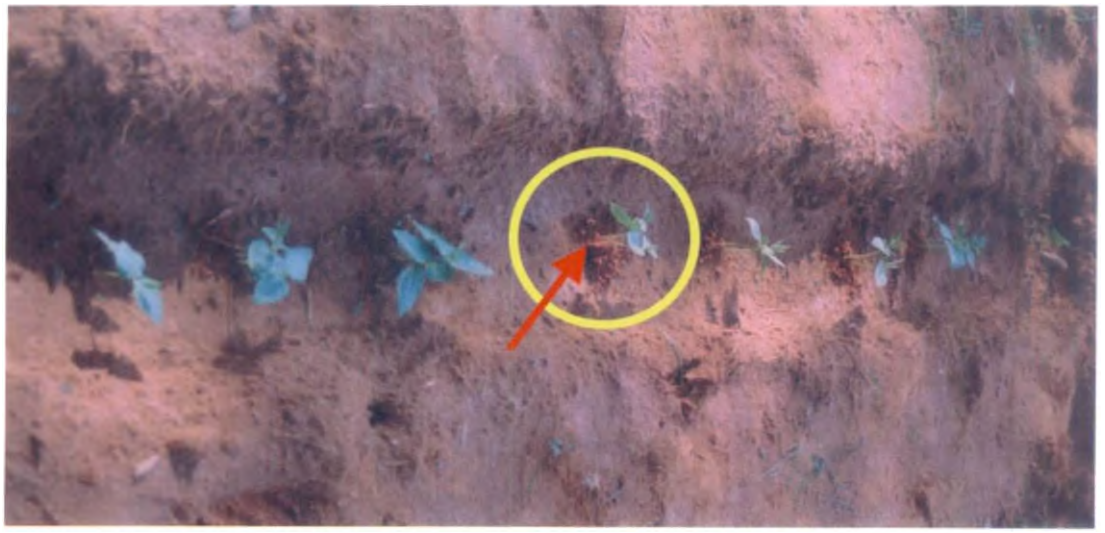


**Plate 8. Field application of inoculum at seven days after sowing**

Rice bran -1 kg

Sucrose -20 g

Multi vitamin tablets -3

Water –sufficient to moisture

Inoculum -10 discs (3 mm)

for the present study 10 kg of inoculum was prepared as above for field application. Rice bran was mixed with multi vitamin tablets and sucrose. The mixture was moistened with water sufficient enough to promote fungal growth. This mixture is taken in polythene bags and sterilised in autoclave at 121.5°C for 20 minutes. Actively growing culture disks of Fusarium was aseptically transferred sufficiently to multiply into the polythene bags and incubated at room temperature for 15 days to develop fungal growth (Plate 7).

***3.2.2.3 Inoculation of Pathogen***

Mass multiplied Fusarium inoculum was applied (5 g $pit^{-1}$) to the furrows in the field, thoroughly mixed with the soil .A second application was done seven days after sowing at the root zone of the cowpea seedlings and the soil mixed thoroughly (Plate 8).

***3.2.2.4 Disease Intensity***

The percentage of wilt intensity was calculated using score chart (Fig. 1) (Senthilkumar, 2003). The individual plants in each genotype were scored by assigning scores of 0-4 where

0 - Healthy plants

1 - Slight yellowing of leaves.

2 - Yellowing and necrosis of leaves.

3 - Basal swelling, yellowing and necrosis of leaves.

4 - Basal swelling, distortion, yellowing and necrosis of leaves (Total wilting)


**Fig. 1. Score chart**

Percentage disease intensity was calculated by using the modified formula of Chattopadhyay and Sen (1996).

$$\text{Disease intensity} = \frac{\text{Sum total of scores}}{\text{Total number of plants assessed}} \times \frac{100}{\text{Maximum grade}}$$

Genotypes were categorized into five grades namely resistant (0 %), moderately resistant (0-25 %), moderately susceptible (26-50 %), susceptible (51-75 %) and highly susceptible (>76 %)

### 3.2.3 Biometric Observations

Five plants per genotype per replication were selected for recording the biometric observation in Experiment I. The mean value of five observational plants were recorded.

#### *3.2.3.1 Yield Traits*

**Days to 50% flowering**

Number of days taken from sowing to flowering of 50 percent of the plants were recorded.

**Days to first harvest**

Number of days taken from sowing to first harvest was recorded.

**Length of harvest period (days)**

Number of days taken from first harvest to the last harvest were recorded.

**Crop duration (days)**

Number of days taken from sowing to the last harvest were recorded.

**Primary branches per plant**

Number of primary branches were recorded on each observational plant at the time of final harvest.

**Main stem length (cm)**

Length of the vein from the base of the plant to the terminal bud was measured and recorded

**Fresh weight of shoot per plant (g)**

The fresh weight of shoot of observational plants were recorded.

**Dry weight of shoot per plant (g)**

The dry weight of shoot of observational plants were recorded

**Pod clusters per plant**

Number of pod clusters of the observational plants were recorded

**Pods per plant**

Pods obtained in each harvest from each of the observational plants were counted and recorded.

**Pod yield per plant**

Weight of pods from observational plants were recorded after each harvest. Total weight of pods of each observational plant was calculated and recorded.

**Pods per cluster**

Number of pods of each cluster of observational plants was recorded and mean worked out.

**Pod weight (g)**

Weight of five randomly selected individual pods were recorded from each observational plant and mean worked out.

**Pod length (cm)**

Length of five randomly selected individual pods were recorded from each observational plant and mean worked out.

**Pod breadth (cm)**

Breadth of five randomly selected individual pods were recorded from each observational plant and mean worked out.

**Seeds per pod**

Number of seeds of five randomly selected individual pods were recorded from each observational plant and mean worked out.

**Seed colour**

Colour of the seeds from pods of observational plants were recorded.

**100-seed weight (g)**

The weight of100 randomly selected seeds from each observational plant was recorded.

**Fresh weight of roots per plant (g)**

The fresh weight of roots of observational plants were recorded.

**Dry weight of roots per plant (g)**

The dry weight of roots of observational plants were recorded.

**Nodules per plant**

The number of separated nodules from plants uprooted at harvest were recorded.

**Fresh weight of nodules per plant (mg)**

The fresh weight of separated nodules from plants uprooted at harvest were recorded.

**Dry weight of nodules per plant (mg)**

The oven dry weight of separated nodules from plants uprooted at harvest were recorded.

### 3.2.3.2 Biochemical Traits

**Crude fibre content (%)**

Boiled 2g of dried and ground pod with 200 ml of sulfuric acid for 30 minutes with bumping chips. Filtered through muslin and washed with boiling water until washings were no longer acidic Boiled with 200 ml sodium hydroxide solution for 30 minutes, filtered through muslin cloth, washed with 25ml boiling 1.25 per cent sulphuric acid, three 50 ml portions of water and 25 ml alcohol. Removed residue and transferred to ashing dish. Dried the residue for 2 hours at 130 ± 2°C cooled the dish in a dessicator and weighed. Ignited for 30 min at 600 ± 15°C. Cooled in a dessicator and weighed.

**Crude protein content (µg)**

Total soluble protein content was estimated as per the procedure described by Bradford (1976). One g of sample was taken and ground in a pestle and mortar with 10 ml of 0.1 M acetate buffer pH 4.7.The extract was then centrifuged at 5000 rpm at 4°c for 15 minutes. The supernatant was transferred into a test tube and residue was discarded. The reaction mixture contained 0.5 ml of sample extract + 0.5 ml distilled water + 5 ml of dye solution (Coomassie brilliant blue G250). The absorbance was read at 595 nm in a spectrophotometer (Systronics UV-VIS Spectrophotometer 118) against reagent blank. Using BSA standard graph deduced the protein content as albumin equivalent of soluble protein per gram on fresh weight basis.

**Peroxidase**

The procedure described by Srivastava (1987) was used for determining peroxidase activity. Leaf samples (200 mg) were weighed and homogenized in 1ml of 0.1 M Sodium phosphate buffer to which a pinch of PVP was added. The homogenization was done at 4°C. The homogenate was strained using cotton and centrifuged at 5000 rpm for 10 minutes at 4°C. The supernatant was used as the enzyme extract for the assay of peroxidase activity.

The reaction mixture consisting of 1ml of 0.05 M Pyrogallol and 1ml of 1% Hydrogen peroxide was taken in both reference and sample cuvettes, mixed and kept in a spectrophotometer and the reading was adjusted to zero at 420 nm . The enzyme reaction was started by adding 50 µl of enzyme extract into sample cuvettes and change in absorbance was measured at 30 seconds interval up to 180 seconds.

**Poly phenol oxidase**

Poly phenol oxidase activity was determined as per the procedure given by Mayer *et al.* (1965). The enzyme extract is prepared as per the procedure given for the estimation of peroxidase. The reaction mixture contained 1 ml Sodium phosphate buffer pH 6.5 and 1 ml of 0.01 M catechol. The cuvettes were placed in a spectrophotometer (Systronics UV-VIS Spectrophotometer 118) and absorbance was set to zero. The reaction was started after adding 50 µl of enzyme extract. The change in absorbance was recorded at 495 nm and PPO activity was expressed as changes in the absorbance of the reaction mixture per minute per g on fresh weight basis.

**Total Phenols**

Total phenols estimated as per the procedure given by Malick and Singh (1980). Weigh exactly 1g of the sample and grind it with a pestle and mortar in 10 time volume of 80% ethanol. centrifugate the homogenate at 10,000 rpm for 20 minutes. Save the supernatant. Re-extract the residue with five times the volume of 80% ethanol, centrifuge and save the supernatants. Evaporate the supernatant to dryness. Dissolve the residue in a 5ml volume of distilled water, pipette out different aliquots (0.2 to2 ml) into test tubes and make up the volume in each tube to 3 ml with water. Add 0.5 ml of Folin-Ciocalteau reagent. After three minutes add 2 ml of 20 per cent $Na_2CO_3$ solution to each tube. Mix thoroughly place the tubes in a boiling water for exactly one minute, cool and measure the absorbance at 650 nm against a reagent blank. Prepare a standard curve using different concentrations of catechol, from the standard curve find out the concentrations of phenols in the test sample and express as mg phenols/100g material.

### 3.2.4 Statistical Analysis

The data collected were subjected to the following statistical analysis.

3.2.4.1 Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) for randomised block design (RBD) (Panse and Sukhatme, 1985) in respect of the various characters was done.

3.2.4.2 Mean : The arithmetic mean of the $i^{th}$ character $X_i$ was worked out as $\bar{X}_i$

3.2.4.3 *Variance and covariance*

The variance and covariance components were calculated as per the following formulae.

For the character $X_i$,

Environmental variance, $\sigma^2 e_i$ = MSE

Genotypic variance, $\sigma^2 g_i = \dfrac{MST - MSE}{r}$

Phenotypic variance, $\sigma^2 p_i = \sigma^2 g_i + \sigma^2 e_i$

Where, MST and MSE are the mean sum of squares for treatment and error respectively from ANOVA and r is the number of replications. For two characters $X_i$ and $X_j$, the covariance were worked out from the ANCOVA as

Environmental covariance, $\sigma^2 e_{ij}$ = MSPE

Genotypic covariance, $\sigma^2 g_{ij} = \dfrac{MSPT - MSPE}{r}$

Phenotypic covariance, $\sigma^2 p_{ij} = \sigma^2 g_{ij} + \sigma^2 e_{ij}$

Where, MSPT and MSPE are the mean sum of products for treatment and error respectively between $i^{th}$ and $j^{th}$ characters.

### *3.2.4.4 Genetic Parameters*

#### 3.2.4.4.1 Coefficient of variation

The variability in the genotypes for different characters was expressed using the coefficient of variation which is a unit free measurement.

$$\text{Phenotypic coefficient of variation, PCV} = \frac{\sigma p_i}{\bar{X}_i} \times 100$$

$$\text{Genotypic coefficient of variation, GCV} = \frac{\sigma g_i}{\bar{X}_i} \times 100$$

$$\text{Environmental coefficient of variation, ECV} = \frac{\sigma e_i}{\bar{X}_i} \times 100$$

Where, $\sigma p_i$, $\sigma g_i$ and $\sigma e_i$ are the phenotypic, genotypic and environmental standard deviations respectively and $\bar{X}_i$ is the overall mean of the $i^{th}$ character calculated from all varieties.

#### 3.2.4.4.2 Heritability ($H^2$)

Heritability for the chracter in broad sense was calculated as a percentage based on the formula given by Jain (1982).

$$H^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

where $\sigma^2 g$ and $\sigma^2 p$ are the genotypic and phenotypic variance of that character.

Heritability per cent was categorized as suggested by Robinson *et al.* (1949),

| | |
|---|---|
| Low | Below 30 |
| Moderate | 30-60 |
| High | Above 60 |

**3.2.4.4.3 Genetic Advance Under Selection**

Genetic advance as percentage of mean was calculated as per the formula given by Lush (1949).

$$\text{Genetic advance, GA} = \frac{k\, H^2 \sigma p_i}{\bar{X}_i} \times 100$$

Where k is the selection differential (k = 2.06) at five per cent selection intensity (Miller *et al.*, 1958), $H^2$ is heritability in broad sense, $\sigma p_i$ is phenotypic standard deviation and $\bar{X}_i$ is the mean of the character over all varieties.

Genetic advance as percentage were categorized into low (<20 %) and high (>20 %) as suggested by Robinson *et al.* (1949).

***3.2.4.5 Correlation analysis***

The correlation coefficients (phenotypic, genotypic and environmental) between two characters denoted as i and j were worked out as

$$\text{Genotypic correlation } (r_{gij}) = \frac{\sigma g_{ij}}{\sigma g_i \times \sigma g_j}$$

$$\text{Phenotypic correlation } (r_{pij}) = \frac{\sigma p_{ij}}{\sigma p_i \times \sigma p_j}$$

$$\text{Environmental correlation } (r_{eij}) = \frac{\sigma e_{ij}}{\sigma e_i \times \sigma e_j}$$

# Results

Where $\sigma g_{ij}$, $\sigma p_{ij}$ and $\sigma e_{ij}$ are the genotypic, phenotypic and environmental co-variances between the characters i and j. $\sigma g_i$, $\sigma p_i$ and $\sigma e_i$ are the genotypic, phenotypic and environmental standard deviations for the character i and $\sigma g_j$, $\sigma p_j$ and $\sigma e_j$ are the genotypic, phenotypic and environmental standard deviations for the character j.

### *3.2.4.6 Path Coefficient Analysis*

The direct and indirect effect of component character on yield were estimated through path analysis technique (Wright, 1954; Dewey and Lu, 1959).

### *3.2.4.7 Mahalanobis $D^2$ Analysis*

Genetic divergence was studied using Mahalanobis $D^2$ statistic as described by Rao (1952). The genotypes were clustered by Tochers method.

### *3.2.4.8 Selection index*

The various genotypes were discriminated based on nine characters using the selection index developed by Smith (1947) using the discriminant function of Fischer (1936).

The selection index is described by the function $I = b_1x_1 + b_2x_2 + \ldots + b_kx_k$ where $x_1, x_2, \ldots x_k$ are the phenotypic values. Merit of a plant measured in terms of its genetic worth as $H = a_1G_1 + a_2G_2 + \ldots + a_kG_k$ where $G_1, G_2, \ldots G_k$ are the genotypic values of the plant with respect to the characters $X_1, X_2, \ldots X_k$ and $a_1, a_2, \ldots a_k$ are the economic weightages. H denotes the genetic worth of the plant. The economic weightage assigned to each character is assumed to be equal to unity *i e*., $a_1, a_2, \ldots a_k = 1$. The regression coefficients $b_1, b_2, \ldots b_k$ are estimated in such a way that the correlation between H and I is maximum. The procedure will reduce to an equation of the form $b = P^{-1}Ga$, where P is the phenotypic, G is the genotypic variance covariance matrix respectively and a is vector of ones, from which the b values were solved out.

# Results

# 4. RESULTS

The results of the present investigation are presented under two major headings.

i. Evaluation and screening of genotypes for yield and yield components

ii. Screening of genotypes for Fusarium wilt resistance

## 4.1 EVALUATION AND SCREENING OF GENOTYPES FOR YIELD AND YIELD COMPONENTS (Experiment-I)

The performance of 30 genotypes was evaluated for various morphological and yield characters. The recorded observations were statistically analysed and the results are presented below.

### 4.1.1 Mean Performance

The analysis of variance with respect to various characters were worked out and present in Table 2 .It revealed a wide range of variation for all the characters.

The mean value of the 30 genotypes for all the character namely days to 50% flowering, days to first harvest, length of harvest period, crop duration ,primary branches per plant, main stem length , fresh weight of shoot per plant , dry weight of shoot per plant , pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, pod breadth, seeds per pod, seed colour,100-seed weight ,fresh weight of roots per plant ,dry weight of roots per plant ,nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant ,crude fibre content, crude protein content, peroxidase, poly phenol oxidase and total Phenols are presented in Table 3.

The days to 50 per cent flowering was maximum in genotype Vu 29(52.00) and minimum in genotype Vu 25(44.50). Days to first harvest ranged from 50.07 to 59.13 in genotypes Vu 25 and Vu 22 respectively. The days to first harvest was maximum for genotype Vu 22 which was on par with Vu 29, Vu 9,

Table 2. Analysis of variance of various characters in 30 yard long bean genotypes

| Sl. No. | Characters | Mean square | | |
|---|---|---|---|---|
| | | Replication | Genotypes | Error |
| | Degrees of freedom | 2 | 29 | 58 |
| 1 | Days to 50 per cent flowering | 0.52 | 9.28** | 3.10 |
| 2 | Days to first harvest | 1.16 | 14.22** | 2.82 |
| 3 | Length of harvesting period (days) | 13.61 | 22.36** | 6.37 |
| 4 | Crop duration (days) | 14.15 | 15.37** | 2.51 |
| 5 | Primary branches per plant | 0.18 | 0.42** | 0.04 |
| 6 | Main stem length (cm) | 22.33 | 3800.34** | 86.54 |
| 7 | Fresh weight of shoot per plant (g) | 80.40 | 20216.23** | 408.49 |
| 8 | Dry weight of shoot per plant (g) | 26.70 | 1715.82** | 46.17 |
| 9 | Pod clusters per plant | 0.19 | 40.84** | 0.43 |
| 10 | Pods per plant | 1.28 | 42.91** | 0.85 |
| 11 | Pod yield per plant | 136.42 | 1589.71** | 257.68 |
| 12 | Pods per cluster | 0.04 | 0.70** | 0.05 |
| 13 | Pod weight (g) | 0.05 | 34.47** | 0.47 |
| 14 | Pod length (cm) | 6.73 | 82.71** | 3.54 |
| 15 | Pod breadth (cm) | 0.07 | 0.07** | 0.03 |
| 16 | Seeds per pod | 0.04 | 5.39** | 0.34 |
| 17 | 100-seed weight (g) | 0.29 | 12.78** | 0.26 |
| 18 | Fresh weight of roots per plant (g) | 2.16 | 102.10** | 3.21 |
| 19 | Dry weight of roots per plant (g) | 0.21 | 21.86** | 0.30 |
| 20 | Nodules per plant | 0.87 | 26.96** | 1.43 |
| 21 | Fresh weight of nodules per plant (mg) | 82.40 | 2946.87** | 156.54 |
| 22 | Dry weight of nodules per plant (mg) | 5.46 | 185.54** | 9.90 |
| 23 | Crude fibre content (%) | 0.0019 | 0.0719** | 0.0021 |
| 24 | Crude protein content (µg) | 1.14 | 346.26** | 2.71 |
| 25 | Peroxidase | 0.0001 | 0.0264** | 0.0001 |
| 26 | Total phenols | 0.0036 | 2.7206** | 0.0028 |

**Significant at 1 per cent level

Table 3. Varietal differences with respect to various characters

| Genotype | Days to 50 per cent flowering | Days to first harvest | Length of harvesting period (days) | Crop duration (days) | Primary branches per plant | Main stem length (cm) | Fresh weight of shoot per plant (g) | Dry weight of shoot per plant (g) | Pod clusters per plant | Pods per plant | Pod yield per plant | Pods per cluster | Pod weight (g) | Pod length (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vu1 | 45.50 | 50.80 | 32.20 | 83.00 | 4.07 | 519.33 | 686.67 | 185.00 | 7.20 | 6.80 | 110.67 | 1.53 | 16.20 | 36.13 |
| Vu2 | 46.00 | 54.53 | 30.97 | 85.50 | 5.33 | 435.67 | 473.33 | 135.40 | 8.67 | 9.50 | 157.83 | 2.07 | 16.67 | 32.90 |
| Vu3 | 47.00 | 55.00 | 26.00 | 81.00 | 4.47 | 502.67 | 448.33 | 132.10 | 9.33 | 12.80 | 174.00 | 1.73 | 13.60 | 39.57 |
| Vu4 | 46.50 | 56.53 | 28.47 | 85.00 | 4.40 | 484.33 | 648.33 | 180.33 | 8.80 | 12.40 | 311.50 | 2.60 | 25.00 | 51.47 |
| Vu5 | 48.93 | 55.00 | 31.17 | 86.17 | 4.13 | 474.83 | 628.33 | 181.00 | 12.47 | 13.53 | 250.50 | 2.20 | 18.47 | 37.90 |
| Vu6 | 45.83 | 56.00 | 27.00 | 83.00 | 4.20 | 523.33 | 576.67 | 172.17 | 9.53 | 10.20 | 163.00 | 1.87 | 16.27 | 51.00 |
| Vu7 | 47.00 | 57.27 | 26.73 | 84.00 | 4.27 | 530.00 | 576.00 | 175.93 | 8.33 | 8.53 | 112.67 | 2.67 | 13.00 | 42.62 |
| Vu8 | 49.33 | 53.33 | 32.50 | 85.83 | 4.73 | 501.67 | 540.00 | 161.40 | 10.60 | 15.80 | 240.17 | 1.73 | 15.00 | 39.00 |
| Vu9 | 50.33 | 58.53 | 23.47 | 82.00 | 4.00 | 476.00 | 426.67 | 124.67 | 11.80 | 11.40 | 189.17 | 2.87 | 16.60 | 39.87 |
| Vu10 | 49.33 | 56.33 | 28.67 | 85.00 | 4.13 | 521.00 | 585.00 | 175.90 | 15.60 | 13.93 | 258.00 | 2.13 | 18.47 | 36.30 |
| Vu11 | 44.67 | 53.00 | 29.83 | 82.83 | 4.13 | 478.33 | 565.00 | 176.69 | 17.27 | 14.93 | 245.00 | 2.27 | 16.67 | 41.17 |
| Vu12 | 47.00 | 56.00 | 31.00 | 87.00 | 5.07 | 520.00 | 611.67 | 188.92 | 18.67 | 13.00 | 211.33 | 1.27 | 16.20 | 39.17 |
| Vu13 | 47.50 | 55.67 | 27.33 | 83.00 | 4.47 | 462.67 | 415.20 | 125.50 | 8.67 | 12.80 | 207.33 | 2.07 | 16.20 | 43.30 |
| Vu14 | 47.00 | 56.00 | 28.00 | 84.00 | 4.20 | 523.67 | 648.33 | 200.60 | 11.20 | 9.23 | 254.33 | 1.27 | 27.50 | 52.67 |
| Vu15 | 47.00 | 57.00 | 26.33 | 83.33 | 4.47 | 482.33 | 575.00 | 173.75 | 9.60 | 14.13 | 235.00 | 2.33 | 16.67 | 38.83 |
| Vu16 | 47.83 | 58.13 | 30.53 | 88.67 | 4.53 | 578.00 | 609.67 | 186.77 | 17.40 | 16.80 | 421.00 | 1.27 | 24.07 | 43.67 |
| Vu17 | 48.83 | 56.13 | 26.70 | 82.83 | 3.60 | 512.67 | 583.33 | 175.48 | 13.20 | 14.20 | 272.67 | 2.00 | 18.70 | 40.20 |

Table 3 Continued

| Genotype | Days to 50 per cent flowering | Days to first harvest | Length of harvesting period (days) | Crop duration (days) | Primary branches per plant | Main stem length (cm) | Fresh weight of shoot per plant (g) | Dry weight of shoot per plant (g) | Pod clusters per plant | Pods per plant | Pod yield per plant | Pods per cluster | Pod weight (g) | Pod length (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vu18 | 46.33 | 54.67 | 24.17 | 78.83 | 4.20 | 474.33 | 436.67 | 132.09 | 20.67 | 14.13 | 233.50 | 2.00 | 16.53 | 32.47 |
| Vu19 | 48.50 | 57.13 | 24.53 | 81.67 | 4.40 | 531.00 | 538.33 | 165.30 | 15.40 | 19.80 | 370.83 | 2.40 | 18.80 | 44.07 |
| Vu20 | 48.50 | 54.80 | 29.03 | 83.83 | 5.13 | 479.00 | 572.67 | 166.29 | 11.20 | 13.83 | 209.00 | 1.87 | 15.00 | 36.63 |
| Vu21 | 46.50 | 55.73 | 26.43 | 82.17 | 4.07 | 452.67 | 437.50 | 135.90 | 14.60 | 15.93 | 259.00 | 2.53 | 16.20 | 42.66 |
| Vu22 | 48.50 | 59.13 | 26.53 | 85.67 | 4.00 | 511.00 | 536.67 | 158.63 | 12.40 | 15.07 | 211.83 | 1.93 | 14.07 | 43.63 |
| Vu23 | 46.00 | 54.67 | 29.00 | 83.67 | 4.27 | 484.67 | 476.67 | 143.00 | 13.27 | 13.47 | 202.83 | 1.73 | 15.07 | 39.17 |
| Vu24 | 49.50 | 56.13 | 30.03 | 86.17 | 4.20 | 497.00 | 570.00 | 174.10 | 16.40 | 19.93 | 291.17 | 1.87 | 14.87 | 36.20 |
| Vu25 | 44.50 | 50.07 | 30.93 | 81.00 | 4.73 | 520.67 | 518.33 | 160.53 | 8.60 | 9.60 | 130.33 | 1.33 | 13.67 | 33.67 |
| Vu26 | 48.00 | 56.80 | 28.03 | 84.83 | 4.60 | 479.00 | 490.00 | 150.67 | 16.40 | 22.67 | 330.83 | 2.33 | 14.67 | 43.50 |
| Vu27 | 50.67 | 55.67 | 30.83 | 86.50 | 4.47 | 518.00 | 501.67 | 152.87 | 9.27 | 11.67 | 193.33 | 2.47 | 16.67 | 32.83 |
| Vu28 | 47.00 | 55.00 | 34.00 | 89.00 | 4.87 | 587.33 | 738.33 | 225.81 | 8.53 | 9.60 | 143.50 | 1.13 | 15.13 | 36.17 |
| Vu29 | 52.00 | 58.80 | 26.87 | 85.67 | 4.27 | 538.67 | 473.33 | 146.59 | 17.40 | 20.40 | 295.83 | 2.80 | 14.67 | 41.90 |
| Vu30 | 46.67 | 51.27 | 33.57 | 84.83 | 4.13 | 574.33 | 449.33 | 137.77 | 11.60 | 18.13 | 239.67 | 1.47 | 12.73 | 34.93 |
| Mean | 47.61 | 55.50 | 28.70 | 84.20 | 4.38 | 505.81 | 544.57 | 163.37 | 12.47 | 13.81 | 230.86 | 1.99 | 16.78 | 40.12 |
| SE | 1.437 | 1.372 | 2.061 | 1.295 | 0.161 | 7.596 | 16.502 | 5.584 | 0.538 | 0.754 | 13.107 | 0.189 | 0.561 | 1.537 |
| CD | 2.878 | 2.746 | 4.126 | 2.592 | 0.322 | 15.206 | 33.037 | 11.179 | 1.076 | 1.51 | 26.239 | 0.379 | 1.123 | 3.077 |

SE - Standard error of mean
CD - Critical difference at 5 per cent level

Table 3 Continued

| Genotype | Pod breadth (cm) | Seeds per pod | 100-seed weight (g) | Fresh weight of roots per plant (g) | Dry weight of roots per plant (g) | Nodules per plant | Fresh weight of nodules per plant (mg) | Dry weight of nodules per plant (mg) | Crude fibre content (%) | Crude protein content (µg) | Peroxidase | Poly phenol oxidase | Total phenols |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vu1 | 2.51 | 16.27 | 15.34 | 16.60 | 5.84 | 19.50 | 203.80 | 51.27 | 1.84 | 73.33 | 0.039 | 0.0030 | 10.300 |
| Vu2 | 2.49 | 14.27 | 18.69 | 25.00 | 7.13 | 20.17 | 219.90 | 53.01 | 1.95 | 60.33 | 0.316 | 0.0020 | 9.717 |
| Vu3 | 2.50 | 17.20 | 17.52 | 29.33 | 9.33 | 24.83 | 261.17 | 65.21 | 1.75 | 67.67 | 0.031 | 0.0024 | 10.350 |
| Vu4 | 2.76 | 18.33 | 19.69 | 18.67 | 6.25 | 16.67 | 173.33 | 43.86 | 1.70 | 65.00 | 0.104 | 0.0033 | 11.317 |
| Vu5 | 2.54 | 16.20 | 19.59 | 20.27 | 6.25 | 18.50 | 192.40 | 48.57 | 2.06 | 74.33 | 0.055 | 0.0070 | 11.300 |
| Vu6 | 2.39 | 19.93 | 16.66 | 32.23 | 10.58 | 21.17 | 220.13 | 55.56 | 1.87 | 47.67 | 0.125 | 0.0037 | 10.950 |
| Vu7 | 2.35 | 18.07 | 19.76 | 25.57 | 8.65 | 18.50 | 193.57 | 48.56 | 2.08 | 52.00 | 0.084 | 0.0067 | 10.383 |
| Vu8 | 2.48 | 17.53 | 15.12 | 30.83 | 10.80 | 20.83 | 216.67 | 54.69 | 1.98 | 78.33 | 0.126 | 0.0060 | 10.667 |
| Vu9 | 2.68 | 16.67 | 17.05 | 22.57 | 7.81 | 19.17 | 199.33 | 50.45 | 1.85 | 65.00 | 0.025 | 0.0067 | 10.600 |
| Vu10 | 2.62 | 16.67 | 18.75 | 20.07 | 8.25 | 17.83 | 186.73 | 46.81 | 2.00 | 68.00 | 0.086 | 0.0037 | 10.550 |
| Vu11 | 2.39 | 14.27 | 16.95 | 21.60 | 7.59 | 19.67 | 204.47 | 51.76 | 1.74 | 58.67 | 0.214 | 0.0020 | 8.817 |
| Vu12 | 2.78 | 15.60 | 16.78 | 25.17 | 8.87 | 17.83 | 185.47 | 46.86 | 2.16 | 52.00 | 0.209 | 0.0063 | 9.117 |
| Vu13 | 2.34 | 18.53 | 18.34 | 19.97 | 6.73 | 17.83 | 185.47 | 46.89 | 1.95 | 46.67 | 0.188 | 0.0037 | 9.517 |
| Vu14 | 2.97 | 16.83 | 20.89 | 21.60 | 9.43 | 20.67 | 214.93 | 54.25 | 2.15 | 55.00 | 0.025 | 0.0033 | 11.333 |
| Vu15 | 2.52 | 17.40 | 20.29 | 24.67 | 9.35 | 25.33 | 263.83 | 66.57 | 2.10 | 58.00 | 0.105 | 0.0043 | 8.783 |
| Vu16 | 2.63 | 19.53 | 18.04 | 32.17 | 10.20 | 23.50 | 244.40 | 61.69 | 1.86 | 45.00 | 0.118 | 0.0013 | 11.133 |
| Vu17 | 2.50 | 16.27 | 17.09 | 20.17 | 6.90 | 17.67 | 183.73 | 46.38 | 1.90 | 53.00 | 0.076 | 0.0017 | 11.367 |

Table 3 Continued

| Genotype | Pod breadth (cm) | Seeds per pod | 100-seed weight (g) | Fresh weight of roots per plant (g) | Dry weight of roots per plant (g) | Nodules per plant | Fresh weight of nodules per plant (mg) | Dry weight of nodules per plant (mg) | Crude fibre content (%) | Crude protein content (µg) | Peroxidase | Poly phenol oxidase | Total phenols |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vu18 | 2.33 | 15.40 | 12.68 | 17.63 | 6.20 | 17.17 | 178.53 | 45.11 | 1.72 | 80.00 | 0.311 | 0.0036 | 11.333 |
| Vu19 | 2.58 | 16.53 | 19.11 | 24.83 | 8.61 | 20.83 | 216.67 | 54.69 | 2.01 | 84.00 | 0.201 | 0.0043 | 9.233 |
| Vu20 | 2.67 | 15.93 | 14.31 | 21.67 | 6.60 | 19.67 | 204.53 | 51.63 | 2.23 | 60.00 | 0.173 | 0.0057 | 8.950 |
| Vu21 | 2.77 | 18.47 | 19.48 | 20.20 | 6.40 | 17.83 | 185.60 | 46.81 | 1.87 | 64.67 | 0.387 | 0.0035 | 11.333 |
| Vu22 | 2.55 | 17.07 | 21.15 | 42.67 | 20.33 | 28.50 | 296.40 | 74.84 | 2.11 | 74.00 | 0.100 | 0.0023 | 10.500 |
| Vu23 | 2.68 | 17.30 | 17.61 | 32.50 | 10.00 | 26.33 | 273.85 | 69.13 | 1.86 | 65.00 | 0.034 | 0.0020 | 9.417 |
| Vu24 | 2.45 | 17.80 | 17.50 | 25.00 | 7.50 | 20.17 | 209.73 | 52.94 | 1.94 | 69.33 | 0.121 | 0.0045 | 11.033 |
| Vu25 | 2.35 | 16.87 | 14.94 | 15.00 | 5.93 | 16.50 | 171.60 | 43.31 | 1.80 | 68.00 | 0.094 | 0.0020 | 9.200 |
| Vu26 | 2.41 | 18.27 | 20.25 | 20.00 | 6.93 | 22.00 | 228.80 | 57.75 | 2.15 | 76.00 | 0.228 | 0.0023 | 11.317 |
| Vu27 | 2.65 | 15.40 | 18.20 | 20.20 | 6.83 | 17.67 | 183.73 | 46.38 | 2.05 | 54.00 | 0.235 | 0.0042 | 9.250 |
| Vu28 | 2.34 | 16.33 | 17.17 | 27.83 | 8.92 | 21.17 | 220.13 | 55.56 | 1.82 | 60.00 | 0.024 | 0.0150 | 9.117 |
| Vu29 | 2.47 | 17.87 | 18.37 | 23.33 | 7.23 | 18.00 | 187.20 | 47.25 | 2.26 | 82.00 | 0.110 | 0.0060 | 11.050 |
| Vu30 | 2.43 | 16.47 | 14.91 | 26.47 | 7.33 | 22.67 | 235.73 | 59.50 | 1.89 | 59.67 | 0.094 | 0.0050 | 8.817 |
| Mean | 2.54 | 16.98 | 17.74 | 24.13 | 8.29 | 20.27 | 210.96 | 53.24 | 1.96 | 63.89 | 0.135 | 0.0040 | 10.225 |
| SE | 0.142 | 0.479 | 0.419 | 1.463 | 0.451 | 0.976 | 10.22 | 2.57 | 0.04 | 1.34 | 0.006 | 0.0005 | 0.123 |
| CD | 0.283 | 0.959 | 0.839 | 2.93 | 0.902 | 1.955 | 20.45 | 5.14 | 0.07 | 2.69 | 0.013 | 0.0010 | 0.247 |

SE - Standard error of mean
CD - Critical difference at 5 per cent level

Vu 16, Vu 7, Vu 19, Vu 15, Vu 26 and Vu 4, while the minimum was for genotype Vu 25 which was on par with Vu 30 and Vu 1.

The maximum length of harvest period was noted for genotype Vu 28 (34) and the minimum was for genotype Vu 9 (23.47).

The maximum crop duration was seen in genotype Vu 28 (89), which was on par with Vu 16, Vu 12 and Vu 27. Minimum crop duration seen in genotype Vu 18 (78.83) which was on par with Vu 25 and Vu 3.

Number of primary branches per plant was the highest for genotype Vu 2 (5.33), which was on par with Vu 20 and Vu 12 and the lowest for genotype Vu 17 (3.6).

Main stem length was the highest for genotype Vu 28 (587.33), which was on par with Vu 16 and Vu 30 and the lowest for genotype Vu 2 (435.67).

Maximum fresh weight of shoot per plant was seen for genotype Vu 28 (738.33), the minimum for Vu 13 (415.20), which was on par with Vu3, Vu 9, Vu 18 and Vu 21.

Dry weight of shoot per plant was highest for genotype Vu 28 (225.81), the lowest for Vu 9 (124.67), which was on par with Vu 13, Vu 3 and Vu 18.

The genotype Vu 18 recorded the maximum pod clusters per plant (20.67) and the minimum was for Vu 1 (7.2). Pods per plant was highest in genotype Vu 26 (22.67) and lowest in Vu 1 (6.8).

The pod yield per plant ranged from 110.67 (Vu 1) to 421 (Vu 16). Significantly higher pod yield in comparison to other varieties was recorded by the top yielder Vu 16, the lowest pod yield was for Vu 1, which was on par with Vu 7 and Vu 25.

Highest number of pods per cluster was seen for genotype Vu 9 (2.87) which was on par with Vu 29, Vu 7, Vu 4 and Vu 21and the lowest for Vu 28 (1.13) which was on par with Vu 16, Vu 14, Vu 12, Vu 25 and Vu 30.

Pod weight was maximum for genotype Vu 14 (27.5) and the minimum for Vu 30 (12.73) which was on par with Vu 7, Vu 25 and Vu 3.

Pod length was highest for genotype Vu 14 (52.67), which was on par with Vu 4 and Vu 6 and the lowest pod length was for Vu 18 (32.47), which was on par with Vu 27, Vu 2, Vu 25 and Vu 30. Pod breadth was maximum in genotype Vu 14 (2.97) and minimum in Vu 18 (2.33).

Seeds per pod was highest in genotype Vu 6 (19.93) which was on par with Vu16 and lowest in Vu 2 and Vu 11 (14.27). The variation in seed colour presented in the Table 4 and Plate 9. Among the genotypes eleven genotype seeds were black in colour, eight were variegated with brown and white colour, seven were dark brown colour and two were light brown colour. Brown and brown with white tip seed colour in single genotype each.

Maximum 100 seed weight was noted in genotype Vu 22 (21.15) which was on par with Vu 14 while Vu 18 had the minimum (12.68).

Highest fresh weight of roots per plant was seen in genotype Vu 22 (42.67), the lowest in Vu 25 (15) which was on par with Vu 1 and Vu 18.

Dry weight of roots per plant was highest for genotype Vu 22 (20.33) and the lowest in Vu 1 (5.84), which was on par with Vu 25, Vu 18, Vu 4, Vu 5, Vu 21, Vu 20 and Vu 13.

Nodules per plant was highest in genotype Vu 22 (28.5) and lowest in Vu 25 (16.5), which was on par with Vu 29. A range of 171.60 (Vu 25) to 296.40 (Vu 22) was observed for fresh weight of nodules per plant. Highest dry weight of nodules per plant was noted in genotype Vu 22 (74.84) and the lowest in Vu 25 (43.31).

A wide range of crude fibre content was noticed among the genotypes studied. The highest value was for genotype Vu 29 (2.26) which was on par with Vu 20. The lowest crude fibre content was for genotype Vu 4(1.70), which was on par with Vu 3, Vu 4 and Vu 11.

Table 4. Seed colour

| Sl. No. | Accession No. | Varieties | Seed colour |
|---|---|---|---|
| 1 | Vu1 | Kayamkulam local | Black |
| 2 | Vu2 | Malappuram local-2 | Variegated with brown and white colour |
| 3 | Vu3 | Ookodu local-1 | Variegated with brown and white colour |
| 4 | Vu4 | Thiruvananthapuram local-1 | Dark brown |
| 5 | Vu5 | Sarika | Black |
| 6 | Vu6 | Thiruvananthapuram local-4 | Dark brown |
| 7 | Vu7 | Kollengode local | Black |
| 8 | Vu8 | Vaijayanthi | Black |
| 9 | Vu9 | KMV-1 | Dark brown |
| 10 | Vu10 | Thiruvananthapuram local-3 | Light brown |
| 11 | Vu11 | Malappuram local-1 | Dark brown |
| 12 | Vu12 | Kalliyoor local | Variegated with brown and white colour |
| 13 | Vu13 | Kuttichal local | Variegated with brown and white colour |
| 14 | Vu14 | VS27 | Light brown |
| 15 | Vu15 | Palapoor local-3 | Black |
| 16 | Vu16 | VS86 | Black |
| 17 | Vu17 | Vellayani local | Variegated with brown and white colour |
| 18 | Vu18 | CPCH-1 | Dark brown |
| 19 | Vu19 | Vella valli payar | Dark brown |
| 20 | Vu20 | Palapoor local-2 | Variegated with brown and white colour |
| 21 | Vu21 | Varuvila local-1 | Black |
| 22 | Vu22 | Thiruvananthapuram local-2 | Black |
| 23 | Vu23 | Ookodu local-2 | Variegated with brown and white colour |
| 24 | Vu24 | Malika | Brown with white tip |
| 25 | Vu25 | Palakkad local | Black |
| 26 | Vu26 | Varuvila local-2 | Variegated with brown and white colour |
| 27 | Vu27 | Thrissur local | Dark brown |
| 28 | Vu28 | Kasargode local | Black |
| 29 | Vu29 | Palapoor local-1 | Brown |
| 30 | Vu30 | Lola | Black1 |

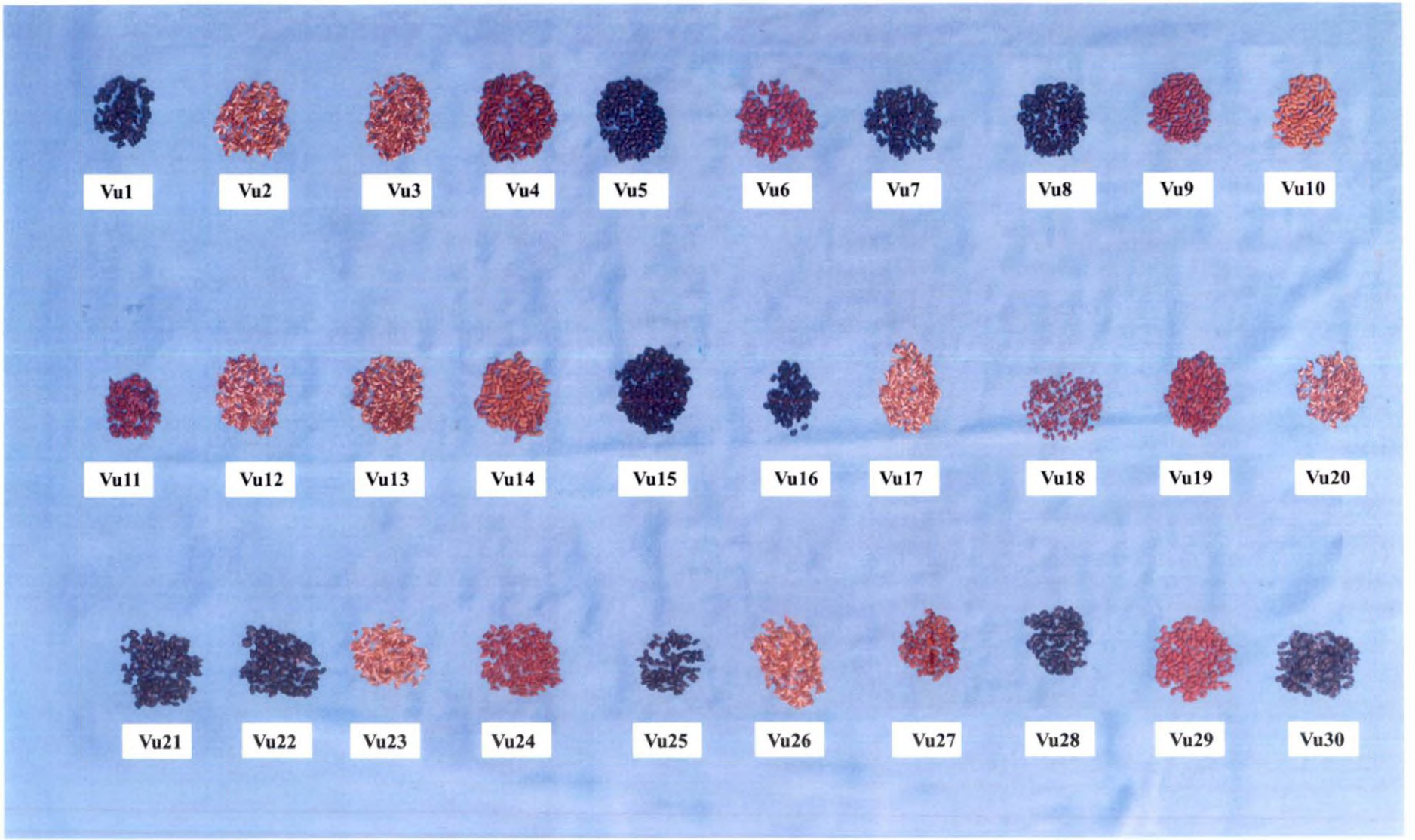



Plate 9. Variation in seed colour

The crude protein content among the genotypes ranged from 45 to 84. Vu 19 recorded the highest protein content (84) and Vu 29 was on par with it, while the least value was observed for Vu 16 (45) which was on par with Vu 6 and Vu 13.

The highest peroxidase content was observed for genotype Vu 21 (0.387), least peroxidase content for Vu 28 (0.024), which was on par with Vu 23, Vu 3, Vu 14 and Vu 9.

The poly phenol oxidase activity showed wide variation. The highest value was observed for genotype Vu 28 (0.0150). The lowest poly phenol oxidase value was noticed for Vu 16 (0.0013), which was on par with Vu17, Vu2, Vu11, Vu23,Vu25, Vu22 and Vu26.

Vu 17 (11.367) recorded a high value of total phenols, which was on par with Vu 14, Vu 18,Vu16, Vu 21, Vu 4, Vu 26 and Vu 5. The lowest total phenols value was observed for Vu 15 (8.783) which was on par with Vu 11, Vu 30 and Vu 20.

### 4.1.2 Genetic Parameters

The phenotypic, genotypic and environmental variances for the various characters have been calculated and presented. Estimates of variance showed that for all the characters, genetic variance makes up the major part of the phenotypic variance with very little contribution by the environment.

#### *4.1.2.1 Coefficient of Variation*

The phenotypic coefficient of variation, genotypic coefficient of variation and environmental coefficient of variation were worked out. The environmental coefficient of variation values are not exhibit much variation. The PCV and GCV of the characters are given in the Table 5 and Fig. 2.

##### 4.1.2.1.1 Phenotypic Coefficient of Variation (PCV)

The PCV was maximum for dry weight of roots per plant (33.00). The pod yield per plant (31.64), pod clusters per plant (29.9), pods per plant (27.93) and pods per cluster (26.11) also had high PCV indicating a high degree of variation. PCV was very less for crop duration (3.10) and days to first harvest (4.64).

Table 5. Estimates of genetic parameters with respect to yield and selected characters in 30 genotypes of yard long bean

| Sl. No. | Characters | Variance | | | Coefficient of variation (%) | | Heritability as % ($H^2$) | Genetic advance as % of mean |
|---|---|---|---|---|---|---|---|---|
| | | $\sigma_g^2$ | $\sigma_p^2$ | $\sigma_e^2$ | PCV | GCV | | |
| | **Yield traits** | | | | | | | |
| 1 | Daysto50 per cent flowering | 2.06 | 5.16 | 3.10 | 4.77 | 3.02 | 39.94 | 3.93 |
| 2 | Days to first harvest | 3.80 | 6.62 | 2.82 | 4.64 | 3.51 | 57.37 | 5.48 |
| 3 | Length of harvest period (days) | 5.33 | 11.70 | 6.37 | 11.92 | 8.05 | 45.55 | 11.19 |
| 4 | Crop duration (days) | 4.29 | 6.80 | 2.52 | 3.10 | 2.46 | 63.02 | 4.02 |
| 5 | Primary branches per plant | 126.00 | 0.17 | 0.04 | 9.27 | 8.11 | 76.47 | 14.61 |
| 6 | Main stem length (cm) | 1237.93 | 1324.48 | 86.54 | 7.20 | 6.96 | 93.47 | 13.85 |
| 7 | Fresh weight of shoot per plant | 6602.58 | 7011.07 | 408.49 | 15.38 | 14.92 | 94.17 | 29.83 |
| 8 | Dry weight of shoot per plant (g) | 556.35 | 603.12 | 46.77 | 15.03 | 14.44 | 92.25 | 28.57 |
| 9 | Pod clusters per plant | 13.47 | 13.90 | 0.43 | 29.90 | 29.43 | 96.88 | 59.68 |
| 10 | Pods per plant | 14.02 | 14.87 | 0.85 | 27.93 | 27.12 | 94.26 | 54.24 |
| 11 | Pod yield per plant | 5077.34 | 5335.02 | 257.68 | 31.64 | 30.87 | 95.17 | 62.03 |
| 12 | Pods per cluster | 0.22 | 0.27 | 0.05 | 26.11 | 23.37 | 80.10 | 43.08 |
| 13 | Pod weight (g) | 11.33 | 11.81 | 0.47 | 20.48 | 20.06 | 96.00 | 40.50 |

Table 5. Continued

| Sl. No. | Characters | Variance | | | Coefficient of variation (%) | | Heritability as % ($H^2$) | Genetic advance as % of mean |
|---|---|---|---|---|---|---|---|---|
| | | $\sigma_g^2$ | $\sigma_p^2$ | $\sigma_e^2$ | PCV | GCV | | |
| | **Yield traits** | | | | | | | |
| 14 | Pod length (cm) | 26.39 | 29.93 | 3.54 | 13.64 | 12.80 | 88.16 | 24.77 |
| 15 | Pod breadth (cm) | 0.02 | 0.05 | 0.03 | 8.36 | 4.82 | 33.21 | 5.72 |
| 16 | Seeds per pod | 1.68 | 2.03 | 0.34 | 8.38 | 7.64 | 83.02 | 14.34 |
| 17 | 100-seed weight (g) | 4.17 | 4.43 | 0.26 | 11.87 | 11.51 | 94.06 | 23.00 |
| 18 | Fresh weight of roots per plant (g) | 32.94 | 36.18 | 3.21 | 24.93 | 23.80 | 91.12 | 46.79 |
| 19 | Dry weight of roots per plant (g) | 7.19 | 7.49 | 0.31 | 33.00 | 32.32 | 95.93 | 65.22 |
| 20 | Nodules per plant | 8.51 | 9.94 | 1.43 | 15.55 | 14.39 | 85.62 | 27.43 |
| 21 | Fresh weight of nodules per plant (mg) | 930.11 | 1086.65 | 156.54 | 15.63 | 14.46 | 85.59 | 27.55 |
| 22 | Dry weight of nodules per plant (mg) | 58.55 | 68.45 | 9.9 | 15.54 | 14.37 | 85.54 | 27.38 |
| | **Bio chemical traits** | | | | | | | |
| 23 | Crude fibre content (%) | 0.023 | 0.025 | 0.002 | 8.15 | 7.80 | 91.82 | 15.41 |
| 24 | Crude protein content (µg) | 114.517 | 117.225 | 2.708 | 16.95 | 16.75 | 97.69 | 34.10 |
| 25 | Total phenols | 0.899 | 0.922 | 0.023 | 9.39 | 9.27 | 97.52 | 18.87 |

#### 4.1.2.1.2 Genotypic Coefficient of Variation (GCV)

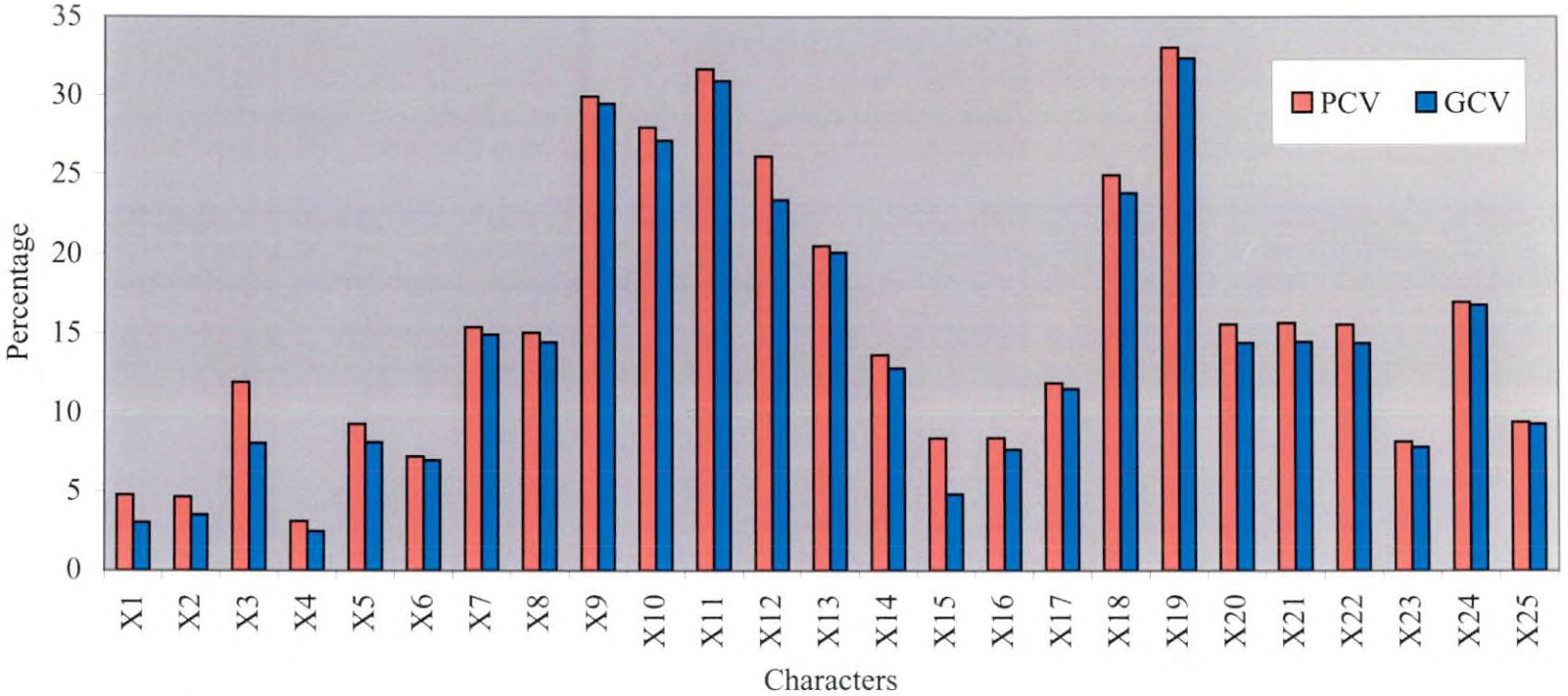
Crop duration and days to 50 per cent flowering had less GCV of 2.46 and 3.02 respectively. The highest value of GCV was observed for dry weight of roots per plant (32.32) , pod yield per plant (30.87), pod clusters per plant (29.43), pods per plant (27.12) and pods per cluster (23.37) also recorded high values.

### *4.1.2.2 Heritability (broad sense)*

The heritability estimate recorded for the various characters are given in Table 5 and Fig. 3. Very high heritability estimate was observed for pod clusters per plant (96.88 %). According to the classification suggested by Robinson *et al.* (1949) in this work crop duration, primary branches per plant, main stem length, fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, seeds per pod, 100-seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant and dry weight of nodules per plant had high heritability estimates. Days to 50 per cent flowering, days to first harvest, length of harvest period and pod breadth had moderate heritability, the least heritability was for pod breadth (33.21). Biochemical characters viz., crude fibre content (91.82), crude protein content (97.69) and total phenols (97.52) recorded very high heritability estimates.

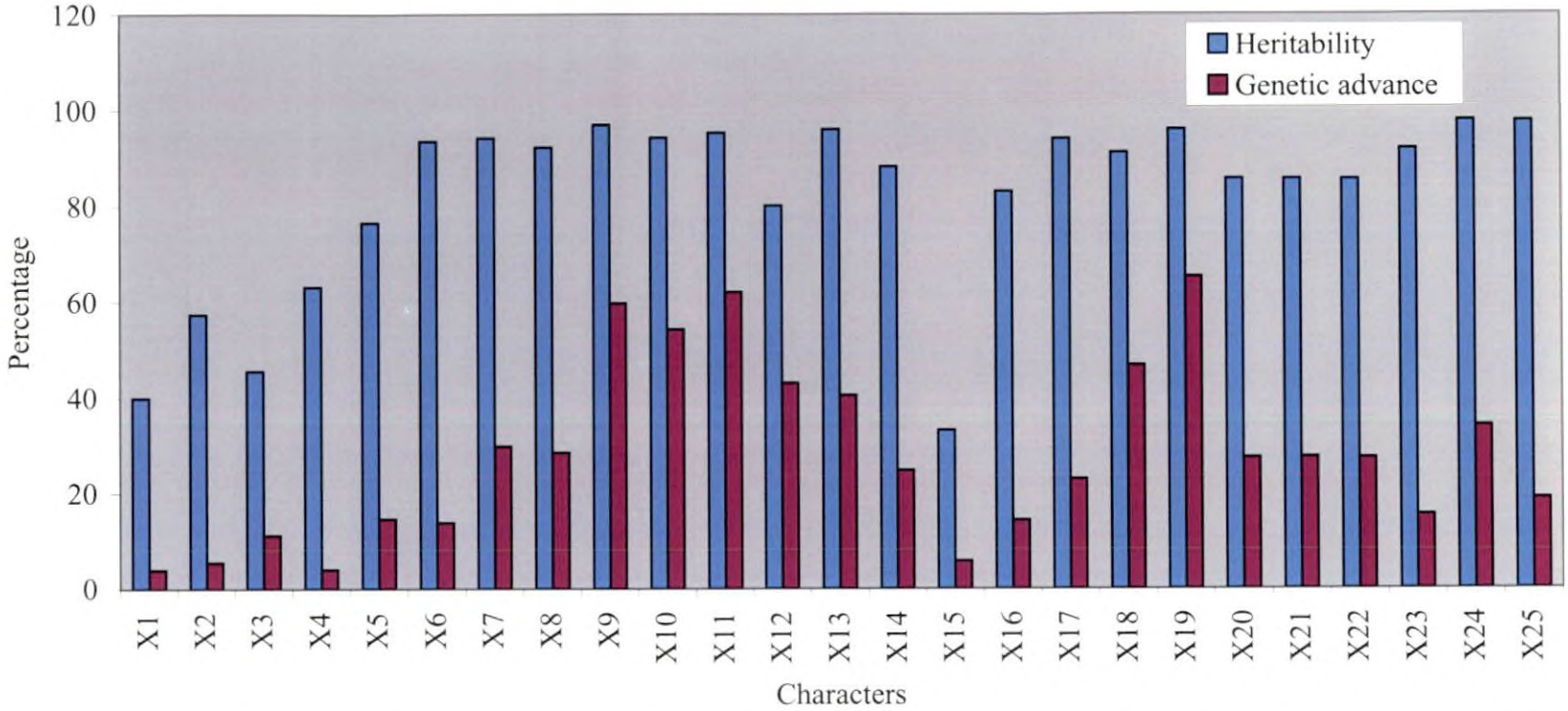
### *4.1.2.3 Genetic Advance (as % of mean)*

The genetic advance estimates of the various characters as percentage of mean is given in Table 5 and Fig. 3. The highest estimates of genetic advance was observed for dry weight of roots per plant (65.22 %). According to the classification of Robinson *et al.* (1949) fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, 100-seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant and dry weight of nodules per plant had high genetic advance, while days to 50 per cent flowering, days to first harvest, length of harvest period, crop duration,




| | | | | | |
|---|---|---|---|---|---|
| X1 | Daysto50 per cent flowering | X10 | Pods per plant | X19 | Dry weight of roots per plant (g) |
| X2 | Days to first harvest | X11 | Pod yield per plant | X20 | Nodules per plant |
| X3 | Length of harvest period (days) | X12 | Pods per cluster | X21 | Fresh weight of nodules per plant (mg) |
| X4 | Crop duration (days) | X13 | Pod weight (g) | X22 | Dry weight of nodules per plant (mg) |
| X5 | Primary branches per plant | X14 | Pod length (cm) | X23 | Crude fibre content (%) |
| X6 | Main stem length (cm) | X15 | Pod breadth (cm) | X24 | Crude protein content (µg) |
| X7 | Fresh weight of shoot per plant | X16 | Seeds per pod | X25 | Total phenols |
| X8 | Dry weight of shoot per plant (g) | X17 | 100-seed weight (g) | | |
| X9 | Pod clusters per plant | X18 | Fresh weight of roots per plant (g) | | |

**Fig. 2. Phenotypic and genotypic coefficients of variation for the various characters in 30 yard long bean genotypes**




| | | | | | |
|---|---|---|---|---|---|
| X1 | Daysto50 per cent flowering | X10 | Pods per plant | X19 | Dry weight of roots per plant (g) |
| X2 | Days to first harvest | X11 | Pod yield per plant | X20 | Nodules per plant |
| X3 | Length of harvest period (days) | X12 | Pods per cluster | X21 | Fresh weight of nodules per plant (mg) |
| X4 | Crop duration (days) | X13 | Pod weight (g) | X22 | Dry weight of nodules per plant (mg) |
| X5 | Primary branches per plant | X14 | Pod length (cm) | X23 | Crude fibre content (%) |
| X6 | Main stem length (cm) | X15 | Pod breadth (cm) | X24 | Crude protein content (µg) |
| X7 | Fresh weight of shoot per plant | X16 | Seeds per pod | X25 | Total phenols |
| X8 | Dry weight of shoot per plant (g) | X17 | 100-seed weight (g) | | |
| X9 | Pod clusters per plant | X18 | Fresh weight of roots per plant (g) | | |

**Fig. 3. Heritability and genetic advance for the various characters in 30 yard long bean genotypes**

primary branches per plant, main stem length, pod breadth and seeds per pod had low genetic advance. The lowest genetic advance was observed for days to 50 per cent flowering (3.93%). Among the biochemical characters crude protein content recorded high genetic advance (34.10) while crude fibre content (15.41) and total phenols (18.87) had low genetic advance.

High heritability coupled with high genetic advance was observed for fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, 100 seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant and crude protein content.

### 4.1.3 Correlation Studies

The phenotypic, genotypic and environmental correlations among the various characters were estimated. The results of the correlation analysis are presented under the following subtitles.

a) Correlation between yield and other characters

b) Correlation among the yield components

#### *4.1.3. 1 Correlation between Yield and other Characters*

The phenotypic, genotypic and environmental correlation coefficients of yield with other characters are presented in Table 6.

The phenotypic correlation was found to be highly significant and positive for days to first harvest (0.3598), pod clusters per plant (0.6046), pods per plant (0.7789), pod weight (0.4732) and seeds per pod (0.3015). All the characters except length of harvest period, primary branches per plant and fresh weight of shoot per plant recorded positive correlation with pod yield.

Pods per plant had the highest significant positive genotypic correlation with pod yield per plant (0.7709) followed by pod clusters per plant (0.6412), days to first harvest (0.5008), pod weight (0.4829), days to 50% flowering

**Table 6 Phenotypic, genotypic and environmental correlation coefficients between green pod yield per plant and other characters**

| Sl. No | Characters | Correlation coefficient | | |
|---|---|---|---|---|
| | | Phenotypic | Genotypic | Environmental |
| 1 | Days to 50 per cent flowering | 0.2614 | 0.4523** | -0.1023 |
| 2 | Days to first harvest | 0.3598** | 0.5008** | -0.0723 |
| 3 | Length of harvest period (days) | -0.1423 | -0.2140 | -0.0084 |
| 4 | Crop duration (days) | 0.1684 | 0.2329 | -0.0895 |
| 5 | Primary branches per plant | -0.1349 | -0.1671 | 0.0724 |
| 6 | Main stem length (cm) | 0.0221 | 0.0418 | -0.0133 |
| 7 | Fresh weight of shoot per plant (g) | -0.0203 | -0.0119 | -0.1714 |
| 8 | Dry weight of shoot per plant (g) | 0.0445 | 0.0544 | -0.1053 |
| 9 | Pod clusters per plant | 0.6046** | 0.6412** | -0.2870* |
| 10 | Pods per plant | 0.7789** | 0.7709** | 0.9247** |
| 11 | Pods per cluster | 0.1320 | 0.1673 | -0.1433 |
| 12 | Pod weight (g) | 0.4732** | 0.4829** | 0.2621 |
| 13 | Pod length (cm) | 0.3211 | 0.3584** | -0.0944 |
| 14 | Pod breadth (cm) | 0.2437 | 0.3412* | 0.2886* |
| 15 | Seeds per pod | 0.3015* | 0.3790** | 0.0727 |
| 16 | 100-seed weight (g) | 0.2664 | 0.2887* | -0.1267 |
| 17 | Fresh weight of roots per plant (g) | 0.0316 | 0.0414 | -0.1055 |
| 18 | Dry weight of roots per plant (g) | 0.0074 | 0.0055 | 0.0475 |
| 19 | Crude fibre content (%) | 0.1229 | 0.1390 | -0.1116 |
| 20 | Crude protein content (µg) | 0.1686 | 0.1779 | -0.0886 |
| 21 | Total phenols | 0.3394 | 0.3555** | -0.0898 |

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

(0.4523), seeds per pod (0.379), pod length (0.3584), pod breadth (0.3412), 100-seed weight (0.2887) and total phenols (0.3555). The genotypic correlation of yield with all the characters except length of harvest period, primary branches per plant and fresh weight of shoot per plant were found to be positive. While considering the environmental correlation of yield with other characters pods per plant (0.9247) had the highest significant positive correlation with yield followed by pod breadth (0.2886) whereas pod clusters per plant showed significant negative correlation (-0.2870). Primary branches per plant, pod weight, pod breadth, seeds per pod and dry weight of roots per plant also recorded positive correlation with pod yield.

### *4.1.3.2 Correlation among the Major Yield Components*

The phenotypic, genotypic and environmental correlations among the various yield components were studied and the coefficients are given in Tables 7, 8 and 9.

**Days to 50% Flowering**

At phenotypic level significant positive phenotypic correlation was observed with days to first harvest (0.7049), pods per plant (0.3149), pods per cluster (0.2954) and crude fibre content (0.4205) while length of harvest period (-0.3797) recorded significant negative correlation. Genotypic correlation was significant and positive with days to first harvest (0.4703), crop duration (0.4913), main stem length (0.4222), pods per plant (0.5568), pods per cluster (0.5342), pod clusters per plant (0.2741),crude fibre content (0.6583), crude protein (0.3113) and total phenols (0.3285) while seeds per pod showed significant negative correlation (-0.3065). Days to first harvest recorded high significant positive environmental correlation (0.9485) while length of harvest period (-0.6967) recorded significant negative correlation.

**Days to first harvest**

Days to first harvest showed significant positive phenotypic correlation with days to 50% flowering (0.7049), pods per cluster (0.3607), pod length

Characters

| | |
|---|---|
| $X_1$ | Days to 50 per cent flowering |
| $X_2$ | Days to first harvest |
| $X_3$ | Length of harvesting period (days) |
| $X_4$ | Crop duration (days) |
| $X_5$ | Primary branches per plant |
| $X_6$ | Main stem length (cm) |
| $X_7$ | Fresh weight of shoot per plant (g) |
| $X_8$ | Dry weight of shoot per plant (g) |
| $X_9$ | Pod clusters per plant |
| $X_{10}$ | Pods per plant |
| $X_{11}$ | Pods per cluster |
| $X_{12}$ | Pod weight (g) |
| $X_{13}$ | Pod length (cm) |
| $X_{14}$ | Pod breadth (cm) |
| $X_{15}$ | Seeds per pod |
| $X_{16}$ | 100-seed weight (g) |
| $X_{17}$ | Fresh weight of roots per plant (g) |
| $X_{18}$ | Dry weight of roots per plant (g) |
| $X_{19}$ | Crude fibre content (%) |
| $X_{20}$ | Crude protein content (μg) |
| $X_{21}$ | Total phenols |

Table 7. Estimates of phenotypic correlation coefficients among the yield components in yard long bean

| Character | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $X_{19}$ | $X_{20}$ | $X_{21}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1.0000 | | | | | | | | | | | | | | | | | | | | |
| $X_2$ | 0.7049 | 1.0000 | | | | | | | | | | | | | | | | | | | |
| $X_3$ | -0.3797 | -0.6545 | 1.0000 | | | | | | | | | | | | | | | | | | |
| $X_4$ | 0.1976 | 0.1282 | 0.6659 | 1.0000 | | | | | | | | | | | | | | | | | |
| $X_5$ | -0.1060 | -0.1234 | 0.2729 | 0.2362 | 1.0000 | | | | | | | | | | | | | | | | |
| $X_6$ | 0.1793 | 0.1087 | 0.0251 | 0.1403 | -0.1887 | 1.0000 | | | | | | | | | | | | | | | |
| $X_7$ | -0.0984 | -0.0406 | 0.3439 | 0.4110 | 0.0546 | 0.1505 | 1.0000 | | | | | | | | | | | | | | |
| $X_8$ | -0.0786 | 0.0045 | 0.3137 | 0.4159 | 0.0601 | 0.1917 | 0.9608 | 1.0000 | | | | | | | | | | | | | |
| $X_9$ | 0.1686 | 0.2441 | -0.1704 | 0.0172 | -0.1485 | 0.0120 | -0.1712 | -0.0640 | 1.0000 | | | | | | | | | | | | |
| $X_{10}$ | 0.3149 | 0.2479 | -0.1211 | 0.0857 | -0.1038 | -0.0571 | -0.3261 | -0.2379 | 0.6359 | 1.0000 | | | | | | | | | | | |
| $X_{11}$ | 0.2954 | 0.3607 | -0.4413 | -0.2230 | -0.2438 | -0.1523 | -0.3654 | -0.3877 | 0.0764 | 0.2186 | 1.0000 | | | | | | | | | | |
| $X_{12}$ | -0.0464 | 0.1838 | -0.0395 | 0.1296 | -0.1175 | 0.0578 | 0.4173 | 0.4028 | 0.0491 | -0.1434 | -0.1131 | 1.0000 | | | | | | | | | |
| $X_{13}$ | -0.0252 | 0.3850 | -0.2894 | 0.0002 | -0.2684 | 0.0610 | 0.1971 | 0.2087 | -0.0276 | 0.0401 | 0.1108 | 0.5077 | 1.0000 | | | | | | | | |
| $X_{14}$ | 0.1726 | 0.2537 | -0.1106 | 0.1051 | 0.0619 | 0.0581 | 0.1136 | 0.1023 | 0.0609 | -0.0208 | -0.0637 | 0.4756 | 0.2594 | 1.0000 | | | | | | | |
| $X_{15}$ | -0.2253 | 0.0307 | -0.0441 | -0.0275 | -0.2386 | -0.0557 | -0.0099 | 0.0244 | 0.2199 | 0.2054 | 0.0973 | 0.1583 | 0.4433 | -0.1293 | 1.0000 | | | | | | |
| $X_{16}$ | 0.1644 | 0.5250 | -0.1976 | 0.2588 | -0.1230 | -0.0965 | 0.1266 | 0.1499 | -0.0823 | 0.1068 | 0.3357 | 0.3234 | 0.5039 | 0.2606 | 0.1639 | 1.0000 | | | | | |
| $X_{17}$ | 0.0879 | 0.3222 | -0.0242 | 0.2861 | 0.0415 | 0.1656 | 0.0062 | 0.0365 | -0.0048 | 0.1236 | -0.2071 | -0.1588 | 0.2005 | 0.0137 | 0.1191 | 0.2051 | 1.0000 | | | | |
| $X_{18}$ | 0.0916 | 0.3570 | -0.1202 | 0.1946 | -0.0796 | 0.1618 | 0.0726 | 0.1053 | -0.0031 | 0.0522 | -0.1565 | -0.0540 | 0.2745 | 0.0689 | 0.0765 | 0.3392 | 0.8663 | 1.0000 | | | |
| $X_{19}$ | 0.4205 | 0.3448 | -0.0153 | 0.3202 | 0.1956 | -0.0589 | 0.0570 | 0.1021 | 0.1143 | 0.2515 | 0.1390 | -0.1049 | 0.0916 | 0.1549 | -0.2509 | 0.3620 | 0.1070 | 0.1917 | 1.0000 | | |
| $X_{20}$ | 0.2052 | -0.0323 | -0.1424 | -0.2186 | -0.1107 | -0.1037 | -0.1634 | -0.2105 | 0.2692 | 0.4014 | 0.2344 | -0.2527 | -0.1935 | -0.0994 | -0.1249 | -0.0748 | -0.0817 | 0.0122 | 0.0494 | 1.0000 | |
| $X_{21}$ | 0.2125 | 0.3240 | -0.2636 | -0.0260 | -0.4205 | -0.0283 | 0.0301 | -0.0055 | 0.2425 | 0.1492 | 0.1939 | 0.3631 | 0.3940 | 0.1342 | 0.3133 | 0.2309 | -0.0460 | 0.0143 | -0.0451 | 0.2187 | 1.0000 |

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

Characters

| | |
|---|---|
| $X_1$ | Days to 50 per cent flowering |
| $X_2$ | Days to first harvest |
| $X_3$ | Length of harvesting period (days) |
| $X_4$ | Crop duration (days) |
| $X_5$ | Primary branches per plant |
| $X_6$ | Main stem length (cm) |
| $X_7$ | Fresh weight of shoot per plant (g) |
| $X_8$ | Dry weight of shoot per plant (g) |
| $X_9$ | Pod clusters per plant |
| $X_{10}$ | Pods per plant |
| $X_{11}$ | Pods per cluster |
| $X_{12}$ | Pod weight (g) |
| $X_{13}$ | Pod length (cm) |
| $X_{14}$ | Pod breadth (cm) |
| $X_{15}$ | Seeds per pod |
| $X_{16}$ | 100-seed weight (g) |
| $X_{17}$ | Fresh weight of roots per plant (g) |
| $X_{18}$ | Dry weight of roots per plant (g) |
| $X_{19}$ | Crude fibre content (%) |
| $X_{20}$ | Crude protein content (µg) |
| $X_{21}$ | Total phenols |

Table 8. Estimates of genotypic correlation coefficients among the yield components in yard long bean

| Character | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $X_{19}$ | $X_{20}$ | $X_{21}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1.0000 | | | | | | | | | | | | | | | | | | | | |
| $X_2$ | 0.4703 | 1.0000 | | | | | | | | | | | | | | | | | | | |
| $X_3$ | 0.0438 | -0.5380 | 1.0000 | | | | | | | | | | | | | | | | | | |
| $X_4$ | 0.4913 | 0.3415 | 0.6084 | 1.0000 | | | | | | | | | | | | | | | | | |
| $X_5$ | -0.1921 | -0.1941 | 0.5053 | 0.3808 | 1.0000 | | | | | | | | | | | | | | | | |
| $X_6$ | 0.4222 | 0.2190 | 0.1309 | 0.3520 | -0.2498 | 1.0000 | | | | | | | | | | | | | | | |
| $X_7$ | -0.1674 | -0.0569 | 0.5342 | 0.5422 | 0.0736 | 0.2444 | 1.0000 | | | | | | | | | | | | | | |
| $X_8$ | -0.1481 | -0.0070 | 0.5343 | 0.5893 | 0.0852 | 0.3077 | 0.9731 | 1.0000 | | | | | | | | | | | | | |
| $X_9$ | 0.2741 | 0.3387 | -0.2954 | -0.0104 | -0.1692 | -0.0261 | -0.1806 | -0.0651 | 1.0000 | | | | | | | | | | | | |
| $X_{10}$ | 0.5568 | 0.3623 | -0.1855 | 0.1343 | -0.1237 | -0.0894 | -0.3415 | -0.2517 | 0.6767 | 1.0000 | | | | | | | | | | | |
| $X_{11}$ | 0.5342 | 0.5681 | -0.7205 | -0.2686 | -0.3305 | -0.2669 | -0.4112 | -0.4525 | 0.0660 | 0.2572 | 1.0000 | | | | | | | | | | |
| $X_{12}$ | -0.0628 | 0.2544 | -0.0868 | 0.1428 | -0.1036 | 0.0673 | 0.4409 | 0.4208 | 0.0622 | -0.1578 | -0.1038 | 1.0000 | | | | | | | | | |
| $X_{13}$ | -0.0854 | 0.5214 | -0.4319 | 0.0094 | -0.2482 | 0.0373 | 0.2153 | 0.2343 | -0.0354 | 0.0510 | 0.1553 | 0.5534 | 1.0000 | | | | | | | | |
| $X_{14}$ | 0.1631 | 0.3250 | -0.0929 | 0.2024 | -0.0856 | 0.0788 | 0.2199 | 0.1919 | 0.1319 | -0.1084 | 0.0535 | 0.7786 | 0.4871 | 1.0000 | | | | | | | |
| $X_{15}$ | -0.3068 | 0.2108 | -0.2753 | -0.1087 | -0.3263 | -0.3202 | -0.0206 | 0.0347 | 0.2455 | 0.2552 | 0.1536 | 0.2063 | 0.5118 | -0.3582 | 1.0000 | | | | | | |
| $X_{16}$ | 0.2365 | 0.6944 | -0.2978 | 0.3218 | -0.1710 | -0.2152 | 0.1311 | 0.1608 | -0.0950 | 0.1211 | 0.3817 | 0.3401 | 0.5493 | 0.4370 | 0.1835 | 1.0000 | | | | | |
| $X_{17}$ | 0.0859 | 0.3967 | 0.0321 | 0.4094 | 0.0227 | 0.3198 | -0.0042 | 0.0327 | -0.0018 | 0.1405 | -0.2377 | -0.1706 | 0.2331 | -0.0099 | 0.1311 | 0.2062 | 1.0000 | | | | |
| $X_{18}$ | 0.0890 | 0.4508 | -0.1358 | 0.2730 | -0.1156 | 0.2341 | 0.0712 | 0.1021 | 0.0009 | 0.0517 | -0.1947 | -0.0629 | 0.3000 | 0.0994 | 0.0800 | 0.3354 | 0.8880 | 1.0000 | | | |
| $X_{19}$ | 0.6583 | 0.4663 | -0.0569 | 0.3756 | 0.2348 | -0.0443 | 0.0532 | 0.1107 | 0.1130 | 0.2756 | 0.1578 | -0.1064 | 0.0884 | 0.3396 | -0.3400 | 0.3898 | 0.1115 | 0.2058 | 1.0000 | | |
| $X_{20}$ | 0.3113 | -0.0609 | -0.1671 | -0.2437 | -0.1071 | -0.2163 | -0.1642 | -0.2213 | 0.2757 | 0.4227 | 0.2587 | -0.2596 | -0.2184 | -0.1363 | -0.1687 | -0.0771 | -0.0896 | 0.0114 | 0.0576 | 1.0000 | |
| $X_{21}$ | 0.3285 | 0.4264 | -0.3871 | -0.0304 | -0.4751 | -0.0815 | 0.0323 | -0.0133 | 0.2484 | 0.1601 | 0.2274 | 0.3655 | 0.4263 | 0.2029 | 0.3882 | 0.2397 | -0.0535 | 0.0116 | -0.0478 | 0.2221 | 1.0000 |

**Significant at 1 per cent level

* Significant at 5 per cent level

Characters

| | |
|---|---|
| $X_1$ | Days to 50 per cent flowering |
| $X_2$ | Days to first harvest |
| $X_3$ | Length of harvesting period (days) |
| $X_4$ | Crop duration (days) |
| $X_5$ | Primary branches per plant |
| $X_6$ | Main stem length (cm) |
| $X_7$ | Fresh weight of shoot per plant (g) |
| $X_8$ | Dry weight of shoot per plant (g) |
| $X_9$ | Pod clusters per plant |
| $X_{10}$ | Pods per plant |
| $X_{11}$ | Pods per cluster |
| $X_{12}$ | Pod weight (g) |
| $X_{13}$ | Pod length (cm) |
| $X_{14}$ | Pod breadth (cm) |
| $X_{15}$ | Seeds per pod |
| $X_{16}$ | 100-seed weight (g) |
| $X_{17}$ | Fresh weight of roots per plant (g) |
| $X_{18}$ | Dry weight of roots per plant (g) |
| $X_{19}$ | Crude fibre content (%) |
| $X_{20}$ | Crude protein content (µg) |
| $X_{21}$ | Total phenols |

Table 9. Estimates of error correlation coefficients among the yield components in yard long bean

| Character | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $X_{19}$ | $X_{20}$ | $X_{21}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1.0000 | | | | | | | | | | | | | | | | | | | | |
| $X_2$ | 0.9485 | 1.0000 | | | | | | | | | | | | | | | | | | | |
| $X_3$ | -0.6967 | -0.7878 | 1.0000 | | | | | | | | | | | | | | | | | | |
| $X_4$ | -0.1038 | -0.1946 | 0.7576 | 1.0000 | | | | | | | | | | | | | | | | | |
| $X_5$ | 0.0003 | 0.0165 | -0.0708 | -0.0954 | 1.0000 | | | | | | | | | | | | | | | | |
| $X_6$ | 0.0313 | 0.0178 | -0.0471 | -0.0559 | -0.1487 | 1.0000 | | | | | | | | | | | | | | | |
| $X_7$ | 0.0228 | 0.0077 | -0.0336 | -0.0450 | -0.0671 | 0.0432 | 1.0000 | | | | | | | | | | | | | | |
| $X_8$ | 0.0525 | 0.0528 | -0.1590 | -0.1973 | -0.0850 | 0.0652 | 0.8018 | 1.0000 | | | | | | | | | | | | | |
| $X_9$ | -0.0142 | -0.0736 | 0.1978 | 0.2363 | -0.0333 | 0.1942 | 0.0313 | -0.0489 | 1.0000 | | | | | | | | | | | | |
| $X_{10}$ | -0.1442 | -0.1189 | 0.0023 | -0.1225 | 0.0101 | -0.0266 | -0.0750 | -0.0473 | -0.2525 | 1.0000 | | | | | | | | | | | |
| $X_{11}$ | -0.0195 | -0.0844 | -0.0187 | -0.1188 | 0.0689 | -0.0257 | -0.0769 | 0.0097 | 0.2317 | -0.0457 | 1.0000 | | | | | | | | | | |
| $X_{12}$ | -0.0492 | -0.0406 | 0.1240 | 0.1544 | -0.3009 | 0.1157 | -0.0482 | 0.1184 | -0.3139 | 0.1448 | -0.2507 | 1.0000 | | | | | | | | | |
| $X_{13}$ | 0.0956 | 0.0626 | -0.0620 | -0.0325 | -0.3873 | 0.1455 | 0.0106 | -0.0266 | 0.0847 | -0.0781 | -0.1286 | -0.0260 | 1.0000 | | | | | | | | |
| $X_{14}$ | 0.1788 | 0.2096 | -0.1236 | 0.0252 | 0.2651 | 0.0472 | -0.0474 | -0.0174 | -0.0961 | 0.2038 | -0.2504 | 0.2219 | -0.0148 | 1.0000 | | | | | | | |
| $X_{15}$ | -0.1519 | -0.2376 | 0.2260 | 0.1085 | -0.0453 | 0.1946 | 0.0398 | -0.0112 | 0.2700 | 0.0676 | -0.0407 | -0.0107 | 0.3035 | 0.0668 | 1.0000 | | | | | | |
| $X_{16}$ | 0.1030 | 0.0925 | -0.0150 | 0.0741 | 0.1861 | 0.1469 | 0.0541 | 0.0012 | 0.1960 | -0.1232 | 0.0404 | 0.0002 | 0.0449 | 0.0821 | 0.1565 | 1.0000 | | | | | |
| $X_{17}$ | 0.1561 | 0.1814 | -0.2044 | -0.1334 | 0.1565 | -0.0729 | 0.1399 | 0.0792 | -0.0595 | -0.0915 | -0.0304 | 0.0138 | -0.0824 | 0.0786 | 0.1111 | 0.1951 | 1.0000 | | | | |
| $X_{18}$ | 0.2338 | 0.1708 | -0.2042 | -0.1439 | 0.1985 | 0.1507 | 0.1021 | 0.1637 | -0.1102 | 0.0630 | 0.1576 | 0.1627 | -0.0195 | 0.0779 | 0.1189 | 0.4176 | 0.5996 | 1.0000 | | | |
| $X_{19}$ | 0.0988 | 0.0334 | 0.1022 | 0.1984 | -0.0081 | -0.1460 | 0.1085 | 0.0024 | 0.1529 | -0.0714 | 0.0287 | -0.0888 | 0.1222 | -0.1396 | 0.0349 | - 0.0029 | 0.0598 | -0.0259 | 1.0000 | | |
| $X_{20}$ | 0.0911 | 0.1345 | -0.2754 | -0.2958 | -0.2457 | 0.2011 | -0.1593 | -0.0105 | 0.0343 | -0.1161 | 0.0823 | -0.0368 | 0.1755 | -0.1756 | 0.0712 | -0.0236 | 0.0619 | 0.0392 | -0.1178 | 1.0000 | |
| $X_{21}$ | 0.0617 | 0.0482 | -0.0476 | -0.0226 | -0.1342 | 0.1586 | -0.0226 | 0.1626 | 0.0367 | -0.1152 | -0.1011 | 0.2977 | -0.0240 | 0.1462 | 0.1124 | 0.0359 | 0.0959 | 0.0972 | 0.0034 | 0.0763 | 1.0000 |

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

(0.3850) 100-seed weight (0.5250), fresh weight of roots per plant (0.3220), dry weight of roots per plant (0.3570) and crude fibre content(0.3448). Length of harvest period showed significant negative correlation (-0.6545). Genotypic correlation was positive and significant for days to 50% flowering (0.4703), crop duration (0.3415), pods per plant (0.3623), pods per cluster (0.5681), pod clusters per plant (0.3387), pod length (0.5214), pod breadth (0.3750), 100-seed weight (.6944), fresh weight of roots per plant (0.3967), dry weight of roots per plant (0.4508) crude fibre content (0.4663) and total phenols (0.4264) and was negatively significant for length of harvest period (-0.5380). Environmental correlation was significant and positive for days to 50% flowering (0.9485) while length of harvest period showed significant negative correlation (-0.7878).

**Length of harvest period**

Crop duration (0.6659), primary branches per plant (0.2729), fresh weight of shoot per plant (0.3439), dry weight of shoot per plant (0.3137) showed significant positive correlation at phenotypic level, while significant negative correlation were observed for days to 50% flowering (-0.3797), days to first harvest (-0.6545), pods per cluster (-0.4413) and pod length (-0.2894). At genotypic level crop duration (0.6084), primary branches per plant (0.5053), fresh weight of shoot per plant (0.5342) and dry weight of shoot per plant (0.5343) showed significant positive correlation. Days to first harvest (-0.5380), pods per cluster (-0.7205), pod length (-0.4319), pod clusters per plant (-0.2954), seeds per pod (-0.2753), 100 seed weight (-0.2978) and total phenols (-0.3871) recorded significant negative correlation. High positive environmental correlation with crop duration (0.7576) while negative correlation with days to 50% flowering (-0.6967) days to first harvest (-0.7878) and crude protein content (-0.2754).

**Crop duration**

Significant positive phenotypic correlation was observed for length of harvest period (0.6659), fresh weight of shoot per plant (0.4110), dry weight of shoot per plant (0.4159), fresh weight of roots per plant (0.2861) and crude fibre content (0.3202). Days to 50% flowering (0.4913), length of harvest period

(0.6084), days to first harvest (0.3415), 100-seed weight (0.3218), dry weight of roots per plant (0.2730), primary branches per plant (0.3803), main stem length (0.3520), fresh weight of shoot per plant (0.5422), dry weight of shoot per plant (0.5893), fresh weight of roots per plant (0.4094) and crude fibre content (0.3756) showed positive and significant genotypic correlation. Length of harvest period (0.7576) recorded significant positive environmental correlation while crude protein content (-0.2958) recorded significant negative correlation with crop duration.

**Primary branches per plant**

Phenotypic correlation was positive and significant for length of harvest period (0.2729) while negative and significant for total phenols (-0.4205). Length of harvest period (0.5053) and crop duration (0.3803) showed positive and significant genotypic correlation while pods per cluster (-0.3305), seeds per pod (-0.3263) and total phenols (-0.4751) showed significant negative correlation. Pod weight (-0.3009) and pod length (-0.3873) showed significant negative environmental correlation with primary branches per plant.

**Main stem length**

Days to 50 per cent flowering (0.4222), crop duration (0.3520), dry weight of shoot per plant (0.3077) and fresh weight of roots per plant (0.3198) showed significant and positive genotypic correlation while seeds per pod (-0.3202) recorded significant negative correlation. Phenotypic correlation and environmental correlation of main stem length with other characters were not significant.

**Fresh weight of shoot per plant**

Phenotypic correlation was significant and positive for length of harvesting period (0.3439), crop duration (0.4110), dry weight of shoot per plant (0.9608) and pod weight (0.4173), while pods per cluster (-0.3654) and pods per plant(-0.3261) recorded significant negative correlation. This character had maximum positive and significant genotypic correlation with dry weight of shoot per plant (0.9731) followed by crop duration (0.5422), length of harvest period

(0.5342) and pod weight (0.4409) while pods per plant (-0.3415) and pods per cluster (-0.4112) showed significant negative correlation. Only dry weight of shoot per plant (0.8018) recorded significant positive environmental correlation with fresh weight of shoot per plant

**Dry weight of shoot per plant**

At phenotypic level significant positive correlation was observed with crop duration (0.4159), length of harvesting period (0.3137), fresh weight of shoot per plant (0.9608) and pod weight (0.4028) while pods per cluster (-0.3877) recorded significant negative correlation. Genotypic correlation was significant and positive with length of harvest period (0.5343), crop duration (0.5893), main stem length (0.3077) fresh weight of shoot per plant (0.9731) and pod weight (0.4208) while pods per cluster (-0.4525) showed significant negative correlation. The only character showing significant positive environmental correlation with dry weight of shoot per plant was fresh weight of shoot per plant (0.8018)

**Pod clusters per plant**

Significant positive phenotypic correlation was recorded for pods per plant (0.6359). Genotypic correlation was significant and positive for days to 50 per cent flowering (0.2741), days to first harvest (0.3387), pods per plant (0.6767) and crude protein content (0.2757) while length of harvesting period (-0.2954) showed significant negative correlation. Seeds per pod (0.2700) showed significant positive environmental correlation and pod weight (-0.3139) showed significant negative correlation with pod clusters per plant.

**Pods per plant**

Significant positive phenotypic correlation was recorded for days to 50 per cent flowering (0.3149), pod clusters per plant (0.6359) and crude protein content (0.4014) while negative correlation was recorded for fresh weight of shoot per plant (-0.3261). Genotypic correlation was significant and positive for days to 50% flowering (0.5568), days to first harvest (0.3623), pod clusters per plant

(0.6767) and crude protein content (0.4227). None of the characters showed significant environmental correlation with pods per plant

**Pods per cluster**

Pods per cluster recorded significant positive phenotypic correlation with days to 50 per cent flowering (0.2954), days to first harvest (0.3607) , 100-seed weight ( 0.3357) while length of harvest period (-0.4413) , fresh weight of shoot per plant (-0.3654) and dry weight of shoot per plant (-0.3877) showed significant negative correlation. Days to first harvest (0.5681) showed significant positive genotypic correlation followed by days to 50% flowering (0.5342) and100-seed weight (0.3817) while length of harvest period (-0.7205), dry weight of shoot per plant (-0.4525), fresh weight of shoot per plant (-0.4112) and primary branches per plant (-0.3305) recorded significant negative correlation. None of the characters showed significant environmental correlation with pods per cluster.

**Pod weight**

Significant positive phenotypic correlation was recorded for fresh weight of shoot per plant (0.4173), dry weight of shoot per plant (0.4028), pod length (0.5077), pod breadth (0.4756), 100-seed weight (0.3234) and total phenols (0.3631). Fresh weight of shoot per plant (0.4409), dry weight of shoot per plant (0.4208), pod length (0.5534), pod breadth (0.7786), 100-seed weight (0.3401) and total phenols (0.3655) showed positive and significant genotypic correlation. Total phenols (0.2977) recorded significant positive environmental correlation while primary branches per plant (-0.3009) and pod clusters per plant (-0.3139) showed significant negative correlation.

**Pod length**

Phenotypic correlation was positive and significant for days to first harvest (0.3850), pod weight (0.5077), seeds per pod (0.4433) 100-seed weight (0.5039), dry weight of roots per plant (0.2745) and total phenols (0.3940) while length of harvest period (-0.2894) showed significant negative correlation. Significant genotypic correlation was recorded for days to first harvest (0.5214), pod weight

(0.5534), pod breadth (0.4871), seeds per pod (0.5118), 100-seed weight (0.5493) ,dry weight of roots per plant (0.3000) and total phenols (0.4263) while length of harvest period (-0.4319) recorded significant negative correlation. Significant positive environmental correlation recorded for seeds per pod (0.3035) while primary branches per plant (-0.3873) showed significant negative correlation.

**Pod breadth**

Phenotypic correlation was positive and significant (0.4756) for pod weight only. Pod weight (0.7786), pod length (0.4871), 100-seed weight (0.4370), crude fibre content (0.3396) and days to first harvest (0.3250) showed significant positive genotypic correlation while seeds per pod (-0.3582) showed significant negative correlation. None of the characters showed significant environmental correlation with pod breadth.

**Seeds per pod**

Phenotypic correlation was significant and positive for pod length (0.4433) and total phenols (0.3133). Pod length (0.5118) and total phenols (0.3882) recorded significant and positive genotypic correlation while pod breadth (-0.3582), days to 50 per cent flowering (-0.3068), length of harvest period (-0.2753), primary branches per plant (-0.3263), main stem length (-0.3202) and crude fibre content (-0.3400) showed significant negative correlation. Significant positive environmental correlation was recorded for pod clusters per plant (0.2700) and pod length (0.3035)

**100-seed weight**

Significant positive phenotypic correlation was observed for days to first harvest (0.5250), pods per cluster (0.3357), pod weight (0.3234), pod length (0.5039) and dry weight of roots per plant (0.3392). Genotypic correlation were significant and positive for days to first harvest (0.6944), pods per cluster (0.3817), pod length (0.5493), pod breadth (0.4370), crop duration (0.3218), pod weight (0.3401), dry weight of roots per plant (0.3354) and crude fibre content

(0.3898) while length of harvesting period (-0.2978) showed significant negative correlation. The only character showing significant positive environmental correlation with100-seed weight was dry weight of roots per plant (0.4176).

**Fresh weight of roots per plant**

At phenotypic level days to first harvest (0.3222), crop duration (0.2861) and dry weight of roots per plant (0.8663) recorded significant positive correlation with fresh weight of roots per plant. Genotypic correlation was positive and significant for days to first harvest (0.3967), crop duration (0.4094), main stem length (0.3198) and dry weight of roots per plant (0.8880). The only character showing significant positive environmental correlation with fresh weight of roots per plant was dry weight of roots per plant (0.5996).

**Dry weight of roots per plant**

Significant positive phenotypic correlation was observed for fresh weight of roots per plant (0.8663), pod length (0.2745) and 100-seed weight (0.3392). Days to first harvest (0.4508), fresh weight of roots per plant (0.8880), crop duration (0.2730), pod length (0.3000) and 100-seed weight (0.3354) showed positive and significant genotypic correlation. Environmental correlation was significant and positive for 100-seed weight (0.4176) and fresh weight of roots per plant (0.5996).

**Crude fibre content**

Phenotypic correlation was positive and significant for days to 50% flowering (0.4205), days to first harvest (0.3448), crop duration (0.3202) and 100 seed weight (0.3620). At genotypic level significant positive correlation was observed for days to 50% flowering (0.6583), days to first harvest (0.4663), crop duration (0.3756), pods per plant (0.2756), pod breadth (0.3396) and100-seed weight (0.3898) while seeds per pod (-0.3400) showed significant negative correlation.

**Crude protein content**

Significant and positive phenotypic correlation was recorded for pods per plant (0.4014) only. Genotypic correlation was significant and positive for pods per plant (0.4227), days to 50 per cent flowering (0.3113) and pod clusters per plant (0.2757). Significant negative environmental correlation was recorded for length of harvest period (-0.2754) and crop duration (-0.2958).

**Total phenols**

Total phenols recorded significant positive phenotypic correlation with pod weight (0.3631), days to first harvest (0.3240), seeds per pod (0.3133) and pod length (0.3940) while primary branches per plant (-0.4205) showed significant negative correlation. Days to first harvest (0.4264), days to 50 per cent flowering (0.3285), pod weight (0.3655), pod length (0.4263) and seeds per pod (0.3882) showed positive and significant genotypic correlation while length of harvest period (-0.3871) and primary branches per plant (-0.4751) showed significant negative correlation. The environmental correlation was significant and positive for pod weight (0.2977) and dry weight of roots per plant (0.3835).

### 4.1.4 Path Analysis

In path coefficient analysis, the genotypic coefficient among yield and its component characters were partitioned into different components to find the direct and indirect contribution of each character to pod yield.

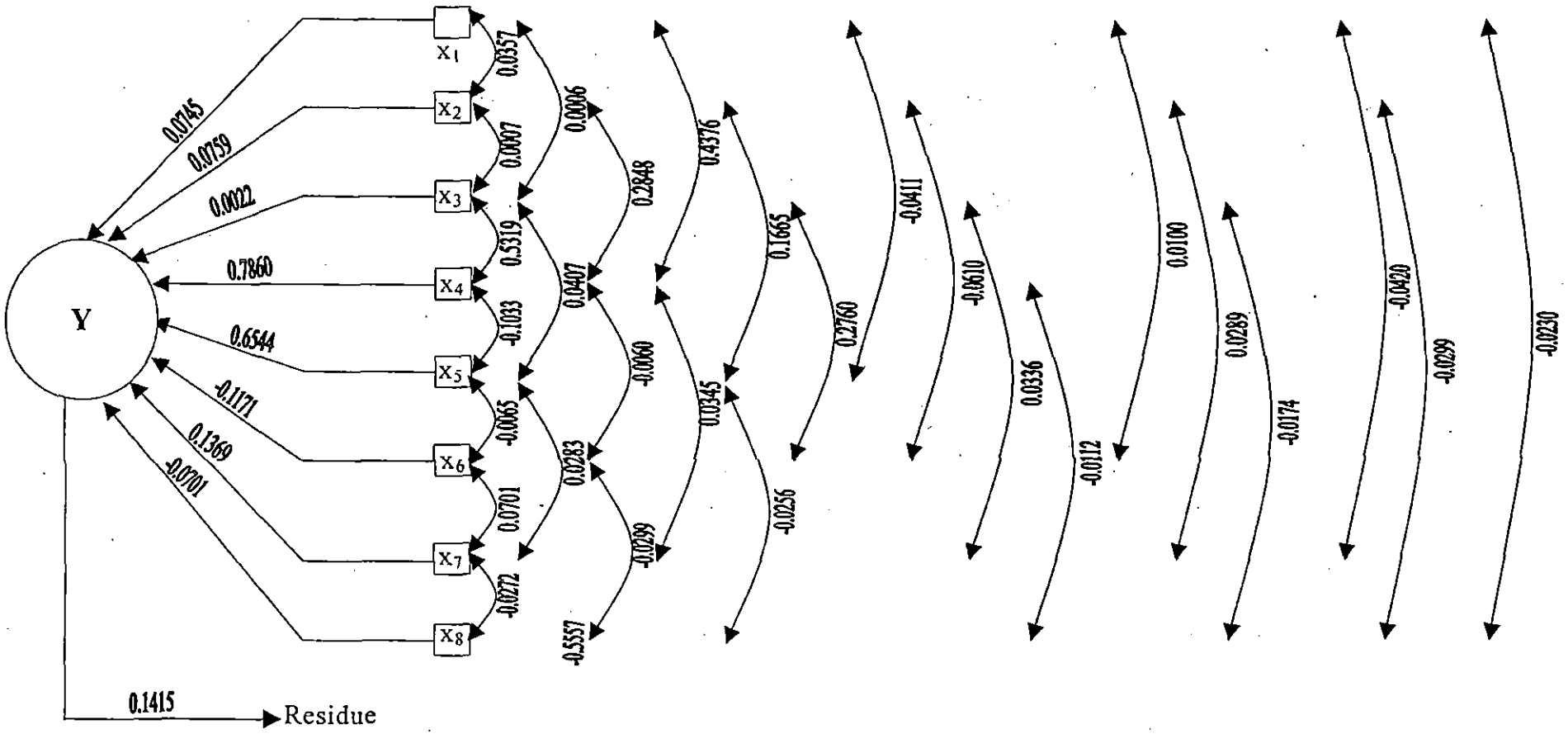
Pod yield per plant was taken as the dependent character and path analysis was done. The characters showing high significant association with yield were selected for the analysis *viz.*, days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod weight, pod length, seeds per pod and total phenols. The analysis revealed the direct and indirect effects of various characters on yield as presented in Table 10 and Fig. 4.

The highest direct effect was observed for pods per plant(0.7860) followed by pod weight(0.6544), seeds per pod(0.1369), days to first harvest (0.0759), days to 50 per cent flowering (0.0745), pod clusters per plant (0.0022), total phenols

**Table 10. Direct and indirect effects of component characters on yield in yard long bean**

| Characters | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | Genotypic correlation with yield |
|---|---|---|---|---|---|---|---|---|---|
| Days to50 % flowering ($X_1$) | **0.0745** | 0.0357 | 0.0006 | 0.4376 | -0.0411 | 0.0100 | -0.0420 | -0.0230 | 0.4523 |
| Days to first harvest ($X_2$) | 0.0350 | **0.0759** | 0.0007 | 0.2848 | 0.1665 | -0.0610 | 0.0289 | -0.0299 | 0.5009 |
| Pod clusters per plant ($X_3$) | 0.0204 | 0.0257 | **0.0022** | 0.5319 | 0.0407 | 0.0042 | 0.0336 | -0.0174 | 0.6413 |
| Pods per plant ($X_4$) | 0.0415 | 0.0275 | 0.0015 | **0.7860** | -0.1033 | -0.0060 | 0.0345 | -0.0112 | 0.7704 |
| Pod weight ($X_5$) | -0.0047 | 0.0193 | 0.0001 | -0.1240 | **0.6544** | -0.0065 | 0.0283 | -0.0256 | 0.5413 |
| Pod length ($X_6$) | -0.0064 | 0.0396 | -0.0001 | 0.0401 | 0.3621 | **-0.1171** | 0.0701 | -0.0299 | 0.3584 |
| Seeds per pod ($X_7$) | -0.0229 | 0.0160 | 0.0005 | 0.2006 | 0.1350 | -0.0600 | **0.1369** | -0.0272 | 0.3790 |
| Total phenols ($X_8$) | 0.0245 | 0.0324 | 0.0005 | 0.1258 | 0.2392 | -0.0499 | 0.0531 | **-0.0701** | 0.3555 |

Residue : 0.1415
Direct effects – Diagonal elements
Indirect effect – Off diagonal elements




Direct effects given in straight lines and correlations in curved lines

Y – Yield per plant
$X_1$ – Days to 50 per cent flowering
$X_2$ – Days to first harvest
$X_3$ – Pod clusters per plant
$X_4$ – Pods per plant
$X_5$ – Pod weight
$X_6$ – Pod length
$X_7$ – Seeds per pod
$X_8$ – Total phenols

**Fig. 4. Path diagram showing direct and indirect effects of components on yield**

(-0.0701) and pod length (-0.1171). Days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod weight, seeds per pod had positive direct effect while pod length and total phenols had negative direct effect.

Pod length and total phenols had positive correlation estimates and negative direct effects. A positive correlation as well as positive direct effect was noted for days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod weight and seeds per pod.

The direct effect of days to 50 per cent flowering was low and positive (0.0745) but its indirect effect via pods per plant was high and positive (0.4376) which nearly accounted for the total genotypic correlation with yield (0.4523). Days to first harvest had low and direct positive effect on yield (0.0759) but its indirect positive effect was observed through pods per plant (0.2848) and pod weight (0.1665).

Pod clusters per plant had very low positive direct effect (0.0022) on yield, but the total correlation was positive. This was mainly accounted by the high positive indirect effect through pods per plant (0.5319).

Pods per plant had high direct effect on yield (0.7860) as well as the highest positive genotypic correlation (0.7704) with yield. It also showed a negative indirect effect (-0.1033) via pod weight but the indirect effect through other component characters was negligible. So the correlation recorded explained the true relationship of number of pods per plant and pod yield.

Pod weight had high positive direct effect (0.6544). It also had negative indirect effect through pods per plant (-0.1240).

The direct effect of pod length was negative (-0.1171) but it recorded high positive genotypic correlation with yield (0.3584) due to high positive indirect effect through pod weight (0.3621).

Seeds per pod had positive direct effect (0.1369) on yield. High positive genotypic correlation of seeds per pod with yield (0.3790) was due to its positive indirect effect through pods per plant (0.2006) and pod weight (0.1350).

Total phenols had a positive correlation coefficient with yield inspite of negative direct effect (-0.0701). This was mainly attributed to the positive indirect effect through pod weight (0.2392) and pods per plant (0.1258). Direct effect contributed maximum to genotypic correlation in the case of pods per plant and pod weight.

The residual value was 0.1415 indicating that about 86 percent of the variation in yield was contributed by the characters selected for analysis.

### 4.1.5 Genetic Divergence Analysis

The 30 genotypes were subjected to Mahalanobis $D^2$ analysis based on the nine characters namely days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod yield per plant, pod weight, pod length, seeds per pod and total phenols.

The genotypes were grouped into eight clusters using Tocher's method of clustering. The clustering pattern is presented in Table 11.

The cluster I had the highest number of genotypes (10) followed by cluster II (7), cluster V (4), cluster III (3) and cluster IV (3). clusters VI, VII and VIII had one genotype each. The cluster I had the genotypes Vu5, Vu8, Vu10, Vu11, Vu14, Vu15, Vu17, Vu18, Vu21 and Vu30. The genotypes Vu9, Vu12, Vu13, Vu20, Vu22, Vu23 and Vu27 were included in the cluster II. The cluster III had Vu4, Vu24 and Vu29. The genotypes Vu1, Vu7 and Vu25 constituted the cluster IV, cluster V had Vu2, Vu3, Vu6 and Vu28. The genotypes Vu16, Vu19 and Vu26 remained as divergent genotypes that cannot be accommodated in any of the clusters and each remained as a separate cluster.

The average inter and intra cluster distances were estimated based on the total $D^2$ values. The inter and intra cluster distances (D) of the various clusters were worked out and presented in Table 12 and Fig. 5. The intra cluster distance varied from 0 (Cluster VI, VII and VIII) to 72.48 (Cluster I). The inter cluster distances varied from 104.03 (between clusters III and VIII) to 911.53 (between Clusters IV and VI).

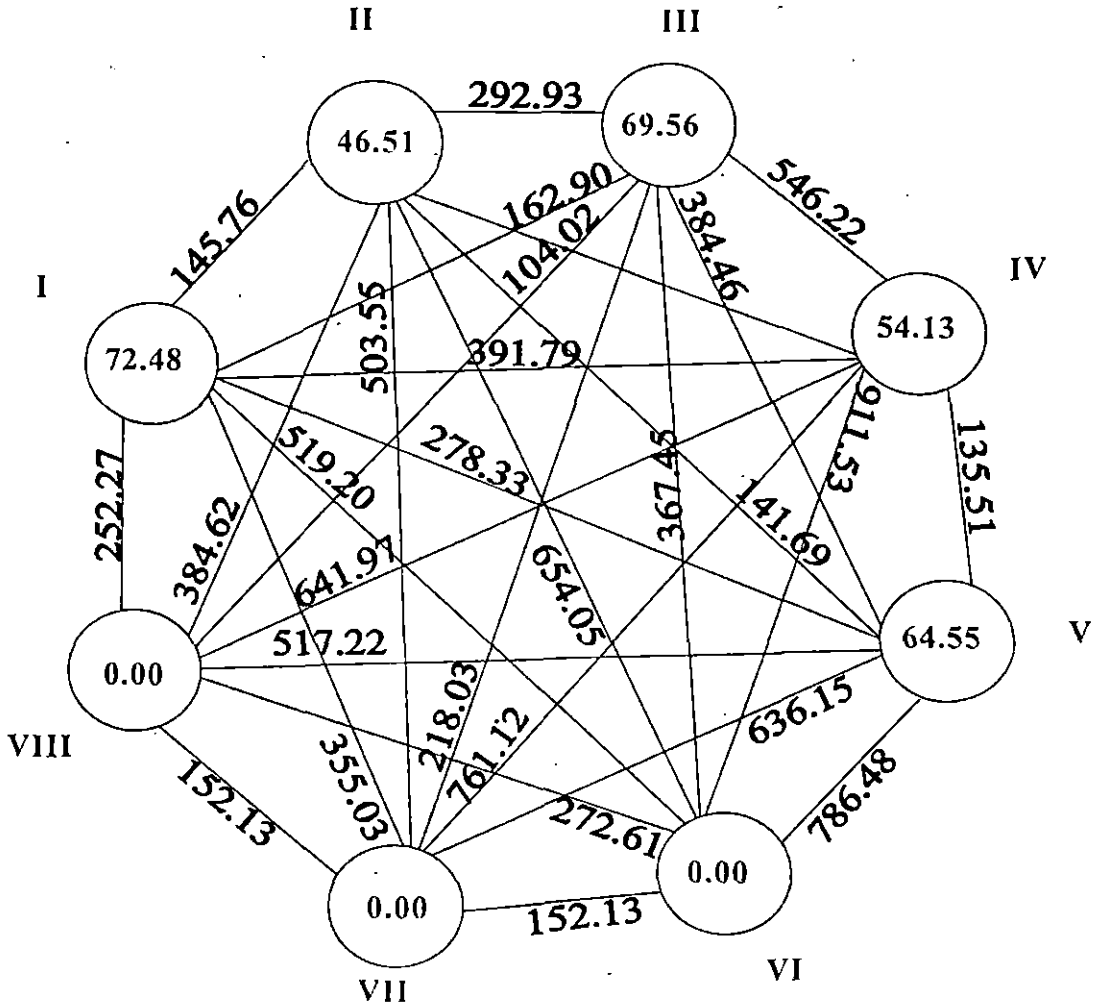
Table 11 Clustering pattern

| Sl. No | Cluster | Number of genotypes | Genotypes |
|---|---|---|---|
| 1 | I | 10 | Vu5, Vu8, Vu10, Vu11, Vu14, Vu15, Vu17, Vu18, Vu21, Vu30 |
| 2 | II | 7 | Vu 9, Vu12, Vu13, Vu20, Vu22, Vu23, Vu27 |
| 3 | III | 3 | Vu4, Vu24, Vu29 |
| 4 | IV | 3 | Vu1, Vu7, Vu25 |
| 5 | V | 4 | Vu2, Vu3, Vu6, Vu28 |
| 6 | VI | 1 | Vu1 |
| 7 | VII | 1 | Vu19 |
| 8 | VIII | 1 | Vu26 |

Table. 12. Average inter cluster and intra cluster distances

| Cluster | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| I | 72.48 | 145.76 | 162.9 | 391.79 | 278.33 | 519.20 | 355.03 | 252.27 |
| II | | 46.51 | 292.93 | 261.72 | 141.69 | 654.05 | 503.55 | 384.62 |
| III | | | 69.56 | 546.22 | 384.46 | 367.45 | 218.03 | 104.02 |
| IV | | | | 54.13 | 135.51 | 911.53 | 761.12 | 641.97 |
| V | | | | | 64.55 | 786.48 | 636.15 | 517.22 |
| VI | | | | | | 0 | 152.13 | 272.61 |
| VII | | | | | | | 0 | 121.61 |
| VIII | | | | | | | | 0 |

Diagonal elements - Intra cluster distance
Off diagonal elements - Inter cluster distance




The values in circles indicate intracluster D values and others indicate intercluster D values

Fig. 5. Cluster diagram

The cluster means for each character is presented in Table 13. The cluster means were high in cluster VI for characters pod yield per plant, pod weight, seeds per pod and days to first harvest. Cluster VIII had high cluster means for pods per plant and total phenols. Cluster mean was high for pod length in cluster VI, pod clusters per plant in cluster IV and days to 50 per cent flowering in cluster III. Among the nine characters considered pod yield per plant contributed maximum towards divergence.

The cluster VI had the greatest distance from Cluster I, followed by Clusters IV, VII, V, VIII, III and II. The cluster II was at the greatest distance from Cluster VI, followed by VII, VIII, III, IV, I and V. The maximum distance of cluster III was from cluster IV, followed by V, VI, II, VII, I and VIII. The cluster IV was at the maximum distance from VI, followed by VII, VIII, III, I, III and V. The cluster V had the greatest distance from VI followed by VII, VIII, III, I, II and IV. The Cluster VI was at the greatest distance from IV followed by V, II, I, III, VIII and VII. The cluster VII was at maximum distance from IV followed by V, II, I, VIII, III and VI. The cluster VIII had the greatest distance from IV followed by V, II, VI, I, VII and III.

### 4.1.6 Selection Index

Selection index for the genotypes was computed based on the nine characters namely days to 50 per cent flowering ($X_1$), days to first harvest ($X_2$), pod clusters per plant ($X_3$), pods per plant ($X_4$), pod yield per plant ($X_5$), pod weight ($X_6$), pod length ($X_7$), seeds per pod ($X_8$) and total phenol ($X_9$). The selection index worked out was as follows:

$I = 32.0118\ X_1 - 24.9836\ X_2 + 2.827636\ X_3 - 16.6569\ X_4 + 1.976049\ X_5 + 9.87745\ X_6 + 7.765108\ X_7 + 33.5242\ X_8 - 49.8316.$

Accordingly selection index values were worked out and presented in the Table 14 in descending order. Based on the analysis genotype Vu-16 attained the maximum selection index value followed by Vu-4 and Vu-19 and the minimum estimates were recorded for Vu 1, Vu 2 and Vu 7.

Table.13 Cluster means of the various characters

| Cluster | Days to 50 per cent flowering | Days to first harvest | Pod clusters per plant | Pods per plant | Pod yield per plant | Pod weight | Pod length | Seed per pod | Total phenols |
|---|---|---|---|---|---|---|---|---|---|
| I | 47.46 | 54.85 | 13.68 | 14.39 | 248.78 | 17.69 | 39.61 | 16.55 | 9.29 |
| II | 48.36 | 56.35 | 12.18 | 13.03 | 203.55 | 15.69 | 39.23 | 16.64 | 9.62 |
| III | 49.33 | 57.15 | 14.2 | 17.56 | 299.5 | 17.53 | 43.19 | 18 | 11.13 |
| IV | 45.67 | 52.71 | 24.13 | 8.31 | 117.89 | 14.29 | 37.47 | 17.07 | 9.96 |
| V | 46.46 | 55.13 | 9.02 | 10.53 | 159.58 | 15.42 | 39.91 | 17 | 10.03 |
| VI | 47.83 | 58.13 | 17.4 | 16.8 | 421 | 24.07 | 43.67 | 19.53 | 11.13 |
| VII | 48.5 | 57.13 | 15.4 | 19.8 | 370.83 | 18.8 | 44.07 | 16.53 | 9.23 |
| VIII | 48 | 56.8 | 16.4 | 22.67 | 330.83 | 14.67 | 43.5 | 18.27 | 11.32 |
| Mean | 47.70 | 56.03 | 15.30 | 15.39 | 268.10 | 17.27 | 41.33 | 17.45 | 10.21 |

**Table 14 Selection indices arranged in descending order**

| Sl. No. | Genotypes | Selection index values |
|---|---|---|
| 1 | Vu 16 | 1356.97 |
| 2 | Vu 4 | 1207.28 |
| 3 | Vu 19 | 1193.73 |
| 4 | Vu 14 | 1166.08 |
| 5 | Vu 11 | 1096.45 |
| 6 | Vu 10 | 1021.92 |
| 7 | Vu 5 | 1020.89 |
| 8 | Vu 8 | 995.42 |
| 9 | Vu 13 | 994.40 |
| 10 | Vu 17 | 976.31 |
| 11 | Vu 26 | 971.58 |
| 12 | Vu 29 | 952.60 |
| 13 | Vu 15 | 948.26 |
| 14 | Vu 24 | 946.82 |
| 15 | Vu 30 | 933.96 |
| 16 | Vu 21 | 929.51 |
| 17 | Vu 27 | 920.42 |
| 18 | Vu 20 | 918.87 |
| 19 | Vu 6 | 916.53 |
| 20 | Vu 12 | 892.49 |
| 21 | Vu 23 | 884.56 |
| 22 | Vu 9 | 852.45 |
| 23 | Vu 18 | 849.28 |
| 24 | Vu 22 | 804.71 |
| 25 | Vu 28 | 801.93 |
| 26 | Vu 25 | 799.18 |
| 27 | Vu 3 | 789.90 |
| 28 | Vu 1 | 774.76 |
| 29 | Vu 2 | 747.13 |
| 30 | Vu 7 | 725.52 |

## 4.2 SCREENING OF GENOTYPES FOR FUSARIUM WILT RESISTANCE (Experiment-II)

### 4.2.1 Identification of the Pathogen

Based on morphology and conidial characters the wilt pathogen was identified as *Fusarium oxysporum*. Further confirmation was made by comparing with the culture available in the Department of Plant Pathology, College of Agriculture, Vellayani.

### 4.2.2 Assessing Disease Intensity

In the present study, disease intensity of Fusarium wilt in the various genotypes were assessed and the data are presented in Table15. The disease intensity ranged from 13.83 to 65 per cent. The lowest disease intensity (13.83 per cent) was observed for the accession Vu 4 (Thiruvananthapuram local-1), which was grouped as moderately resistant. Maximum disease intensity (65 per cent) was recorded for accession Vu11 (Malappuram local-1) which was grouped as susceptible. Among the accessions screened, two genotypes were moderately resistant, 18 genotypes were moderately susceptible and 10 genotypes were susceptible to Fusarium wilt. The accessions found to be moderately resistant to Fusarium wilt were Vu4 and Vu10. The susceptible accessions were Vu5, Vu11, Vu12, Vu15, Vu19, Vu20, Vu25, Vu27, Vu28 and Vu30 (Table 16).

Table 15. Disease intensity of the different cowpea genotypes

| Sl. No. | Accession No. | Varieties | Disease intensity (%) | Disease reaction |
|---|---|---|---|---|
| 1 | Vu1 | Kayamkulam local | 42.25 | MS |
| 2 | Vu2 | Malappuram local-2 | 49.55 | MS |
| 3 | Vu3 | Ookodu local-1 | 45.00 | MS |
| 4 | Vu4 | Thiruvananthapuram local-1 | **13.83** | MR |
| 5 | Vu5 | Sarika | 59.17 | S |
| 6 | Vu6 | Thiruvananthapuram local-4 | 36.75 | MS |
| 7 | Vu7 | Kollengode local | 26.50 | MS |
| 8 | Vu8 | Vaijayanthi | 35.90 | MS |
| 9 | Vu9 | KMV-1 | 27.75 | MS |
| 10 | Vu10 | Thiruvananthapuram local-3 | **21.08** | MR |
| 11 | Vu11 | Malappuram local-1 | 65.00 | S |
| 12 | Vu12 | Kalliyoor local | 61.33 | S |
| 13 | Vu13 | Kuttichal local | 49.98 | MS |
| 14 | Vu14 | VS27 | 41.75 | MS |
| 15 | Vu15 | Palapoor local-3 | 60.33 | S |
| 16 | Vu16 | VS86 | 26.50 | MS |
| 17 | Vu17 | Vellayani local | 38.83 | MS |
| 18 | Vu18 | CPCH-1 | 33.42 | MS |
| 19 | Vu19 | Vella valli payar | 58.33 | S |
| 20 | Vu20 | Palapoor local-2 | 60.50 | S |
| 21 | Vu21 | Varuvila local-1 | 33.25 | MS |
| 22 | Vu22 | Thiruvananthapuram local-2 | 40.25 | MS |
| 23 | Vu23 | Ookodu local-2 | 47.08 | MS |
| 24 | Vu24 | Malika | 26.57 | MS |
| 25 | Vu25 | Palakkad local | 54.83 | S |
| 26 | Vu26 | Varuvila local-2 | 36.08 | MS |
| 27 | Vu27 | Thrissur local | 50.58 | S |
| 28 | Vu28 | Kasargode local | 50.67 | S |
| 29 | Vu29 | Palapoor local-1 | 42.92 | MS |
| 30 | Vu30 | Lola | 59.92 | S |

R – Resistant (0),
MR – Moderately resistant (0-25),
MS – Moderately susceptible (26-50)
S – Susceptible (51-75)
HS – Highly susceptible (>76)

Table 16. Different disease reactions for various cowpea genotypes

| Accession/variety | Disease reaction |
|---|---|
| Thiruvananthapuram local-1, Thiruvananthapuram local-3 | Moderately Resistant |
| Kayamkulam local, Malappuram local-2 , Ookodu local-1, Thiruvananthapuram local-4 , Kollengode local, Vaijayanthi, KMV-1, Kuttichal local, VS27, VS86, Vellayani local, CPCH-1, Varuvila local-1, Thiruvananthapuram local-2, *Ookodu local-2, Malika, Varuvila local-2, Palapoor local-1* | Moderately Susceptible |
| Sarika, Kalliyoor local, Malappuram local-1, Palapoor local-3, Vellavalli payar, Palapoor local-2, Thrissur local, Palakkad local, Kasargode local, Lola | Susceptible |

# *Discussion*

# 5. DISCUSSION

Field experiments were conducted to study the variations in yard long bean genotypes for yield and resistance to Fusarium wilt. The experimental results are discussed under different headings.

## 5.1 EVALUATION AND SCREENING OF GENOTYES FOR YIELD AND YIELD COMPONENTS

The genetic improvement in any crop aims at increasing the production potential and quality by altering the genetic makeup of the existing varieties. To achieve this goal, plant breeder requires information on certain genetic parameters like variability, heritability, genetic advance and association between characters. For development of superior varieties selection is the fundamental process which utilizes the available variability in a crop. Selection based on yield and its components could be more efficient than yield alone (Evans, 1978).

The present study was aimed to estimate the genetic parameters, degree and pattern of association among the characters and genetic diversity in yard long bean.

### 5.1.1 Variability

An estimate of the magnitude of variability present in a population is of great importance as it provides basis for effective selection. The observed variability in a population is the total variation arising due to genotypic and environmental effects. But only the genetic component of total variability contributes to gain under selection. So knowledge on the nature and magnitude of genetic variation governing the inheritance of quantitative characters like yield and its components is essential (Allard, 1960).

There were significant differences among the 30 genotypes of cowpea for all the characters considered in the present study *viz.*, days to 50 per cent flowering, days to first harvest, length of harvest period, crop duration ,primary branches per plant, main stem length , fresh weight of shoot per plant , dry weight of shoot per plant , pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, pod breadth, seeds per pod, seed colour,100-seed weight, fresh weight of roots per plant ,dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant ,crude fibre content, crude protein content, peroxidase, poly phenol oxidase and total phenols.

Variation in varietal mean for days to 50 per cent flowering observed in the present study was supported by the findings of Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean and Sobha and Vahab (1998), Ajith (2001) and Philip (2004) in cowpea.

Wide variation for days to first harvest, length of harvest period and crop duration observed in the study was also recorded by Resmi (1998) in yard long bean and Ajith (2001) in vegetable cowpea.

A wide range of variation in primary branches per plant noticed in the study was supported by Resmi (1998), Vidya (2000) in yard long bean and Sobha and Vahab (1998), Anbuselvam *et al.* (2000) and Philip (2004) in cowpea.

Main stem length showed high variability, which was in accordance with the reports of Resmi (1998) and Vidya (2000) in yard long bean and and Ajith (2001), Anbuselvam *et al.* (2000) and Philip (2004) in cowpea.

Characters like, pods per plant, pod clusters per plant and pods per cluster also showed notable varietal variation. The same was supported by Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

In the present study high variability was noticed for yield per plant. Similar results were obtained in yard long bean by Resmi (1998) and Vidya (2000) and in cowpea by Sobha and Vahab (1998), Ajith (2001), Anbuselvam *et al.* (2000) and Philip (2004).

Remarkable variation in pod characters *viz.*, pod length, pod breadth, pod weight and seeds per pod was evident in the present study. Wide variation in pod length was reported by Resmi (1998) and Vidya (2000) in yard long bean and Sobha and Vahab (1998), Ajith (2001), Anbuselvam *et al.* (2000) and Philip (2004) in cowpea.

Reports of high variability for pod breadth and pod weight in yard long bean was supported by Resmi (1998) and Vidya (2000) and seeds per pod by Resmi (1998) and Vidya (2000) in yard long bean and Sobha and Vahab (1998), Ajith (2001), Anbuselvam *et al.*(2001) and Philip (2004) in cowpea.

Existence of high variability for 100 seed weight noted in yard long bean in the present study was supported by Resmi (1998) in yard long bean and Sobha and Vahab (1998), Dwivedi *et al.* (1999), Ajith (2001), Anbuselvam *et al.* (2000) and Philip (2004) in cowpea.

A wide range of variation in crude protein content was also noticed in the study which was supported by Aghora *et al.* (1994) in cowpea and Resmi (1998) in yard long bean.

The results indicated that there is ample scope for selection based on plant types with respect to pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, pod breadth, seeds per pod and 100-seed weight for developing high yielding varieties.

### 5.1.2 Genetic Parameters

#### *5.1.2.1 Coefficient of Variation*

Variability is also expressed as the coefficient of variation. Coefficient of variation, phenotypic (PCV) and genotypic (GCV) are

better indices for comparison of characters with different units of measurements. The GCV provides a valid basis for comparing and assessing the range of genetic diversity for quantitative characters and PCV measures the extent of total variation. In the present study GCV and PCV for all the characters are presented in Fig. 2.

In the present study, a high PCV was recorded for dry weight of roots per plant, pod yield per plant, pod clusters per plant, pods per plant and pods per cluster while a low PCV was shown by crop duration and days to first harvest.

High PCV for pod yield per plant observed in this study is supported by similar findings of Rajaravindran and Das (1997), Vardhan and Savithramma (1998a), Hazra *et al.* (1999), Selvam *et al.* (2000), Nehru and Manjunath (2001), Narayanankutty *et al.* (2003), Pal *et al.* (2003), Vineetakumari *et al.* (2003) and Philip (2004)in cowpea and Vidya (2000) in yard long bean.

In the present study pod clusters per plant had very high estimates of PCV. Similar results were reported by Sawant (1994), Backiyarani and Nadarajan (1996), Rangaiah *et al.* (1999), Ajith (2001), Nehru and Manjunath (2001) and Vineetakumari *et al.* (2003).

PCV for pods per plant was high in the present study supported by the findings of Sawant (1994), Backiyarani and Nadarajan (1996), Rangaiah *et al.* (1999), Selvam *et al.* (2000), Nehru and Manjunath (2001), Kutty *et al.* (2003), Pal *et al.* (2003), Vineetakumari *et al.* (2003) and Philip (2004) in cowpea. Similarly, high PCV for pods per cluster recorded in this study was supported by Vidya (2000) in yard long bean. Low PCV for days to first harvest was reported by Sobha (1994) and Ajith (2001) in cowpea.

GCV is a better tool to understand useful variability, as it is free from the environmental component affecting variability. Dry weight of

roots per plant, pod yield per plant, pod clusters per plant, pods per plant and pods per cluster expressed high values of GCV, while low values were shown by days to 50 per cent flowering, days to first harvest and length of harvest period.

In the present study, pod yield per plant had very high estimates of GCV. Similar results were reported by the Rajaravindran and Das (1997), Vardhan and Savithramma (1998a), Hazra *et al.* (1999), Kalaiyarasi and Palanisamy (2000), Selvam *et al.* (2000), Kutty *et al.* (2003), Pal *et al.* (2003), Vineetakumari *et al.* (2003) and Philip (2004) in cowpea and Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean

GCV for pod clusters per plant was also high in the present study which was supported by the findings of Sawant (1994), Backiyarani and Nadarajan (1996), Ajith (2001) and Vineetakumari *et al.* (2003) in cowpea.

The study also revealed high estimates of GCV for pods per plant Sawant (1994), Backiyarani and Nadarajan (1996), Kalaiyarasi and Palanisamy (2000), Pournami (2000), Selvam *et al.* (2000), Kutty *et al.* (2003), Pal *et al.* (2003), Vineetakumari *et al.* (2003) and Philip (2004) supported the present findings. A high GCV recorded for pods per cluster was supported by Vidya (2000) in yard long bean. Low GCV for crop duration was reported by Ajith (2001) in cowpea.

High PCV as well as high GCV were observed for pod yield per plant, pod clusters per plant, pods per plant. This suggests the scope for improvement of these characters through selection. Comparatively low GCV for days to first harvest and crop duration indicating presence of low variability and that limiting the scope for further improvement through selection.

### *5.1.2.2 Heritability and Genetic Advance*

While evaluating more than one character their interrelations also have to be worked out. The parameters like heritability and genetic advance are unavoidable. The phenotypic variance which is due to genotypic variance is expressed by heritability. The magnitude of improvement of selection programme is detected by genetic advance. High heritability together with high genetic advance is an important requirement for selection programme. The estimates of heritability and genetic advance as percentage of mean of various characters expressed in Fig.3

High heritability estimates recorded for all characters except days to 50 per cent flowering, days to first harvest, length of harvest period and pod breadth which had moderate heritability. Among yield traits heritability is maximum for pod clusters per plant followed by pod weight dry weight of roots per plant, pod yield per plant, pods per plant, fresh weight of shoots per plant, 100 seed weight, main stem length, dry weight of shoot per plant, fresh weight of roots per plant, pod length, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant, seeds per pod, pods per cluster, primary branches per plant and crop duration. Among the biochemical traits heritability was maximum for crude protein content followed by total phenols and crude fibre content.

High heritability for primary branches per plant in the present study is in agreement with the findings of Vardhan and Savithramma (1998a), Ajith (2001), Pal *et al.* (2003) and Philip (2004) in cowpea.

Studies by Vidya (2000) in yard long bean and Ajith (2001) in cowpea supports the high heritability estimate for main stem length. High heritability for pod clusters per plant seen in the present investigation is in accordance with the reports from Sawant (1994), Ajith (2001) and Vineetakumari *et al.* (2003) in cowpea and Resmi (1998) and Vidya (2000) in yard long bean

High estimates of heritability for pods per plant recorded in the study was supported by Sawant (1994), Mathur (1995), Kalaiyarasi and Palanisamy (2000), Nehru and Manjunath (2001), Kutty *et al.* (2003), Pal *et al.* (2003), Vineetakumari *et al.* (2003) and Philip (2004) in cowpea and Pournami (2000) and Vidya (2000) in yard long bean.

In the present investigation pod yield per plant exhibited high heritability which is in agreement with reports by Sobha (1994), Backiyarani and Nadarajan (1996), Rajaraveendran and Das (1997), Vardhan and Savithramma (1998a), Hazra *et al.* (1999) and Kutty *et al.* (2003) in cowpea and Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

Reports of Vidya (2000) in yard long bean and Philip (2004) ) in cowpea supports the high heritability values recorded for pods per cluster in the present study. Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean and Sobha (1994), Hazra *et al.* (1999), Rangaiah and Mahadevu (1999), Ajith (2001) and Kutty *et al.* (2003) in cowpea reported high heritability values for pod weight. This is in accordance with the present findings.

High heritability for pod length noticed in this study is supported by similar results reported by Sudhakumari (1993), Sawant (1994), Mathur (1995), Hazra *et al.* (1999), Ajith (2001) and Philip (2004) in cowpea and Sreekumar *et al.* (1996) in yard long bean.

High heritability for seeds per pod seen in the present investigation is in accordance with the reports of Siddique and Gupta (1991), Mathur (1995) Ajith (2001) and Philip (2004) in cowpea and Sreekumar *et al.* (1996) in yard long bean.

High heritability recorded in 100 seed weight, in the present study was supported by Savithramma (1992), Sudhakumari (1993), Sawant (1994), Rewale *et al.* (1995), Sreekumar (1995), Backiyarani and

Nadarajan (1996), Kalaiyarasi and Palanisamy (2000) and Philip (2004) in cowpea and Resmi (1998) in yard long bean.

Earlier reports of high heritability for nodules per plant (Mandal *et al.* 1999 in cowpea), weight of nodule (Sreekumar, 1995 in cowpea), and total phenols (Rameshkumar *et al.*, 2002 in cowpea) supports the findings of the present investigation. Studies by Resmi (1998) in yard long bean supports the high heritability estimates for crude protein content and crude fibre content.

High genetic advance was noted for fresh weight of shoot per plant, dry weight of shoots per plant, pod clusters per plant, pods per plant, pod yield plant, pods per cluster, pod weight, pod length, 100 seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant and crude protein content.

The high genetic advance of pod clusters per plant noted in this study is in agreement with the findings of Sawant (1994), Ajith (2001) and Vineetakumari *et al.* (2003) in cowpea and Resmi (1998) and Vidya (2000) in yard long bean.

High genetic advance of pods per plant recorded in the present investigation is in accordance with findings of Sawant (1994), Mathur (1995), Sreekumar (1995), Kalaiyarasi and Palanisamy (2000), Nehru and Manjunath (2001), Kutty *et al.* (2003) and Vineetakumari *et al.* (2003) in cowpea and Pournami (2000) and Vidya (2000) in yard long bean.

High genetic advance for pod yield per plant reported in this investigation is supported by Sobha (1994), Backiyarani and Nadarajan (1996), Vardhan and Savithramma (1998a), Hazra *et al.* (1999), and Kutty *et al.* (2003) in cowpea, Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

Earlier reports of high genetic advance for pods per cluster (Vidya, 2000 in yard long bean), pod weight (Sobha, 1994; Hazra *et al.*, 1999; Rangaiah and Mahadev, 1999; Ajith, 2001 and Kutty *et al.*, 2003 in cowpea and Resmi, 1998; Pournami, 2000 and Vidya, 2000 in yard long bean), pod length (Sudhakumari, 1993; Sawant, 1994; Sobha, 1994; 1996; Hazra *et al.*, 1999 and Ajith 2001 in cowpea and Sreekumar *et al.*,1996 in yard long bean) supports the findings in this investigation.

The high genetic advance for 100 seed weight is in accordance with the findings by Sudhakumari (1993), Sawant (1994), Rewala *et al.* (1995), Backiyarani and Nadarajan (1996) and Kalaiyarasi and Palanisamy (2000) in cowpea.

High heritability and high genetic advance of characters is indicative of additive gene action suggesting the possibility of genetic improvement of those characters through selection. The characters fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield plant, pods per cluster, pod weight, pod length, 100 seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant and crude protein content had high heritability coupled with high genetic advance.

In the present study pod clusters per plant recorded high heritability coupled with high genetic advance indicating the presence of additive gene action. Similar results were reported by Sawant (1994), Ajith (2001) and Vineetakumari *et al.* (2003) for pod clusters per plant in cowpea and Resmi (1998) and Vidya (2000) in yard long bean.

High heritability coupled with high genetic advance recorded for pods per plant was also supported by the reports Sawant (1994), Kalaiyarasi and Palanisamy (2000), Nehru and Manjunath (2001), Kutty *et al.* (2003) and Vineetakumari *et al.* (2003) in cowpea and Pournami (2000) and Vidya (2000) in yard long bean.

In the present investigation high heritability coupled with high genetic advance was recorded for pod yield per plant. It was supported by Sobha (1994), Backiyarani and Nadarajan (1996), Vardhan and Savithramma (1998a), Hazra *et al.* (1999) and Kutty *et al.* (2003) in cowpea and Resmi (1998), Pournami (2000), Vidya (2000) in yard long bean.

The high heritability coupled with high genetic advance for pod weight is in accordance with the findings of Sobha (1994), Hazra *et al.* (1999), Rangaiah and Mahadev (1999), Ajith (2001) and Kutty *et al.* (2003) in cowpea, Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

The high heritability coupled with high genetic advance of pods per cluster is in agreement with the findings of Vidya (2000) in yard long bean.

In the present investigation pod length recorded high heritability coupled with high genetic advance. Similar results were reported by Sudhakumari (1993), Sawant (1994), Sobha (1994), Hazra *et al.* (1999) and Ajith (2001) in cowpea and Sreekumar *et al.* (1996) in yard long bean.

High heritability coupled with high genetic advance was recorded for 100 seed weight recorded in this study is supported by Sudhakumari (1993), Sawant (1994), Rewala *et al.* (1995), Backiyarani and Nadarajan (1996) and Kalaiyarasi and Palanisamy (2000) in cowpea.

The present study suggests preponderance of additive gene effects for important yield traits *viz.*, pod clusters per plant, pods per plant, pod yield plant, pods per cluster, pod weight, pod length and 100 seed weight in cowpea.

### 5.1.3 Correlation Studies

Correlation provides information on the nature and extent of association between characters in a population. The component character

always show interrelationship. When the breeder applies selection on a trait the population under selection is not only improved for that trait but also improve in respect of other characters associated with it. This facilitates simultaneous improvement of two or more characters. Therefore analysis of yield in terms of genotypic and phenotypic correlation coefficient of component characters leads to the understanding of characters that can form the basis of selection. The genotypic correlation between the characters provides a reliable measure of genetic association between characters and helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1981). Hence correlation between green pod yield and other characters and their inter-correlations were estimated.

### *5.1.3.1 Correlation between Yield and other Characters*

In the present study pod yield per plant exhibited high positive genotypic correlation with pods per plant, pod clusters per plant, days to first harvest, pod weight, days to 50 per cent flowering, seeds per pod, pod length, total phenols, pod breadth and 100 seed weight.

The positive genotypic association of yield per plant with number of pods per plant observed in this study was supported by Sawant (1994), Singh *et al.* (1998), Vardhan and Savithramma (1998b), Ajith (2001), Ushakumari *et al.* (2001), Kutty *et al.* (2003), Parmer *et al.* (2003), Vineetakumari *et al.* (2003), Peksen (2004) and Philip (2004) in cowpea and Sreekumar *et al.* (1996), Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

A positive correlation of pod clusters per plant with yield per plant was noticed in the present study. Similar results were reported by Sawant (1994), Tamilselvam and Das (1994), Singh *et al.* (1998), Ajith (2001), Parmer *et al.* (2003), Vineetakumari *et al.* (2003) and Philip (2004) in cowpea.

The earlier reports high positive correlation of yield per plant with days to first harvest (Sobha, 1994 in cowpea), pod weight (Misra *et al.*, 1994; Sobha, 1994; Chattopadhyay *et al.*, 1997; Ajith, 2001; Kutty *et al.*, 2003 and Peksen, 2004 in cowpea and Resmi, 1998; Pournami, 2000 and Vidya,2000 in yard long bean), days to 50 per cent flowering (Tamilselvam and Das, 1994) and seeds per pod (Sreekumar *et al.*, 1996 and Pournami 2000 in yard long bean and Kar *et al.*, 1995; Chattopadhyay *et al.*, 1997; Kalaiyarasi and Palanisamy, 2000 and Philip, 2004 in cowpea) supports the findings in this investigation.

The positive genotypic association of yield per plant with pod breadth observed in this study was supported by Sobha (1994), Vardhan and Savithramma (1998b), Ajith (2001) and Peksen (2004) in cowpea.

The high positive genotypic correlation of yield per plant with 100 seed weight noted in this study is in accordance with the findings by Sudhakumari (1993), Sawant (1994), Sobha (1994), Tamilselvam and Das (1994), Chattopadhyay *et al.* (1997), Kalaiyarasi and Palanisamy (2000), Vineetakumari *et al.* (2003) and Philip (2004) in cowpea.

Significant positive phenotypic and genotypic correlation of yield per plant with pods per plant, pod clusters per plant, days to first harvest, pod weight and seeds per pod imply that selection of these characters would lead to simultaneous improvement of pod yield per plant in yard long bean.

### *5.1.3.2 Correlation among the Yield Components*

Knowledge of the interrelationship among the yield components is necessary since it provides more reliable information for effective selection based on yield components.

Pod clusters per plant had high positive genotypic correlation with pods per plant reported in this study was supported by similar findings by Naidu *et al.* (1996), Parmer *et al.* (2003) and Philip (2004) in cowpea.

In this study pod length expressed high positive genotypic correlation with seeds per pod. This was in agreement with the reports by Mathur (1995), Chattopadhyay *et al.* (1997), Parmer *et al.* (2003) and Philip (2004) in cowpea and Sreekumar *et al.* (1996) in yard long bean.

Positive genotypic correlation between pod length and 100 seed weight was evident in the present study. Singh and Verma (2002) reported positive genotypic correlation of pod length with 100 seed weight in cowpea.

Positive genotypic association of pod length and pod breadth observed in this study was supported by the reports of Pournami (2000), Vidya (2000)in yard long bean.and Xiao-Jie *et al.* (2004) in cowpea.

The present study suggested high negative genotypic correlation between pod breadth and seeds per pod which was in conformity with earlier reports of Mathur (1995) in cowpea and Pournami (2000) and Vidya (2000) in yard long bean.

In the present study number of seeds per pod had high negative genotypic correlation with plant height which was supported by similar findings by Apte *et al.* (1991) in cowpea.

Pod length expressed highly positive genotypic correlation with pod weight reported in the present investigation is in agreement with the reports by Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

The present study suggested that pod clusters per plant had positive correlation with days to first harvest and negative correlation with length of harvest period. A similar report from Pournami (2000) in yard long bean supports this.

### 5.1.4 Path Analysis

The path analysis reveals whether the association of the component characters with yield is due to their direct effect on yield or is a

consequence of their indirect effect via some other trait(s). Thus path coefficient analysis helps in partitioning the genotypic correlation coefficient into direct and indirect effects of the component characters on the yield, on the basis of which improvement programme can be devised effectively. If the correlation between yield and any of its components is due to the direct effect, it reflects a true relationship between them and selection can be practiced for such a character in order to improve yield. But if correlation is mainly due to indirect effect of the character through another component trait, the breeder has to select the latter trait through which the indirect effect is exerted.

In the present investigation, the highest positive and direct effect on yield was exhibited by pods per plant followed by pod weight, seeds per pod, days to first harvest, days to 50 per cent flowering and pod clusters per plant while pod length and total phenols had negative direct effects.

High direct effect of pods per plant is in accordance with earlier findings of Sawant (1994), Chattopadhyay *et al.* (1997), Singh *et al.* (1998), Vardhan and Savithramma (1998b), Ajith (2001), Kalaiyarasi and Palanisamy (2002), Ushakumari *et al.* (2001), Kutty *et al.* (2003), Parmer *et al.* (2003), Subbaiah *et al.* (2003), Venkatesan *et al.* (2003a), Vineetakumari *et al.* (2003) and Philip (2004) in cowpea and Resmi (1998), Pournami (2000) and Vidya (2000) in yard long bean.

The positive direct effect of pod weight on yield as observed in the study was supported by Sobha (1994), Chattopadhyay *et al.* (1997), Ajith (2001), Kutty *et al.* (2003) and Subbiah *et al.* (2003) in cowpea and Resmi (1998)and Vidya (2000) in yard long bean.

In the present investigation seeds per pod showed a positive direct effect on yield. Similar results were obtained by Sawant (1994), Chattopadhyay *et al.* (1997), Singh and Singh (1997), Kapoor *et al.* (2000b), Bastian *et al.* (2001), Kalaiyarasi and Palanisamy (2002), Parmer

*et al.* (2003), Subbiah *et al.* (2003), Venkatesan *et al.* (2003) and Philip (2004) in cowpea.

The positive direct effect of days to 50 per cent flowering found in this study is in agreement with the findings of Sawant (1994) in cowpea and Pournami (2000) in yard long bean.

Pod clusters per plant showed a positive direct effect on yield in the present investigation. Similar results were obtained by Sawant (1994), Singh and Singh (1997), Parmer *et al.* (2003), Venkatesan *et al.* (2003a) and Vineetakumari *et al.* (2003) in cowpea.

Pod length had negative direct effect on yield even though the correlation with the yield is positive (Sawant, 1994 and Kalaiyarasi and Palanisamy, 2002 in cowpea).

From the present study it is evident that selection of genotypes based on pods per plant and pod weight can be effective for improving yield of the crop.

The residue obtained was low indicating that the component characters taken for path analysis well explained the cause and effect system.

### 5.1.5 Genetic Divergence

The importance of genetic diversity of parents in hybridization programme has been emphasised by many workers. The more diverse the parents with in a reasonable range, higher would be the chances of improving the characters in question. Mahalanobis $D^2$ statistic has been found to be a powerful tool in the hands of plant breeders to assess the degree of relationship among the genotypes and to group them based on their phenotypic expression.

Following Mahalanobis $D^2$ statistic (Mahalanobis, 1936), the 30 genotypes were grouped into eight clusters. The maximum number of genotypes (10) were included in Cluster I, followed by Cluster II (7),

Cluster V (4), Cluster III (3) and Cluster IV (3). The Clusters VI, VII and VIII had only one genotype in them.

Maximum divergence was shown between the Clusters IV and VI, while the minimum divergence between clusters III and VIII. The intracluster distance was highest for the Cluster I. Among the nine characters considered pod yield per plant contributed maximum towards divergence.

Grouping of genotypes into different clusters did not reflect the geographical origins of the varieties. Similar results were reported by Jindal (1985), Rewale *et al.*(1996) and Tyagi *et al.* (1999) in cowpea.

### 5.1.6 Selection Index

Selection of genotypes based on a suitable index is highly efficient in any breeding programme. An estimation of discriminant function based on reliable and effective characters is a valuable tool for the practical plant breeder. Superior genotypes can be selected from a collection of germplasm using a selection index employing the discriminant function.

In the present study the selection index for the genotype was computed on the basis of nine characters namely days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod yield per plant, pod weight, pod length, seeds per pod and total phenols.

The maximum selection index value obtained for VS16 and minimum for VS7. The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in the $D^2$ analysis. The genotype in Cluster VI (VS86) topped first, while the genotype in Cluster IV (Kayamkulam local, Kollengode local and Palakkad local) and Cluster V (Malappuram local-2, Ookodu local-1 and Kasargode local) with the least index values.

## 5.2 SCREENING OF GENOTYPES FOR FUSARIUM WILT RESISTANCE

Incidence of pests and diseases is considered to be a major limiting factor affecting the production of yard long bean. Among diseases, Fusarium wilt is known to cause serious losses. In this respect breeding for disease resistance assumes utmost importance. Screening of genotypes to identify the source of resistance to Fusarium wilt, so that we can develop high yielding Fusarium wilt resistant variety of yard long bean.

### 5.2.1 Disease Intensity

A wide range of disease intensity percentage was observed which indicated sufficient variability of resistance among the genotypes. There exists high scope of improvement for selection. The disease intensity ranged from 13.83 to 65. The lowest index was observed for the accession Thiruvananthapuram local-1 which was grouped as moderately resistant. Maximum disease intensity recorded was 65 for accession Malappuram local-1. Among the accessions screened two were moderately resistant, 18 were moderately susceptible and 10 susceptible to Fusarium wilt.

Variability in the degree of susceptibility among genotypes against Fusarium wilt has been earlier reported by Orton (1902), Armstrong and Armstrong (1950), Hare (1953), Hare (1957), Cook (1978), Shihata *et al.* (1988), Shihata *et al.* (1989a) in cowpea and Sala *et al.* (2001) and Cavalcanti *et al.* (2002) in bean. No studies available on the screening of Fusarium in cowpea under Kerala condition. Further studies have to be conformed by repeating the experiment.

Comparing yield with disease intensity, the genotypes Thiruvananthapuram local-1 and Thiruvananthapuram local-3 recorded high yield with moderately resistant to Fusarium wilt, while VS 86, Malika and Varuvila local-1 showed high yield with moderately susceptibility. So these genotypes can be used as parents for further crop improvement programme for Fusarium wilt resistance.

# *Summary*

# 6. SUMMARY

The present investigation was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2003-2005. The present study aimed at evaluating a collection of yard long bean genotypes for yield and Fusarium wilt resistance. The field study was conducted in two experiments Experiment-I for evaluation and screening of genotypes for yield and yield components and Experiment-II for screening of Fusarium wilt disease resistance.

In experiment-I, 30 genotypes of yard long bean were collected from different agro climatic regions of Kerala were evaluated for yield and yield components in a field experiment in Randomised Block Design with three replications. Observations recorded on various characters namely days to 50% flowering, days to first harvest, length of harvest period, crop duration, primary branches per plant, main stem length, fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, pod breadth, seeds per pod, seed colour, 100-seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant, crude fibre content, crude protein content, peroxidase, poly phenol oxidase and total phenols.

Significant difference existed among the genotypes for all the characters as revealed by analysis of variance. The days to 50 per cent flowering and days to first harvest was minimum for genotype Palakkad local. The maximum length of harvest period noted for Kasaragod local. The minimum crop duration seen in genotype CPCH-1 which was on par with Palakkad local and Ookodu local-1.

The genotype CPCH-1 recorded the maximum pod clusters per plant. Highest Pods per plant was for genotype Varuvila local-2. The pod yield per plant was maximum for VS86. Highest number of pods per

cluster was seen for genotype KMV-1. Pod weight was maximum for genotype VS27. Highest pod length was for genotype VS27, which was on par with Thiruvananthapuram local-1 and Thiruvananthapuram local-4. Pod breadth was maximum in genotype VS27.

Seeds per pod was highest in genotype Thiruvananthapuram local-4 which was on par with VS86. Maximum 100 seed weight was noted in genotype Thiruvananthapuram local-2 which was on par with VS27. Dry weight of roots per plant was highest for genotype Thiruvananthapuram local-2. Vellayani local recorded a high value of total phenols.

In this study high PCV was recorded for dry weight of roots per plant, pod yield per plant, pod clusters per plant, pods per plant and pods per cluster. High GCV was recorded for dry weight of roots per plant, pod yield per plant, pod clusters per plant, pods per plant and pods per cluster which indicates high genetic variability and better scope for improvement of these characters through selection. Comparatively low coefficient of variation was observed for crop duration and days to 50 per cent flowering indicating low variability and thus limiting the scope for further improvement through selection.

High heritability estimates were recorded for crop duration, primary branches per plant, main stem length, fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, seeds per pod, 100-seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant, crude fibre content, crude protein content and total phenols .

High genetic advance was noted for fresh weight of shoot per plant, dry weight of shoot per plant, pod clusters per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, 100-seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant

and crude protein content. Days to 50 per cent flowering, days to first harvest, length of harvest period, crop duration, primary branches per plant, main stem length, pod breadth, seeds per pod, crude fibre content and total phenols had low genetic advance.

Fresh weight of shoot per plant, dry weight of shoot per plant, pod cluster per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, 100 seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant and crude protein content had high heritability coupled with genetic advance

In the present study pod yield per plant showed significant positive genotypic correlation with pods per plant, pod clusters per plant, days to first harvest, pod weight, days to 50 per cent flowering, seeds per pod, pod length, 100-seed weight and total phenols.

Pod yield per plant was taken as the dependent character and path analysis was done. Days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod weight, seeds per pod had positive direct effect while pod length and total phenols had negative direct effect.

The maximum direct effect on yield was shown by pods per plant followed by pod weight, seeds per pod, days to first harvest, days to 50 per cent flowering, pod cluster per plant, total phenols and pod length. Pod length and total phenols had positive correlation estimates and negative direct effects. A positive correlation as well as positive direct effect was noted for days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod weight and seeds per pod.

Following Mahalanobis $D^2$ statistic, the 30 genotypes were grouped into eight clusters. Maximum genotypes (10) were included in Cluster I followed by Cluster II (7), Cluster V (4), Cluster III (3) and Cluster IV (3). Clusters VI, VII and VIII had one genotype each. Maximum divergence was

shown between Cluster IV and VI, while it was minimum between clusters III and VIII. The intra cluster distance was highest for the Cluster I.

Selection indices for 30 genotypes were worked out on the basis of yield and eight component characters *viz*., days to 50 per cent flowering, days to first harvest, pod clusters per plant, pods per plant, pod yield per plant, pod weight, pod length, seeds per pod and total phenol. Maximum index values were obtained for VS 86 followed by Thiruvananthapuram local-1 and Vella valli payar. The minimum estimates were recorded for Kayamkulam local, Malappuram local-2 and Kollengode local. The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in the $D^2$ analysis. The genotype in Cluster VI (VS 86) topped the list, while the genotype in Cluster IV (Kayamkulam local, Kollengode local and Palakkad local) and Cluster V (Malappuram local-2, Ookodu local-1 and Kasargode local) with the least index values.

The disease intensity of Fusarium wilt was ranged from 13.83 to 65 per cent. The lowest disease intensity was observed for Thiruvananthapuram local-1, which was grouped as moderately resistant. Maximum disease intensity was recorded for Malappuram local-1 which was grouped as susceptible. Among the accessions screened, 2 genotypes were moderately resistant, 18 genotypes were moderately susceptible and 10 genotypes were susceptible to Fusarium wilt. The accessions found to be moderately resistant were Thiruvananthapuram local-1 and Thiruvananthapuram local-3. The susceptible accessions were Sarika, Malappuram local-1, Kalliyoor local, Palapoor local-3, Vella valli payar, Palapoor local-2, Palakkad local, Thrissur local, Kasargode local and Lola.

Comparing yield with disease intensity, the genotypes Thiruvananthapuram local-1 and Thiruvananthapuram local-3 recorded high yield with moderately resistant to Fusarium wilt, while VS 86, Malika and Varuvila local-1 showed high yield with moderately susceptibility. So these genotypes can be used as parents for further crop improvement programme for Fusarium wilt resistance.

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*Original not seen

# GENETIC VARIABILITY FOR YIELD AND FUSARIUM WILT RESISTANCE IN YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt)

**Madhu Kumar, K.**

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**Department of Plant Breeding and Genetics**
**COLLEGE OF AGRICULTURE**
**VELLAYANI, THIRUVANANTHAPURAM 695 522**

# ABSTRACT

A research programme was carried at the Department of Plant Breeding and Genetics, Collège of Agriculture, Vellayani during the period 2003-2005 with the object of assessing the genetic variability in yard long bean genotypes for yield and Fusarium wilt resistance. Data for the investigation were collected from two field experiments.

Thirty genotypes of yard long bean were screened and evaluated for yield and related characters in a field experiment in Randomised Block Design with three replications. Analysis of variance revealed significant differences among the genotypes for all the twenty-eight characters studied. Genotypic and phenotypic coefficient of variation was high for dry weight of roots per plant, pod yield per plant, pod clusters per plant, pods per plant and pods per cluster. Fresh weight of shoot per plant, dry weight of shoot per plant, pod cluster per plant, pods per plant, pod yield per plant, pods per cluster, pod weight, pod length, 100 seed weight, fresh weight of roots per plant, dry weight of roots per plant, nodules per plant, fresh weight of nodules per plant, dry weight of nodules per plant and crude protein content had high heritability coupled with genetic advance.

Pod yield per plant showed significant positive correlation with Pods per plant, pod clusters per plant, days to first harvest, pod weight, days to 50 per cent flowering, seeds per pod, pod length, 100-seed weight and total phenols at genotypic level. Path analysis revealed that number of pods per plant and pod weight were the primary yield contributing characters due to their high direct effect on pod yield.

Mahalanobis $D^2$ analysis clustered the 30 genotypes into eight clusters. Cluster I formed the largest cluster with 10 genotypes while Clusters VI, VII and VIII had one genotype each. The genetic distance was maximum between Cluster IV and VI, while the minimum divergence

between clusters III and VIII. The intra cluster distance was highest for the Cluster I. Selection index analysis revealed that genotype VS 86 attained the maximum selection index value followed by Thiruvananthapuram local-1 and Vella valli payar and the minimum estimates were recorded for Kayamkulam local, Malappuram local-2 and Kollengode local.

In the field screening program for Fusarium wilt resistance all the 30 yard long bean genotypes were evaluated on the basis of disease intensity percentage. Genotypes showed significant differences in the degree of disease susceptibility. Among the genotypes, two genotypes were moderately resistant, 18 genotypes were moderately susceptible and 10 genotypes were susceptible to Fusarium wilt. The accessions found to be moderately resistant were Thiruvananthapuram local-1 and Thiruvananthapuram local-3. The susceptible accessions were Sarika, Malappuram local-1, Kalliyoor local, Palapoor local-3, Vella valli payar, Palapoor local-2, Palakkad local, Thrissur local, Kasargode local and Lola.

Comparing yield with disease intensity, the genotypes Thiruvananthapuram local-1 and Thiruvananthapuram local-3 recorded high yield with moderately resistant to Fusarium wilt, while VS 86, Malika and Varuvila local-1 showed high yield with moderately susceptibility. So these genotypes can be used as parents for further crop improvement programme for Fusarium wilt resistance.