LEGUME POD BORER RESISTANCE AND GENETIC DIVERGENCE IN DOMESTIC GERMPLASM OF YARD-LONG BEAN (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.)

By

VIDYA. C.

THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING AND GENETICS)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

2000

DECLARATION

I hereby declare that this thesis entitled **"Legume pod borer resistance and genetic divergence in domestic germplasm of yard-long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.)"** 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
4-9-2000

VIDYA. C.

CERTIFICATE

Certified that this thesis entitled **"Legume pod borer resistance and genetic divergence in domestic germplasm of yard-long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.)"** is a record of research work done independently by **Ms. Vidya. C.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
4-9-2000

Dr. SUNNY K. OOMMEN
(Chairman, Advisory Committee)
Associate Professor
Department of Plant Breeding and Genetics,
Collge of Agriculture, Vellayani

Approved by

Chairman :

Dr. SUNNY K. OOMMEN

Members :

1. Dr. P. MANIKANTAN NAIR

2. Dr. VIJAYARAGHAVA KUMAR

3. Dr. THOMAS BIJU MATHEW

External Examiner :

Dedicated

to my beloved

Parents

ACKNOWLEDGEMENT

I wish to place on record my heartfelt gratitude and indebtedness to:

Dr. Sunny K. Oommen, Associate Professor, Department of Plant Breeding and Genetics and Chairman of the Advisory Committee for his expert guidance, timely help, keen interest, constant encouragement and whole hearted co-operation during the entire course of study and research work and in preparation of the thesis.

Dr. P. Manikantan Nair, Professor and Head, Department of Plant Breeding and Genetics for his authentic advice, valuable suggestions and critical scrutiny of the manuscript of the thesis.

Dr. Vijayaraghava Kumar, Associate Professor, Department of Agricultural Statistics for his genuine interest, expert guidance and whole hearted help in statistical analysis of the data and interpretation of results.

Dr. Thomas Biju Mathew, Assistant Professor, Department of Agricultural Entomology for his critical suggestions, ever willing help, sincere guidance and co-operation throughout the course of this investigation.

Dr. V.K. Venugopal, Professor and Head and Dr. Thomas George, Assistant Professor, Department of Soil Science and Agricultural Chemistry for rendering timely help and kind co-operation in carrying out the chemical analysis.

All teaching staff and students of the Department of Plant Breeding and Genetics for their support and co-operation at various stages of the course of the study.

All the non teaching staff and labourers of the Department of Plant Breeding and Genetics for their sincere help and co-operation during the entire field work.

Mr. C.E. Ajith Kumar, Junior Programmer, Department of Agricultural Statistics, for the help in statistical analysis of the data.

My friends Sindu, Sharu and Salini for their selfless help and moral support throughout the course of study and research.

My heartful thanks to Deepthi for her countless help and support and to Preeta chechi, Radhika chechi, Salu and Iswara Prasad for all their encouragement and co-operation throughout the completion of the course.

My father, mother and sister for their blessings, constant encouragement, sincere help and support without which I could not have completed this work.

I thank M/s. Athira Computers, Kesavadasapuram, Thiruvananthapuram for typesetting the thesis with due care and promptness.

Kerala Agricultural University for granting me the KAU Junior Fellowship.

Above all to God Almighty for his blessings which gave me the strength to pursue this endeavour to completion.

Vidya C.

CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

1. INTRODUCTION

Yard-long bean, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc. is a distinct form of cowpea grown as a vegetable crop in southern Asia and the Far East for its immature pods which are used as the vegetable. The crop is most widely cultivated in India, Indonesia, Philippines and Srilanka (Chakraborty, 1986). It is a climbing annual having long, pendant pods which are inflated when young and is quite different in morphology from cowpea grown for grain purpose. The fleshy, tender pods are rich in proteins, minerals, vitamins and dietary fibre. The crop grown throughout India has its most extensive cultivation in Kerala. Cultivation of the crop from ancient times in Kerala resulted in a rich domestic germplasm comprising of locally adapted traditional cultivars and land varieties. The richness of this indigenous germplasm offers immense scope for crop improvement in yard-long bean. Despite its importance as a common vegetable crop, systematic research efforts to improve the crop capitalizing on the existing variability in traditional cultivars has been meagre.

The escalating demand for the vegetable pods of cowpea has resulted in round the year cultivation of the crop. This has aggravated pest and disease problems. Heavy and frequent insecticide application is usually done to protect the crop from insect pests. Yard-long bean being a crop with protracted flowering and fruiting habit, the problem posed by flower and / or fruit feeding insects is very severe. Among such pests, legume pod borer, *Maruca vitrata* (Fab.) stands out on account of its tremendous potential to damage yard-long bean crop in the event of serious infestation. The major feeding sites of the larvae of this pyralid moth are flowers and pods. In view of the environmental and health hazards associated with chemical protection, legume pod borer control strategies that reduce the dependence on insecticides have to be devised. Host plant resistance assumes importance from this view point. Plant resistance to insect pests is often found in traditional varieties and unimproved germplasm (Saxena and Khan, 1991). Hence a search for plant resistance should start with a screening of such material. Various techniques are available for evaluating plant resistance to insect pests. An assessment of plant resistance through measurement of insect damage employing damage criteria that reflect the ultimate crop loss is a rational approach from the practical view point (Tingey, 1986).

Considering the above mentioned aspects, a research programme was undertaken with the broad objective of evaluating a collection of yard-long bean germplasm for yield and legume pod borer resistance. The programme aims at the identification of better yielding varieties and cultivars possessing high level of resistance to legume pod borer. Further, the study envisages the identification of promising parents for hybridization programmes for the genetic improvement of yard-long bean based on cluster analysis employing Mahalanobis D^2 statistic.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study involved evaluation of domestic germplasm of yard-long bean for vegetable pod yield and legume pod borer resistance. The literature pertinent to the study is organized and presented under different headings. Since the work done in yard-long bean appears to be scanty, this review covers the work done in cowpea in general.

2.1. Yield and yield components

2.1.1. Genetic variability, heritability and genetic advance

The preliminary step in any crop improvement programme is the selection of desirable genotypes. For effective selection, the basic requisite is the availability of an array of diverse genotypes. The larger the variability, the better are the chances of identifying superior genotypes. Information on the extent of variability in a population is very essential for the breeder to design his crop improvement programmes. The genetic parameters like coefficient of variation, heritability and genetic advance provide an exact picture of variability in a population.

Lakshmi and Goud (1977) observed wide variability for several characters among 12 varieties of cowpea. The genotypic coefficient of variation was high for plant height, pods per plant and 100-grain weight. Plant height and pod length had high heritability values. High genetic advance was obtained for pod length.

Angadi *et al.* (1978) studied variability for several characters among 50 genotypes of cowpea. 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, seed yield and 100-seed weight had high heritability estimates coupled with high estimates of genetic advance. Number of branches and seeds per pod exhibited high heritability with low genetic advance.

Rajendran *et al.* (1979) reported high heritability estimates for several characters like area of primary leaf, plant height, plant spread, days to first flowering, flowers per bunch, pod set per bunch, 100-seed weight, number of primary branches, number of seeds per pod and seed yield per plant in cowpea.

In a variability study on selected varieties of cowpea, Ramachandran *et al.* (1980) reported high variability for number of days to first harvest, internode length, weight of pods, seed number per pod, pods per plant and yield per plot. Highest genotypic coefficient of variation occurred for yield per plot followed by pod number per plant and internode length. Heritability was highest for number of days to flowering followed by days to first harvest. Genetic advance was maximum for seed number per pod followed by yield per plot and pods per plant.

Jana *et al.* (1982) studied variability among 11 cowpea varieties and found high genotypic coefficient of variation for vegetable yield and pods per plant. Heritability and genetic advance were high for 1000-grain weight and days to flowering.

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 pod per plant, pod length, number of grains per pod, days to maturity and 100-grain weight. High heritability was observed for all these characters. Number of pods per plant showed high genotypic coefficient of variation. Genetic gain was highest for number of pod clusters per plant and least for days to maturity.

Yap (1983) found the existence of substantial genetic variability among cowpea cultivars of Malaysia. High heritability was observed for pod length while pod yield and seed protein content showed low heritability.

In a study on genetic variability with 40 genotypes of cowpea, Dharmalingam and Kadambavanasundaram (1984) obtained high heritability for pod length (87.37 per cent), 100-seed weight (85.38 per cent) and harvest index (69.58 per cent).

High variability was observed by De Mooy (1985) in flowering, plant habit, number of pods per plant and seed characters in cowpea germplasm.

Variability studies with 49 cultivars of cowpea by Patil and Baviskar (1987) revealed 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 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 (90.94 per cent) followed by days to maturity and pod length.

In a study with 24 *V. sesquipedalis* genotypes, Ye and Zhang (1987) reported high heritability for pod length, flowering date and length of flowering period.

Sharma *et al.* (1988) reported maximum genotypic coefficient of variation for dry matter yield followed by plant height, green forage yield, pods per plant, seed weight and green pod yield in cowpea. Heritability ranged from 46.9 per cent for green pod yield to 98 per cent for days to 50 per cent maturity.

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. Both the estimates of heritability and genetic advance were high for plant height, number of seeds per pod and 100-grain weight.

In a variability study with 36 genotypes of cowpea, Thiyagarajan *et al.* (1989) recorded higher heritability estimates coupled with high genotypic coefficient of variation for plant height and seed yield per plant. A high estimate of heritability together with genetic advance was observed for plant height, clusters per plant, pods per plant, seeds per pod and seed yield per plant.

Roquib and Patnaik (1990) reported high heritability 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. These characters also had high estimates of genetic advance.

Siddique and Gupta (1991) worked out estimates of variability in cowpea and reported high genotypic and phenotypic coefficients of variation for pods per plant, plant height and seed yield. Heritability and genetic advance were also quite high for these characters.

Renganayaki and Sree Rengasamy (1992) found that both genotypic and phenotypic coefficients of variation were high for plant height and pods per plant. Genetic advance as percentage of mean was also high for plant height and pods per plant in cowpea.

Savithramma (1992) reported high genotypic coefficient of variation for seed weight per plant, 100-seed weight and petiole length. High heritability values were observed for plant height, pod length and 100-seed weight. High genetic advance was recorded for plant height, seed weight per plant and 100-seed weight.

Damarany (1994) reported high heritability for weight of seeds per plant (94.4 per cent), number of pods per plant (85.9 per cent) and 100-seed weight (83.3 per cent) in cowpea.

Ram *et al.* (1994) observed wide range of variability particularly for plant height and seed yield per plant in cowpea. High heritability and genetic advance were estimated for plant height, seed yield per plant and pods per plant.

Sawant (1994) 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 in cowpea.

Significant differences among 31 genotypes of bush type vegetable cowpea were observed by Sobha (1994). Pod weight and pod yield had high genotypic coefficient of variation. High heritability and genetic advance were observed for pod weight, pod yield, days to harvest, pod length and pod girth.

Rewale *et al.* (1995) studied variability and heritability in 70 diverse cowpea genotypes on 12 yield related traits and found that the estimates of heritability and genetic advance were high for 100-seed weight, plant height and harvest index.

Sreekumar (1995) observed high heritability for days to 50 per cent flowering, weight of 100 seeds and seed protein content in cowpea. Medium heritability was noticed for pod length and number of pods per plant and low heritability for plant dry weight and grain yield. Genetic advance as percentage of mean was high for number of pods per plant and 100-seed weight.

Backiyarani and Nadarajan (1996) studied variability on 10 yield related characters in 34 genotypes of cowpea and observed high phenotypic and genotypic coefficients of variation for leaf area index, number of pods per plant, number of clusters per plant and 100-seed weight. Heritability and genetic advance were high for 100-seed weight, harvest index, leaf area index and single plant yield.

Hazra *et al.* (1996) observed significant variability for several characters in vegetable cowpea including vine length, number of primary branches per plant, days to flowering, pods per plant, pod length, pod weight, seeds per pod, 100-seed weight and pod yield per plant.

Sreekumar *et al.* (1996) studied 18 vegetable cowpea genotypes and reported the highest genotypic coefficient of variation for green pod yield (45.06) followed by pod length (43.99). The relative magnitude of difference between phenotypic coefficient of variation and genotypic coefficient of variation was low for characters such as days to flower, days to first picking, pod length and seeds per pod indicating low degree of environmental influence. But this difference was high for characters like number of fruiting points, pods per plant and yield of green pods indicating high influence of environment on these characters. Pod length had the highest heritability value, followed by number of days to first picking, number of seeds per pod and days to flower. High genetic advance was obtained for pod length and number of seeds per pod.

Rajaravindran and Das (1997) studied variability in five yield related traits in seven vegetable cowpea genotypes and reported highest genotypic and phenotypic coefficient of variation for green pod yield. Days to maturity recorded 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. Number of pods per plant recorded lowest heritability. Genetic advance was high for green pod yield and number of pods per plant.

High heritability estimates were recorded for pod and peduncle length, green pod yield per plant, seeds per pod, days to 50 per cent flowering, days to maturity, plant height, branches per plant and 100-

seed weight in a variability study with 34 cowpea genotypes by Ram and Singh (1997). High heritability combined with high genetic advance were observed for pod length and green pod yield per plant.

Wang Yan Feng *et al.* (1997) studied 10 important agronomic characters of 1192 accessions of yard-long bean and observed very high variability for characters like pod length, pod weight, pod shape, pod colour and seed coat colour.

Resmi (1998) studied 30 different genotypes of yard-long bean and observed significant differences among the genotypes for all the 24 characters studied. The highest phenotypic coefficient of variation was recorded for pod yield per plant (30.56) followed by number of pods per kg (26.54) and number of inflorescences per plant (25.16). The highest genotypic coefficient of variation was obtained for pod yield per plant (29.5) followed by number of pods per kg (26.5). Heritability was highest for number of pods per kg (0.98) and 100-seed weight (0.98) followed by pod weight (0.96) and pod length (0.95). High heritability along with high genetic advance were reported for pod yield per plant, number of pods per kg, number of inflorescences per plant and weight of pods.

Vardhan and Savithramma (1998a) evaluated 29 accessions of cowpea and found high phenotypic and genotypic coefficients of variation, heritability and genetic advance for characters *viz.*, green pod yield, pods per plant, plant height and number of secondary branches.

Evaluation of 102 accessions of cowpea by Vardhan and Savithramma (1998) showed significant variation among them for different characters. High phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance were observed for plant height, number of primary branches, number of secondary branches, seed yield per plant and green pod yield.

Sharma (1999) studied genetic variability for eight yield related traits among 42 diverse genotypes of cowpea and found significant differences for all the characters studied. High heritability was observed for almost all the characters. Plant height showed high heritability coupled with high genetic advance.

Pournami (2000) conducted variability studies with 15 vegetable cowpea genotypes and observed significant differences among varieties for several characters . Maximum genotypic coefficient of variation was observed for number of pods per plant (26.55) followed by yield of vegetable pods per plant (24.94). Heritability was highest for number of pods per plant (96.12 per cent) followed by yield of vegetable pods per plant (95.12 per cent). High values of heritability coupled with high genetic advance were recorded for number of pods per plant, pod yield per plant, length of peduncle and pod weight.

2.1.2. Correlation studies

Yield is a complex character determined by several component characters. Improvement in yield is possible only through selection for the desirable component characters. Hence the knowledge of correlation between yield and its component characters and among component characters is essential for yield improvement through selection programmes.

Kumar *et al.* (1976) observed positive correlation of pod yield with branches per plant, pod length, pod thickness, days to flowering and days to maturity in cowpea.

Chauhan and Joshi (1980) found negative correlation between pod number per plant and 100-seed weight in their study with 36 cowpea varieties.

Jana *et al.* (1982) found that pod yield of cowpea was positively and significantly correlated with primary branches per plant. Primary branches per plant was negatively correlated with days to flower and pod length.

Correlation studies in cowpea with 49 cultivars by Patil and Bhapkar (1987a) revealed that pods per plant and seeds per pod were negatively correlated with each other.

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

Tewari and Gautam (1989) in a correlation study with 20 diverse cultivars of cowpea obtained high positive correlation between green pod yield and primary branches per plant, pods per cluster, clusters per plant, 100-seed weight and seeds per pod.

Samiullah and Imtiaz (1993) found significant and positive correlation of green pod yield with pod number at the genotypic level only. They suggested that number of fruiting branches and days to flowering were the reliable and effective selection criteria for the improvement of pod yield in cowpea.

Sobha (1994) obtained high and positive correlation between pod yield and days to harvest, pod length, pod girth, pod weight, pods per kg, seeds per pod and 100-seed weight in cowpea.

Tamilselvam and Das (1994) reported positive correlation of plant height with days to 50 per cent flowering, number of clusters per plant, pod length and 100-seed weight. Pod length was positively correlated with number of seeds per pod 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.

Hussein and Farghali (1995) reported significant phenotypic correlation between pod length and 100-seed weight in cowpea. There was 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 pod fibre content and seeds per pod in vegetable cowpea.

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 vegetable cowpea 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. They suggested the use of characters like number of fruiting points, number of pods per plant, pod length and number of seeds per pod as selection criteria for yield improvement in vegetable cowpea in view of their high positive correlation with green pod yield.

The genotypic and phenotypic correlations of green pod yield with different components were estimated using 20 genotypes of vegetable cowpea by Chattopadhyay *et al.* (1997). Pod length, green pod weight, dry pod weight, seeds per pod and 100-seed weight exhibited significant positive phenotypic and genotypic correlation with green pod yield. Days to flowering registered high and negative correlation with green pod yield both at phenotypic and genotypic levels. Pod number was negatively correlated with green pod weight and pod length.

Correlation studies by Resmi (1998) with 30 genotypes of vegetable cowpea indicated high positive correlation of pod yield with pod weight, pod length and number of pods per plant.

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

Pournami (2000) reported positive genotypic correlation of pod yield per plant with number of seeds per pod, number of pods per plant, length of harvesting period, number of pods per inflorescence, pod weight and pod length.

2.1.3. Path analysis

Certain characters might indirectly influence yield but their correlation with yield may not be statistically significant. In such cases, path coefficient analysis is an efficient technique which permits the separation of correlation coefficients into components of direct and indirect effects (Dewey and Lu, 1959).

Jana *et al.* (1983) reported that pod number per plant had the highest direct effect on pod yield per plant in cowpea, while Ye and Zhang (1987) identified number of pods per inflorescence as the character with the greatest direct effect on pod yield.

Pod weight exerted 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 pod length and fibre content were the main determinants of pod yield in vegetable cowpea.

Path coefficient analysis of green pod yield in cowpea by Chattopadhyay *et al.* (1997) indicated green pod weight, dry pod weight, pod number and seeds per pod as the most important components of pod yield because of their high positive direct effects. Days to flowering registered highly negative direct effect indicating early flowering contributes to yield. They suggested that weight, dry pod weight, pod number, seeds per pod and days to flower were the important characters to be considered for improving pod yield in vegetable 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 and number of pods per kg while pod weight exerted indirect effect through number of pods per kg. Number of pods per kg had negative direct effect on pod yield.

Path coefficient analysis for green pod yield in cowpea by Vardhan and Savithramma (1998a) indicated that green pods per plant, pod length, pod width and number of primary branches were the major traits contributing to yield.

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.

2.1.4. 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 diverse the parents within a reasonable range, the more would be the chance of improving a character in question through hybridization programme.

Chandrika (1979) grouped 202 varieties of cowpea into 17 clusters based on genetic distance using Mahalanobis D^2 analysis.

Kumar *et al.* (1982) grouped 50 genotypes of cowpea using Mahalanobis D^2 statistic into seven clusters. Days to 50 per cent maturity, pod length, pod width and 100-grain weight contributed to genetic divergence.

Chikkadyavaiah (1985) studied 207 indigenous and 117 exotic genotypes of cowpea and assigned 23 stable diverse genotypes to one cluster using cluster analysis.

Jindal (1985) studied genetic divergence in 52 varieties of cowpea and grouped them into eight clusters using Mahalanobis D^2 statistic. The clustering did not reflect the geographical origin of the varieties.

Marangappanavar (1986) studied genetic diversity of 46 genotypes of cowpea and found that the intercluster spatial patterns were not consistent with geographical distribution.

Patil and Bhapkar (1987) studied genetic divergence among 28 indigenous and 21 exotic genotypes of cowpea and grouped them into 16 clusters using Mahalanobis D^2 statistic. They could not find any relationship between genetic diversity and geographic origin.

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

Dharmalingam and Kadambavanasundaram (1989) found wide genetic diversity among the 13 clusters formed from 40 genotypes of cowpea. Based on the their intracluster mean values as well as their wide genetic diversification, types suitable for hybridization among themselves have been identified.

Renganayaki and Rangaswamy (1991) could cluster six genotypes of cowpea into four clusters. Seed weight, pod length and seed yield contributed most towards genetic divergence.

Hazra *et al.* (1993) studied genetic divergence among cowpea genotypes belonging to three cultigroups *viz.*, *unguiculata, biflora* and *sesquipedalis* under two environments using D^2 statistic. The genotypes were grouped into four clusters in both the environments. No close correspondence was observed between geographic distribution and genetic divergence. Maximum genetic divergence was observed between the genotypes of the cultigroups, *sesquipedalis* and *biflora*.

Sobha (1994) grouped 31 cowpea genotypes into six clusters and observed strict parallelism between genetic diversity and geographic distribution.

Sudhakumari and Gopimony (1994) studied genetic divergence in 59 cowpea varieties and grouped them into eight clusters using Mahalanobis D^2 technique. Maximum genetic divergence was observed between clusters V and VII which contained two and one genotype respectively.

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

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

Resmi (1998) grouped 30 yard-long bean varieties into four clusters based on D^2 analysis. The largest cluster had 18 genotypes. Intercluster distance was maximum between cluster I and III (224.89) and least between cluster I and II (80.55). The characers chosen for D^2 analysis were vine length, number of primary branches, petiole length, length of lateral leaflet, breadth of lateral leaflet, days to first flowering, pod length, pod girth, pod weight, pods per inflorescence, pods per kg, pods per plant and pod yield per plant.

2.2. Legume pod borer resistance evaluation

2.2.1. About the pest

Legume pod borer, *Maruca vitrata* (Fab.) (Syn. *Maruca testulalis*, Geyer) (Lepidoptera : Pyralidae) is a highly damaging post-flowering pest of several leguminous crops including cowpea (Jackai and Adalla, 1997). It is a polyphagous borer with a host range surpassing the limits of leguminosae family. Attachi and Djihou (1994) found 22 host species distributed in eight families of which 77 per cent are leguminous. *Cajanus cajan* (L.) Millsp. and *Vigna unguiculata* (L.) Walp. are two vulnerable species, the former being highly preferred for oviposition by the insect.

The pest which was of minor importance in southeast Asia earlier has become recently a major pest of legumes in the region (Tamo *et al.*, 1997). Bottenberg *et al.* (1997) identified the amount and distribution of rainfall, relative humidity and temperature as the key factors influencing population levels of the pest. Legume pod borer develops and reproduces better under high relative humidity and moderate temperature while population density tends to be lower in drier weather (Jackai *et al.,* 1990).

The crop loss in yard-long bean in the event of serious attack by the pest is tremendous since their larvae feed on flowers and developing pods. The moth lays eggs on flower buds, flowers and young pods. The eggs hatch within two to three days and their first instar larvae start feeding at the oviposition sites. They bore into the pods and devour the developing seeds one after another. The larval burrow on pods is marked by a mass of brownish frass at the entrance of the gallery. After about 10 days, the fifth instar larvae pupate. Pupal period is about a week (Anitha Kumari, 1992).

2.2.2. Plant characters and legume pod borer resistance in cowpea

Morphological features of varieties may influence host finding and utilization by insect pests. Flowers and developing pods being the major feeding sites of *Maruca vitrata* larvae in cowpea, their distribution and hence plant architecture are important in deciding varietal differences in damage by the pest. Cowpea varieties with upright and long peduncles that hold flowers and pods away from the canopy as well as from each other suffer less damage by legume pod borer (Singh, 1978). Oghiakhe *et al.* (1991) found that *V. unguiculata* cultivars with pods held within the leaf canopy suffered significantly more damage than cultivars with pods held above the canopy. van Emden (1989) attributed the resistance in cowpea with long peduncles and those which hold pods widely apart on the peduncle to the reduced accessibility of larvae of the borer to pods to further pod infestation. Oghiakhe *et al.* (1992d) also observed reduction in pod damage caused by *M. vitrata* in cowpea varieties with wide pod angle.

Chiang and Jackai (1988) found pod wall toughness to be important in contributing to pod resistance in cowpea to pod sucking bugs. Oghiakhe *et al.* (1992c) measured pod wall toughness of cowpea varieties with differing levels of resistance to legume pod borer and found that there was no relationship between pod damage and pod wall toughness.

2.2.3. Resistance evaluation and field screening techniques

A detailed account of the techniques for evaluating plant resistance to insects was provided by Tingey (1986). For field screening of germplasm and assessment of plant resistance, either laboratory reared or field collected test insect population can be released into field plots, if natural infestation fails to develop at desired time or magnitude. Measurement of resistance can be accomplished by insect population or growth and development assessment or plant growth and damage assessment.

The earliest attempt to develop a technique for field screening of cowpea for legume pod borer resistance was the one made by Wolley and Evans (1979). The screening methodology evolved by Dabrowski *et al.* (1983) involves artificial infestation of plants with eggs in the pre-flowering period.

Insecticides with selective properties can be a powerful tool for conserving and enhancing target pest population (Tingey, 1986). The effectiveness of the technique depends on the availability of an insecticide, the use of which at a specific dosage is relatively inactive against the target pest, but toxic to non-target species including competing pests and natural enemies (Eveleens *et al.*, 1973; Shepard *et al.*, 1977). Successful screening of cowpea for legume pod borer resistance requires selective elimination of non-target pests like flower thrips, *Megalurothrips sjostedti* (Tryborn) and hemipteran pod bugs including

Riptortus spp. and *Clavigralla* spp. to ensure that these non-target pests do not mask the effect of *M.vitrata* on the crop (Jackai, 1982). Monocrotophos is ineffective against legume pod borer at dose rates sufficient to control thrips and hemipteran pod-bugs (Jackai, 1983). Application of monocrotophos at low dose rate of 200 g a.i. per ha to control non-target pests including leaf feeding beetles, aphids, thrips and pod sucking bugs is a standard practice in legume pod borer resistance studies on cowpea (Jackai and Singh, 1988; Oghiakhe *et al.* 1992a).

Jackai (1982) assessed legume pod borer damage to stem, flower, pods and seeds in cowpea employing different damage parameters in an attempt to suggest an appropriate field screening methodology. Based on the study it was concluded that flower, pod and seed damage measurements are important in the assessment of plant resistance. He stressed the importance of seed damage assessment in resistance evaluation since seed damage showed no correlation with flower and pod damage measurements. The flower and pod damage measurements showed positive correlation between them.

The field screening technique suggested by Jackai (1982) involved the computation of overall plant resistance index based on flower, pod and seed damage parameters. Several later studies on resistance of cowpea to legume pod borer employed this field screening technique (Oghiakhe, 1992, Oghiakhe *et al.*, 1992a, Oghiakhe *et al.*, 1993). For initial screening of a large collection of genotypes Oghiakhe *et al.* (1992b) developed a rapid field screening technique involving only measurements of flower and/or pod damage.

Pournami (2000) found significant differences among yard-long bean varieties in flower, pod and seed damages caused by legume pod borer. Studying the correlation among flower, pod and seed damage parameters, she found that there was no correlation between flower damage assessed on the basis of larval count in flowers and pod damage assessed either as percentage of infested pods or number of larval entry/exit holes on a random sample of pods, but observed significant positive correlation between pod damage and seed damage values.

Reaction of hostplant to an insect pest may vary from high level of resistance to extreme susceptibility. Hostplant resistance of a variety is definable only in terms of other and usually more susceptible varieties. A variety that suffers lesser attack or crop loss in the event of comparable pest population can be considered partially resistant (Dent, 1995). The potential and profitability of partial resistance in combination with other control strategies are now well realized.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study aimed at the evaluation of variation in domestic germplasm of yard-long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.) for yield and legume pod borer, *Maruca vitrata* (Fab.) resistance was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 1999-2000.

The data for the investigation were collected from two field experiments. Experiment I was for the study of genetic divergence based on yield and related characters and Experiment II was for the evaluation of the genotypes for legume pod borer resistance.

3.1. Experiment I : Estimation of genetic divergence

3.1.1. Materials

The materials for the study included 48 local varieties of yard-long bean collected from different parts of Kerala and two improved varieties, Malika and Sharika released by the Kerala Agricultural University. The test entries are designated by accession numbers Vs 1 to Vs 50. The details of the accessions and their source are presented in Table 1. The variation in pod characters are evident from plates 1 to 6.

Table 1. List of yard-long bean accessions used for the study, their sources and prominent morphological features

Acc.No.	Source	Prominent morphological characters
Vs 1	Sreekariyam, Thiruvananthapuram District	Pigmented stem, green, medium long, fleshy pods with thick pod wall, brown seed coat
Vs 2	Venganoor, Thiruvananthapuram District	Pigmented stem and peduncles, short, green pods with thin pod wall, seed coat variegated with brown and white colour
Vs 3	Kidangoor, Kottayam District	Medium long, green pods with thin pod wall, brown seed coat
Vs 4	Neezhoor, Kottayam District	Medium long, green pods with thick pod wall, black seed coat
Vs 5	Ayirooppara, Thiruvananthapuram District	Dark green foliage, long, fleshy, dark green pods with light purple tip and thick pod wall, black seed coat
Vs 6	Manjoor, Kottayam District	Medium long, slender, green pods with purple tip and thin pod wall, brown seed coat

Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 7	Vallikkezhu, Kollam District	Medium long, green pods with purple tip and thick pod wall, black seed coat
Vs 8	Aralumoodu, Thiruvananthapuram District	Long, pigmented peduncles, medium long, fleshy, green pods with purple tip and thick pod wall, black seed coat
Vs 9	Vayala, Kottayam District	Very long, fleshy, green pods with thick pod wall, brown seed coat
Vs 10	Russelpuram, Thiruvananthapuram District	Short peduncles, medium long, green pods with purple tip and thin pod wall, black seed coat
Vs 11	Kalliyoor, Thiruvananthapuram District	Pigmented stem and peduncles, medium long, slender, green pods with thin pod wall, brown seed coat
Vs 12	Vakathanam, Kottayam District	Medium long, green pods with purple tip and thick pod wall, black seed coat
Vs 13	Kallara, Thiruvananthapuram District	Medium long, fleshy, green pods with purple tip and thick pod wall, black seed coat

Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 14	Kavumbhagom, Pathanamthitta District	Very long, fleshy, green pods with purple tip and thick pod wall, black seed coat
Vs 15	Venganoor, Thiruvananthapuram District	Pigmented stem, short, fleshy, green pods with purple tip and thick pod wall, black seed coat
Vs 16	Kanakkari, Kottayam District	Long peduncles, long, fleshy, green pods with purple tip and thick pod wall, black seed coat
Vs 17	Kezhekkambalam, Ernakulam District	Medium long, green pods with purple tip and thick pod wall, brown seed coat
Vs 18	Kakkamoola, Thiruvananthapuram District	Medium long, fleshy, green pods with thick pod wall, brown seed coat
Vs 19	Kottukal, Thiruvananthapuram District	Medium long, fleshy, green pods with thick pod wall and brown seed coat
Vs 20	Vattukulam, Kottayam District	Long peduncles, very long, fleshy, green pods with purple tip and thick pod wall, black seed coat

Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 21	Ponakam, Alappuzha District	Short, fleshy, green pods with thick pod wall, seed coat variegated with brown and white colour
Vs 22	Thekkekkara, Alappuzha District	Medium long, fleshy, green pods with thick pod wall, seed coat variegated with brown and white colour
Vs 23	Chingavanam, Kottayam District	Medium long, slender, green pods with thin pod wall, seed coat variegated with brown and white colour
Vs 24	Thuruthi, Kottayam District	Pigmented stem and petioles, medium long, green pods with purple tip and thin pod wall, black seed coat
Vs 25	Balaramapuram, Thiruvananthapuram District	Medium long, slender, green pods with purple tip and thin pod wall, seed coat variegated with brown and white colour
Vs 26	Vazhappally, Kottayam District	Short peduncles, short, fleshy, green pods with thick pod wall, brown seed coat

Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 27	Punnamoodu, Thiruvananthapuram District	Pigmented stem, medium long, green pods with purple tip and thick pod wall, black seed coat
Vs 28	Malika, Kerala Agricultural University	Long, light green pods with thin pod wall, brown seed coat
Vs 29	Perunna, Kottayam District	Long, fleshy, purple pods with green tip and thick pod wall, brown seed coat
Vs 30	Palappoor, Thiruvananthapuram District	Medium long, slender, green pods with thin pod wall, brown seed coat
Vs 31	Paliakkara, Pathanamthitta District	Long, green pods with purple tip and thin pod wall, black seed coat
Vs 32	Puthiakavu, Alappuzha District	Long, green pods with thick pod wall, brown seed coat
Vs 33	Kolanchery, Ernakulam District	Medium long, slender, purple pods with green tip and thin pod wall, brown seed coat

Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 34	Koliyoor, Thiruvananthapuram District	Short, green pods with purple tip and thick pod wall, black seed coat
Vs 35	Adoor, Pathanamthitta District	Medium long, slender, green pods with purple tip and thin pod wall, brown seed coat
Vs 36	Karumam, Thiruvananthapuram District	Short, slender, green pods with thin pod wall, brown seed coat
Vs 37	Vattukulam, Kottayam District	Short, fleshy, green pods with purple tip and thick pod wall, black seed coat
Vs 38	Kilikolloor, Kollam District	Short peduncles, long, fleshy, green pods with thick pod wall, seed coat variegated with brown and white colour
Vs 39	Karukachal, Kottayam District	Long, fleshy, purple pods with green tip and thick pod wall, brown seed coat
Vs 40	Manjoor, Kottayam District	Medium long, slender, green pods with thin pod wall, brown seed coat

Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 41	Thalavady, Alappuzha District	Pigmented stem and peduncles, medium long, slender, green pods with purple tip and thin pod wall, black seed coat
Vs 42	Ettumanoor, Kottayam District	Long, pigmented peduncles, short, green pods with thick pod wall, brown seed coat
Vs 43	Kunnamkulam, Thrissur District	Highly pigmented stem, short peduncles, long, fleshy, green pods with thick pod wall, brown seed coat
Vs 44	Neerettupuram, Pathanamthitta District	Short peduncles, medium long, slender, green pods with thin pod wall, brown seed coat
Vs 45	Paipad, Alappuzha District	Medium long, fleshy, green pods with thick pod wall, brown seed coat
Vs 46	Kundara, Kollam District	Very long, fleshy, green pods with thick pod wall, brown seed coat

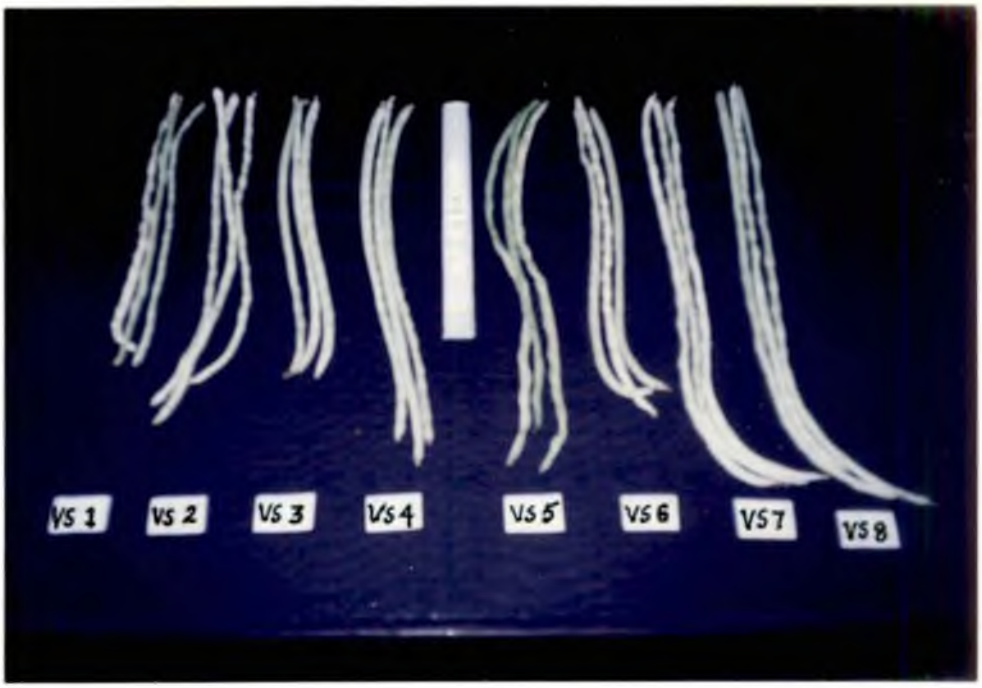
Contd...

(Table 1. Contd...)

Acc.No.	Source	Prominent morphological characters
Vs 47	Nedumudi, Alappuzha District	Short peduncles, medium long, fleshy, green pods with thick pod wall, seed coat variegated with brown and white colour
Vs 48	Sharika, Kerala Agricultural University	Long, fleshy green pods with purple tip and thick pod wall, black seed coat
Vs 49	Erattupetta, Kottayam District	Medium long, green pods with purple tip and thick pod wall, black seed coat
Vs 50	Aanaprambal, Alappuzha District	Short, slender, green pods with thin pod wall, brown seed coat

Plate 1. Variation in pod characters - 1

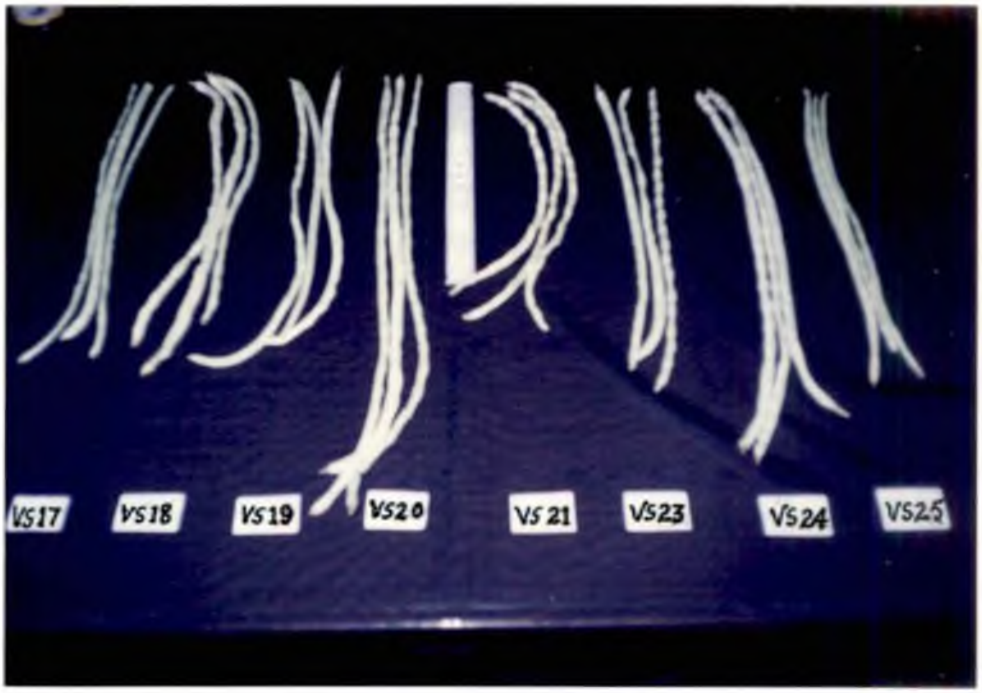
Plate 2. Variation in pod characters - 2


VS 1
VS 2
VS 3
VS 4
VS 5
VS 6
VS 7
VS 8


VS 9
VS 10
VS 11
VS 12
VS 13
VS 14
VS 15
VS 16

Plate 3. Variation in pod characters - 3

Plate 4. Variation in pod characters - 4


VS17
VS18
VS19
VS20
VS21
VS23
VS24
VS25

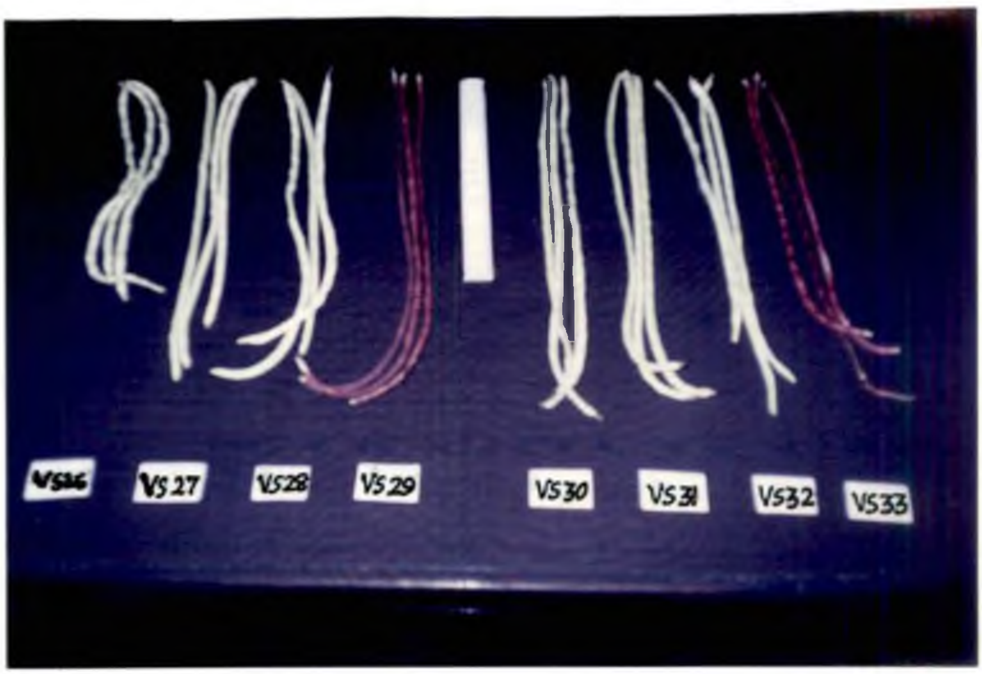

VS26
VS27
VS28
VS29
VS30
VS31
VS32
VS33

Plate 5. Variation in pod characters - 5

Plate 6. Variation in pod characters - 6


VS34
VS35
VS36
VS37
VS38
VS39
VS40
VS41


VS42
VS44
VS45
VS46
VS47
VS48
VS49
VS50

3.1.2. Methods

3.1.2.1. Layout and conduct of the experiment

The 50 test entries were planted in a field experiment in randomized block design with three replications. The land was well prepared incorporating farm yard manure @ 20 t/ha. The entire field was divided into three blocks of fifty plots each. Treatments were allotted to the plots in each block at random. Plot size was 3.0 x 2.1m. Spacing was 1.0m between rows and 0.3m between plants in a row. A basal dressing of 10 kg N, 30 kg P_2O_5 and 10 kg K_2O per ha was given and 10 kg N per ha was applied two weeks after sowing. Need based application of insecticides was done to protect the crop from insect pests.

The experimental crop was raised during the period September to December 1999. Plants were trailed on coir ropes tied between wooden standards erected 1.0m apart along the rows of plant.

3.1.2.2. Biometric observations

The observations on the following characters were recorded from five randomly selected plants in each plot. The data for statistical analysis were obtained from the mean values worked out thereafter.

a. Days to first flowering : Number of days taken from sowing to the appearance of the first flower

b. Length of harvesting period : Number of days from the first to the last harvest

c. Number of pods per plant	:	The number of pods obtained from each observational plant in each harvest was counted and recorded.
d. Yield of vegetable pods per plant (g)	:	The yield of green pods from each observational plant from each harvest was recorded and total yield computed.
e. Number of inflorescences per plant	:	The number of inflorescences on each observational plant was recorded
f. Number of pods per inflorescence	:	Number of pods set on five randomly chosen inflorescences on each observational plant.
g. Length of main stem (cm)	:	Length of main stem measured from the base to the tip at the time of final harvest
h. Number of primary branches	:	The number of primary branches in each of the observational plant was recorded at full maturity of the plant.

Pod characters *viz.*, pod length (cm), pod girth (mm), pod weight (g) and number of seeds per pod were recorded from ten randomly selected pods at vegetable maturity stage from each plot and mean value for each character was worked out.

3.1.2.3. Statistical analysis

The data collected were subjected to the following statistical analyses.

3.1.2.3.1. Analysis of variance

The analysis of variance was carried out

a) To test the significance of differences among the genotypes with respect to various characters and

b) To estimate the variance components and other genetic parameters like coefficients of variation, heritability and genetic advance (Singh and Choudhary, 1979).

Estimation of components of variance

i) Variance (for a trait x)

$$\text{Environmental variance } (\sigma^2_{ex}) = E_{xx}$$

$$\text{Genotypic variance } (\sigma^2_{gx}) = \frac{G_{xx} - E_{xx}}{r}$$

$$\text{Phenotypic variance } (\sigma^2_{px}) = \sigma^2_{gx} + \sigma^2_{ex}$$

where,

Exx = Observed mean square for error

Gxx = Observed mean square for genotype

ii) Coefficient of variation

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

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

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

where,

σ_{gx} = Genotypic standard deviation

σ_{px} = Phenotypic standard deviation

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

iii) Heritability (broad sense)

Heritability (H^2) was calculated to estimate the proportion of heritable component of variation.

$$H^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

where H^2 is the heritability expressed in percentage (Jain, 1982).

iv) Genetic advance as percentage of mean

To estimate the change in the mean genotypic value of population brought about by selection, genetic advance is calculated as

$$GA \text{ (as \% of mean)} = \frac{kH^2 \sigma_p}{\bar{x}} \times 100$$

where k is the standardised selection differential with value 2.06 at 5 per cent selection intensity (Miller *et al.,* 1958).

3.1.2.3.2. Covariance analysis

Covariance analysis was done for the estimation of correlation coefficients, path analysis and genetic divergence.

Table 2. Analysis of variance / covariance for two traits x and y

Source	Degrees of freedom	Observed mean square for x	Expected mean square for x	Observed mean square for y	Expected mean square for y	Observed mean sum of products for x&y	Expected mean sum of products for x&y
Block	(r-1)	B_{xx}		B_{yy}		B_{xy}	
Genotype	(v-1)	G_{xx}	$\sigma^2_{ex} + r\sigma^2_{gx}$	G_{yy}	$\sigma^2_{ey} + r\sigma^2_{gy}$	G_{xy}	$\sigma_{exy} + r\sigma_{gxy}$
Error	(v-1) (r-1)	E_{xx}	σ^2_{ex}	E_{yy}	σexy	E_{xy}	σ_{exy}
Total	(vr-1)	T_{xx}		T_{yy}		T_{xy}	

where r = number of replications

v = number of treatments.

The covariances are estimated for two traits as

Environmental covariance (σ_{exy}) = E_{xy}

Genotypic covariance (σ_{gxy}) $= \dfrac{G_{xy} - E_{xy}}{r}$

Phenotypic covariance (σ_{pxy}) $= \sigma_{gxy} + \sigma_{exy}$

Estimation of components of covariance

i) Correlation analysis

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

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

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

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

ii) Path analysis

The path coefficients were worked out by the method suggested by Wright (1921) using six characters which showed high significant correlation with yield. The simultaneous equations which gives the estimates of path coefficients are as follows.

$$\begin{vmatrix} r_{1y} \\ r_{2y} \\ \vdots \\ r_{iy} \\ \vdots \\ r_{ky} \end{vmatrix} = \begin{bmatrix} 1 & r_{12} & r_{13} \ldots r_{1j} \ldots r_{1k} \\ & 1 & r_{23} \ldots r_{2j} \ldots r_{2k} \\ & & \vdots \quad \vdots \\ & & r_{ij} \ldots r_{ik} \\ & & \vdots \\ & & 1 \end{bmatrix} \times \begin{vmatrix} p_1 \\ p_2 \\ \vdots \\ p_i \\ \vdots \\ p_k \end{vmatrix}$$

ie $\underset{\sim}{R}_y = \underset{\sim}{R}_x.\underline{P}$

$\therefore \underline{P} = \underset{\sim}{R}_x^{-1}.\underline{R}_y$

where R_y is the vector of r_{iy}, the genotypic correlation between i^{th} trait with yield y.

$$i,j = 1,2,\ldots..k$$

R_x is the matrix of r_{ij}, the genotypic correlation between i^{th} trait with j^{th} trait.

$$P_i = \text{path coefficient of } x_i$$

The residual factor (h) which measures the contribution of other factors not defined in the causal scheme was estimated by the formula

$$h = \sqrt{(1 - \sum_{i=1}^{k} P_i r_{iy})}$$

Indirect effect of different characters on yield is obtained as $P_i r_{ij}$ for the i^{th} character via j^{th} character.

iii) Mahalanobis D^2 analysis

Genetic divergence was studied using Mahalanobis D^2 statistic using six quantitative characters selected for of path analysis along with pod yield per plant. Grouping of genotypes into clusters were done by Tocher's method (Rao, 1952).

3.2 Experiment II : Field screening for legume pod borer resistance

3.2.1 Materials

The same as that of experiment I

3.2.2 Methods

3.2.2.1 Layout and conduct of the experiment

The 50 cultivars were evaluated for pod borer resistance in a field experiment in randomised block design with two replications. The entire field was divided into two blocks of fifty plots each. The varieties were alloted at random to the plots in each block. Plot size was 2.1 x 1.0m, spacing was 1.0m between rows and 0.3m between plants in a row. Application of manures and fertilizers was done as in experiment I.

The experimental crop was raised during February to May 2000. In order to build up the legume pod borer population, their larvae were col lected in large numbers from infested cowpea fields and released in the experimental plots at the early flowering phase of the crop. To control non-target pests like aphids, flower thrips and pod sucking bugs, monocrotophos (Nuvacron 40 EC) was sprayed twice @ 200 g a.i. per ha at initial flowering phase and early podding stage of the crop. Jackai (1983) has reported that monocrotophos was ineffective in controlling *M. vitrata* at the rate of application used in this experiment.

3.2.2.2 Data collection

Different damage parameters were measured as described below.

a. Percentage infestation of flowers

A sample of 25 flowers was randomly collected from each plot at peak flowering stage of the crop and the number of flowers with larval entry / exit holes were counted. Percentage of damaged flowers was worked out.

b. Number of larvae per 25 flowers

Flower samples used for assessment of percentage flower infestation were used for determining the larval count in flowers. Flowers were soon dissected and the number of larvae in them ascertained.

c. Percentage infestation of pods

A sample of 25 pods at vegetable maturity stage were harvested at the peak podding phase from each plot and the number of pods with larval entry / exit holes counted and expressed as percentage of the number of pods collected from each plot.

d. Number of larval entry / exit holes per pod (Pod damage severity)

Pod samples used for the assessment of percentage pod infestation were examined for the number of larval exit / entry points. The results were expressed as number of holes per pod.

e. Percentage of infested peduncles with multiple pod damage

A sample of 20 infested peduncles were examined from each plot and the number of peduncles showing infestation on more than one pod were counted and expressed as the percentage of total number of peduncles examined.

f. Number of damaged seeds in a sample of 25 pods

The sample used for assessing percentage pod infestation was also used for assessing seed damage. The number of damaged seeds in a sample of 25 pods was counted. A seed damage index (I_{sd}) was worked out using the formula.

$$I_{sd} = \frac{ds \times 100}{pt}$$

where ds = number of damaged seeds

pt = number of pods sampled

g. Plant resistance index (Ipr)

Ipr value was computed for each variety using a combination of the three damage parameters (Jackai, 1982).

i) Number of larvae per 25 flowers - (M)

ii) Percentage pod infestation - (T)

iii) Seed damage index (I_{sd}) - (S)

$$Ipr = \frac{W_1S + W_2T + W_3M}{W_1 + W_2 + W_3}$$

where weights W_1, W_2 and W_3 are taken as 1, 2 and 3 respectively. These weighted measurements reflect the relative importance attached to each.

Data on the following plant characters were obtained as detailed below.

a. Pod wall thickness

A visual assessment of each variety was done by observing the cross section of pods at vegetable maturity stage and the varieties were catagorised into two groups, ie., with thin and thick pod walls.

b. Fibre content of pods

Green pods at vegetable maturity stage of five resistant and five susceptible cultivars (with Ipr values below and above the overall mean of Ipr values respectively) were harvested and dried along with seeds and the crude fibre content of the dried pods was estimated by acid and alkali digestion method and expressed as percentage (Sadasivam and Manickam, 1992).

3.2.2.3. Statistical analysis

The data were subjected to the following statistical analysis.

3.2.2.3.1 Analysis of variance

The data on damage parameters and plant resistance index were subjected to analysis of variance for varietal differentiation.

3.2.2.3.2 Correlation analysis

A correlation analysis was done to determine the degree of association between the different damage parameters.

3.2.2.3.3 Mahalanobis D^2 analysis

Grouping of accessions based on the different was done using D^2 analysis.

3.2.2.3.4 Relationship of pod characters with pod damage parameters

The association between pod wall thickness and pod damage (ie., percentage pod infestation and pod damage severity) by legume pod borer was found out using the Chi-square test. Correlation analysis between pod damage and fibre content of pods was done using the data on pod damage and fibre content of 10 selected cultivars.

RESULTS

4. RESULTS

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

(i) Yield evaluation

(ii) Screening for legume pod borer resistance

4.1. Yield evaluation

The data on vegetable pod yield and eleven other characters collected from the field experiment with 50 varieties were subjected to statistical analysis. The results are presented below.

4.1.1. Analysis of variance

The analysis of variance (Table 3) revealed significant differences among the 50 yard-long bean varieties for all the twelve characters studied.

4.1.2. Mean performance of the varieties

The mean values of each of the 50 cultivars for the 12 characters studied are presented in Table 4.

Table 3. Analysis of variance of 12 characters in 50 yard-long bean genotypes

Sl.No.	Characters	Mean squares		
		Replication	Genotype	Error
	df	2	49	98
1.	Days to first flowering	4.08	19.59**	2.33
2.	Length of harvesting period	15.34**	30.49**	12.96
3.	Number of pods per plant	40.37**	104.72**	4.35
4.	Yield of vegetable pods per plant (g)	15672**	29485.35**	1004.49
5.	Number of inflorescences per plant	6.22**	22.17**	0.73
6.	Number of pods per inflorescence	0.13**	1.31**	0.024
7.	Length of main stem (cm)	2238**	22433.18**	319.47
8.	Number of primary branches	0.0045	1.15**	0.006
9.	Pod length (cm)	40.92**	92.66**	2.69
10.	Pod girth (mm)	0.84	38.69**	1.77
11.	Pod weight (g)	1.55*	25.10**	0.45
12.	Number of seeds per pod	2.06**	3.69**	0.37

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

Among the varieties, days to first flowering ranged from 40.07 to 52.33. Vs 42 was the earliest and Vs 7 was the latest to flower. No variety was statistically on par with Vs 42 for days to first flowering. Length of harvesting period was maximum for Vs 33 (41.27 days) and minimum for Vs 12 (27.07 days). The varieties Vs 42, Vs 27, Vs 47 and Vs 23 were statistically on par with Vs 33 for length of harvesting period.

Regarding number of pods per plant, Vs 49 recorded the highest value of 45.53 and no other variety was statistically on par with it. Vs 4 had the lowest number of pods per plant (14.13).

The maximum number of inflorescences per plant was recorded by Vs 8 (23.73). The only variety statistically on par with Vs 8 was Vs 46. The least number of inflorescences per plant was recorded by Vs 5 (12.53). Regarding the number of pods per inflorescence, the highest and lowest values of 4.47 and 1.67 were recorded by Vs 42 and Vs 24 respectively. The only variety statistically on par with Vs 42 for pod number per inflorescence was Vs 49.

The vegetative characters *viz.*, length of the main stem and number of primary branches showed wide variation among the varieties. Maximum main stem length of 652.47 cm was recorded by the variety Vs 46 and no other variety was statistically on par with it. Vs 26 had the largest number of primary branches (5.4) and the cultivars Vs 41, Vs 14, Vs 38,

Table 4. Mean values for 12 biometric characters in 50 yard-long bean genotypes

ACC No.	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod ~~plant~~	Yield of vegetable pods/ plant (g)
Vs1	46.20	33.87	20.00	16.87	2.33	371.67	3.93	43.33	27.87	17.40	18.80	334.10
Vs2	47.87	34.73	27.73	19.73	2.80	401.80	3.93	33.07	27.27	14.67	17.13	386.87
Vs3	51.67	32.93	17.93	21.00	1.87	411.27	3.20	44.00	27.27	16.67	19.60	294.20
Vs4	47.53	34.33	14.13	16.20	2.13	443.87	3.67	39.07	25.60	16.33	17.07	224.03
Vs5	50.67	31.40	30.80	12.53	4.13	444.67	4.47	46.20	27.60	17.93	18.27	538.63
Vs6	45.40	34.87	21.27	13.80	3.27	399.40	3.53	40.67	20.67	14.33	20.60	296.17
Vs7	52.33	31.73	20.27	14.93	2.87	537.93	4.67	38.20	22.00	14.50	17.73	279.00
Vs8	47.13	35.27	21.60	23.73	1.87	374.80	3.93	45.67	27.87	17.10	18.53	351.80
Vs9	49.73	35.20	19.80	16.53	2.33	473.33	3.20	57.07	29.73	16.00	19.13	304.43
Vs10	47.33	35.73	23.40	18.20	2.53	430.20	4.07	44.60	25.47	15.47	17.80	350.30
Vs11	47.47	36.33	20.20	17.40	2.27	331.93	4.53	38.93	23.33	12.67	20.07	244.63
Vs12	47.60	27.07	25.20	18.87	2.73	603.13	5.00	46.93	27.47	16.23	17.33	400.67
Vs13	49.93	33.47	24.33	16.67	2.60	442.27	4.40	41.53	25.73	14.90	20.33	356.10

Table 4 (Contd...)

ACC No.	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod ~~plant~~	Yield of vegetable pods/ plant (g)
Vs14	50.33	35.47	18.93	20.07	1.87	606.73	5.13	50.60	30.00	20.63	18.67	376.13
Vs15	44.33	31.07	20.40	14.60	2.53	431.80	3.53	37.07	29.07	13.90	18.00	271.93
Vs16	51.33	33.60	19.60	18.20	2.13	338.80	4.87	47.93	28.73	17.20	19.00	324.17
Vs17	45.47	35.60	17.67	17.80	1.93	579.87	5.00	38.67	24.20	14.20	18.80	236.23
Vs18	45.33	31.53	21.20	22.00	2.00	521.13	3.67	45.93	28.67	18.03	17.93	366.93
Vs19	44.80	29.40	19.13	13.60	2.33	363.40	3.40	38.33	28.20	15.20	18.13	277.40
Vs20	45.93	34.73	23.13	15.00	2.80	597.60	3.67	56.27	23.67	18.47	19.13	416.67
Vs21	51.33	33.60	17.60	17.87	1.93	324.13	4.07	38.40	28.20	13.90	18.87	233.03
Vs22	46.80	33.33	27.80	16.70	3.40	467.73	5.07	43.87	29.00	15.60	17.53	423.17
Vs23	45.20	38.93	25.33	17.13	3.00	446.80	4.87	32.33	18.73	13.57	17.93	334.20
Vs24	51.53	28.67	15.73	18.33	1.67	616.67	5.07	36.20	26.67	13.67	19.20	208.37
Vs25	44.87	36.93	25.47	21.53	2.40	527.20	3.87	44.13	20.80	16.43	18.73	408.10
Vs26	48.67	36.80	23.27	15.87	2.73	484.27	5.40	37.67	27.73	15.00	18.47	337.97
Vs27	44.33	40.40	29.07	15.67	3.40	443.53	4.07	40.60	25.87	17.17	19.13	486.00

Table 4 (Contd...)

ACC No.	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod ~~plant~~	Yield of vegetable pods/ plant (g)
Vs28	47.53	34.07	19.07	16.73	2.20	558.27	4.13	37.67	25.13	14.30	17.33	260.87
Vs29	48.33	30.73	22.67	15.60	2.60	558.73	4.00	48.80	28.53	13.73	17.53	299.70
Vs30	43.60	37.20	33.80	14.13	4.00	347.47	4.33	41.60	21.33	14.50	19.07	479.23
Vs31	49.07	35.33	24.53	20.73	2.33	384.47	4.00	47.67	27.13	18.57	18.80	442.87
Vs32	46.07	37.80	23.13	21.80	2.13	343.20	3.47	48.40	30.53	15.03	17.33	332.77
Vs33	45.67	41.27	22.07	20.73	2.13	338.53	4.73	38.33	19.27	12.43	19.93	258.37
Vs34	46.80	33.80	17.67	15.20	2.33	410.47	3.40	36.13	21.73	16.93	18.07	283.07
Vs35	47.93	31.27	18.73	15.27	2.33	424.00	3.67	40.27	21.07	14.77	18.60	261.67
Vs36	50.13	30.93	20.27	13.53	2.67	438.00	4.60	39.20	24.60	14.43	19.93	275.70
Vs37	50.73	34.60	28.27	14.80	3.47	553.00	4.67	39.33	28.80	18.27	21.40	505.80
Vs38	47.13	36.80	24.53	16.40	2.87	417.60	5.13	47.60	32.33	21.70	17.67	524.47
Vs39	49.87	30.20	29.47	17.60	3.13	397.73	5.07	43.27	28.00	13.97	16.73	398.60
Vs40	47.27	34.73	21.87	17.27	2.60	412.27	4.20	46.60	24.73	15.17	18.13	322.63
Vs41	48.40	31.13	21.80	16.07	2.60	525.93	5.33	44.60	21.20	13.20	21.40	275.60

Table 4 (Contd...)

ACC No.	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod ~~plant~~	Yield of vegetable pods/ plant (g)
Vs42	40.07	40.80	40.13	15.40	4.47	428.47	4.60	33.80	25.93	13.47	18.20	527.97
Vs43	44.27	38.53	18.40	21.67	1.87	448.87	4.00	47.67	33.40	16.37	17.40	287.73
Vs44	46.67	34.07	19.67	15.20	2.53	480.53	4.53	41.20	23.67	13.00	19.13	244.33
Vs45	48.93	34.67	17.33	17.00	2.07	365.47	4.53	42.53	29.53	28.60	17.00	486.93
Vs46	47.67	38.40	21.80	22.67	1.93	652.47	3.33	53.33	30.87	19.63	19.67	414.97
Vs47	45.13	40.07	32.93	20.47	3.20	361.53	5.13	45.47	33.13	19.07	19.33	614.27
Vs48	44.40	38.60	22.93	17.13	2.67	397.33	4.47	35.87	27.47	11.90	18.27	262.50
Vs49	44.73	37.40	45.53	21.40	4.40	339.67	5.07	43.20	21.87	12.20	20.27	543.87
Vs50	44.80	34.47	27.00	15.87	3.13	384.67	4.60	36.73	21.60	12.70	17.80	332.57
SE	± 0.88	± 0.89	± 1.20	± 0.49	± 0.0089	± 10.32	± 0.14	± 0.95	± 0.77	± 0.39	± 0.35	± 18.29
$CD_{(0.05)}$	2.48	2.49	3.39	1.38	0.25	29.04	0.39	2.67	2.16	1.09	0.99	51.49

Vs 47, Vs 22, Vs 24, Vs 39 and Vs 49 were on par with it. Vs 3 and Vs 9 had the lowest number of primary branches (3.2).

The pod characters *viz.*, pod length, pod girth, pod weight and number of seeds per pod differed significantly among varieties. Pod length ranged from 57.07 cm (Vs 9) to 32.33 cm (Vs 23). The only variety statistically on par with Vs 9 for pod length was Vs 20. The variation in pod girth was conspicuous with its measure ranging from 33.4 mm (Vs 43) to 18.73 mm (Vs 23). The varieties on par with Vs 43 in pod girth were Vs 47 and Vs 38. Significantly higher pod weight in comparison to other varieties was recorded for Vs 45 (28.6 g). Pod weight was minimum for Vs 48 (11.9 g). Number of seeds per pod was maximum for the varieties Vs 37 and Vs 41 (21.40) and minimum for Vs 39 (16.73).

The yield of vegetable pods per plant ranged from 208.37 g (Vs 24) to 614.27 g (Vs 47). The results indicated significant superiority of Vs 47 over the other varieties. Several of the varieties were poor yielders, more than one-third of them giving pod yield less than half of the top yielder.

4.1.3. Variability studies

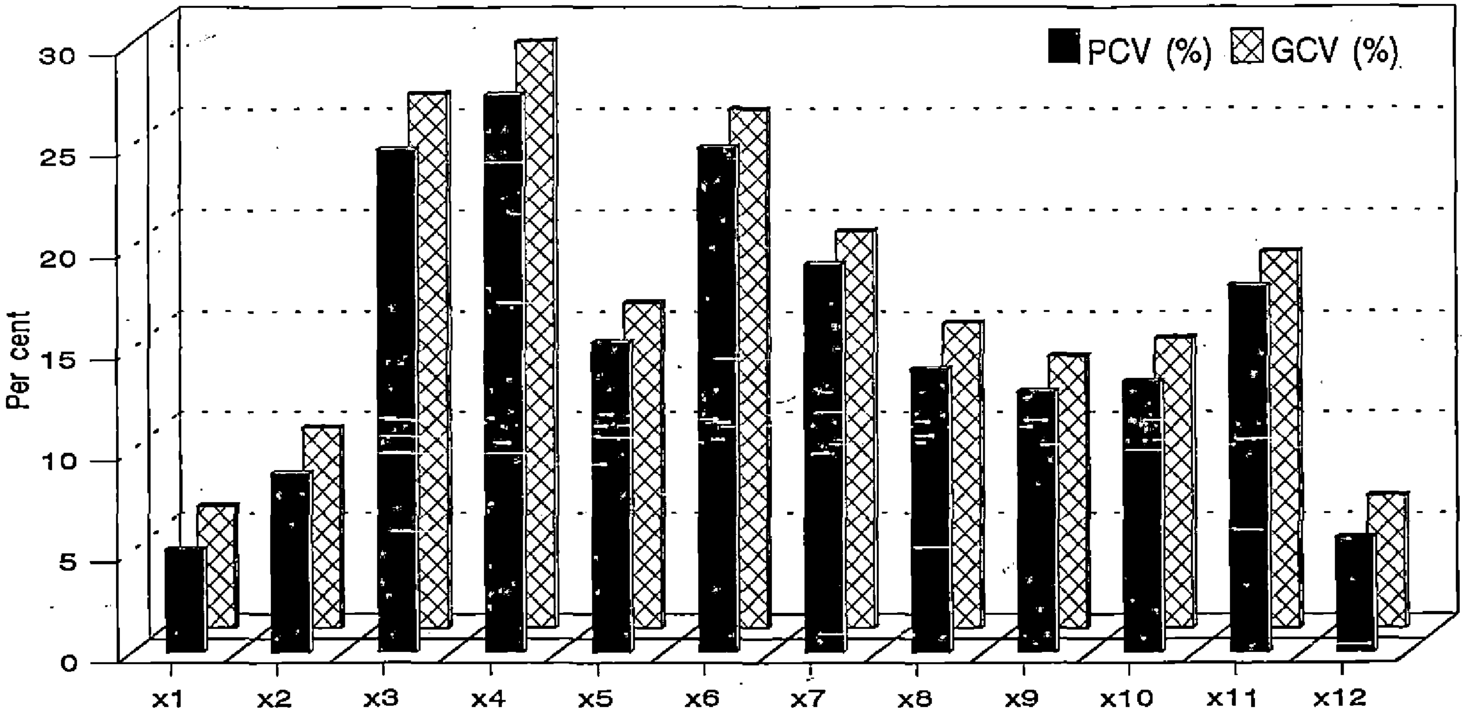
The phenotypic, genotypic and environmental variance and co-efficients of variation for the 12 characters are presented in Table 5. Figure 1 indicate the phenotypic and genotypic coefficients of variation

Table 5. Components of variance for the 12 characters in yard-long bean

Sl.No.	Characters	Mean ± SE	σ^2g	σ^2e	σ^2p	GCV %	PCV %
1.	Days to first flowering	47.33 ± 0.88	5.754	2.332	8.086	5.07	6.01
2.	Length of harvesting period (days)	34.68 ± 0.89	9.379	2.353	11.732	8.83	9.88
3.	Number of pods per plant	23.29 ± 1.20	33.457	4.354	37.811	24.83	26.39
4.	Yield of vegetable pods per plant (g)	353.95 ± 18.29	9493.599	1004.510	10498.110	27.53	28.95
5.	Number of inflorescences per plant	17.46 ± 0.49	7.146	0.726	7.872	15.31	16.07
6.	Number of pods per inflorescence	2.63 ± 0.0089	0.430	0.024	0.454	24.92	25.60
7.	Length of main stem (cm)	447.69 ± 10.32	7371.239	319.469	7690.708	19.18	19.59
8.	Number of primary branches	4.30 ± 0.14	0.365	0.057	0.422	14.03	15.09
9.	Pod length (cm)	42.53 ± 0.95	29.990	2.694	32.684	12.88	13.44
10.	Pod girth (mm)	26.19 ± 0.77	12.306	1.774	14.079	13.39	14.33
11.	Pod weight (g)	15.82 ± 0.39	8.215	0.454	8.669	18.12	18.61
12.	Number of seeds per pod	18.62 ± 0.35	1.105	0.375	1.480	5.65	6.53

σ^2g = Genotypic variance σ^2e = Environmental variance σ^2p = Phenotypic variance

GCV = Genotypic coefficient of variation PCV = Phenotypic coefficient of variation



x1 - Days to first flowering
x2 - Length of harvesting period
x3 - Number of pods per plant
x4 - Yield of vegetable pods per plant
x5 - No. of inflorescences/plant
x6 - No. of pods/inflorescence
x7 - Length of main stem
x8 - Number of primary branches
x9 - Pod length
x10 - Pod girth
x11 - Pod weight
x12 - No. of seeds/pod

Fig. 1. Phenotypic and genotypic coefficients of variation for the twelve characters in yard-long bean

for the 12 characters. The maximum value for GCV was observed for yield of vegetable pods per plant (27.53) followed by number of pods per inflorescence (24.92), number of pods per plant (24.83), length of main stem (19.18) and pod weight (18.12). GCV was least for days to first flowering (5.07).

The highest PCV was observed for yield of vegetable pods per plant (28.95) followed by number of pods per plant (26.39), number of pods per inflorescence (25.6), length of main stem (19.59) and pod weight (18.61). Least PCV was for days to first flowering (6.01).

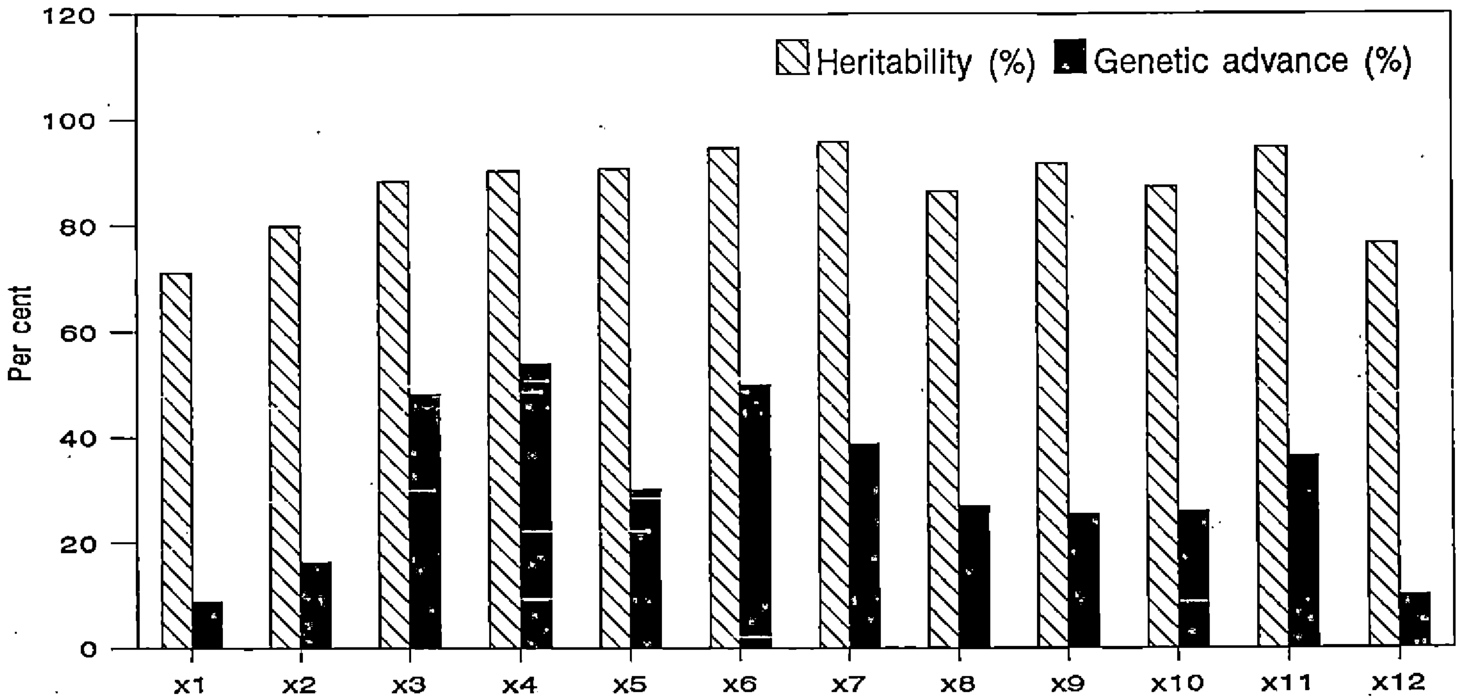
The difference between genotypic and phenotypic coefficients of variation was least for length of main stem (0.41 %) followed by pod weight (0.49 %) and was relatively high for number of pods per plant (1.56 %) and yield of vegetable pods per plant (1.42 %).

4.1.4. Heritability and genetic advance

The estimates of heritability and genetic advance are presented in Table 6 and Fig. 2. The heritability estimates recorded for all the 12 characters were high with a maximum estimate of 95.85 per cent for length of main stem followed by pod weight (94.77 %), number of pods per inflorescence (94.70 %), pod length (91.76 %), number of inflorescence per plant (90.78 %), yield of vegetable pods per plant (90.43 %) and number of pods per plant (88.48 %). The minimum value

Table 6. Heritability, genetic advance and genetic gain for the 12 characters in yard-long bean

Sl.No.	Characters	Heritability (%)	Genetic advance (at 5 % selection intensity)	Genetic gain (as % of mean)
1.	Days to first flowering	71.16	4.17	8.81
2.	Length of harvesting period	79.95	5.64	16.26
3.	Number of pods per plant	88.48	11.21	48.13
4.	Yield of vegetable pods per plant (g)	90.43	190.87	53.93
5.	Number of inflorescences per plant	90.78	5.25	30.07
6.	Number of pods per inflorescence	94.70	1.31	49.81
7.	Length of main stem (cm)	95.85	173.15	38.68
8.	Number of primary branches	86.53	1.16	26.98
9.	Pod length (cm)	91.76	10.81	25.42
10.	Pod girth (mm)	87.40	6.76	25.81
11.	Pod weight (g)	94.77	5.75	36.35
12.	Number of seeds per pod	74.69	1.87	10.04



x1 - Days to first flowering
x2 - Length of harvesting period
x3 - Number of pods per plant
x4 - Yield of vegetable pods per plant
x5 - No. of inflorescences/plant
x6 - No. of pods/inflorescence
x7 - Length of main stem
x8 - Number of primary branches
x9 - Pod length
x10 - Pod girth
x11 - Pod weight
x12 - No. of seeds/pod

Fig. 2. Heritability and genetic advance for the twelve character in yard-long bean

of heritability was observed for days to first flowering (71.16 %) followed by number of seeds per pod (74.69 %).

Expected genetic gain as percentage of mean was high for yield of vegetable pods per plant (53.93) followed by number of pods per inflorescence (49.81), number of pods per plant (48.13), length of main stem (38.68), pod weight (36.35) and number of inflorescences per plant (30.07). Number of seeds per pod and length of harvesting period exhibited low genetic advance with the least value for days to first flowering (8.81).

High values of heritability coupled with high genetic advance were 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.

4.1.5. Correlation analysis

The genotypic, phenotypic and environmental correlation coefficients were estimated for all the pairs of characters. The results of the correlation analysis are presented under the following subtitles.

a) Correlation between yield and other characters

b) Correlation among the yield component characters

a) Correlation between yield and other characters

The phenotypic, genotypic and enviromental correlation coefficients of yield with other characters are presented in Table 7. Correlation diagram showing genotypic correlation between yield and other characters is provided in Fig. 3.

The phenotypic correlation was found to be highly significant and positive for number of pods per plant (0.7766), number of pods per inflorescence (0.6543), pod weight (0.4836) and length of harvesting period (0.3277). Pod length, pod girth, number of primary branches and number of inflorescences per plant also recorded positive correlation with pod yield, while days to first flowering (-0.2124) recorded negative phenotypic correlation.

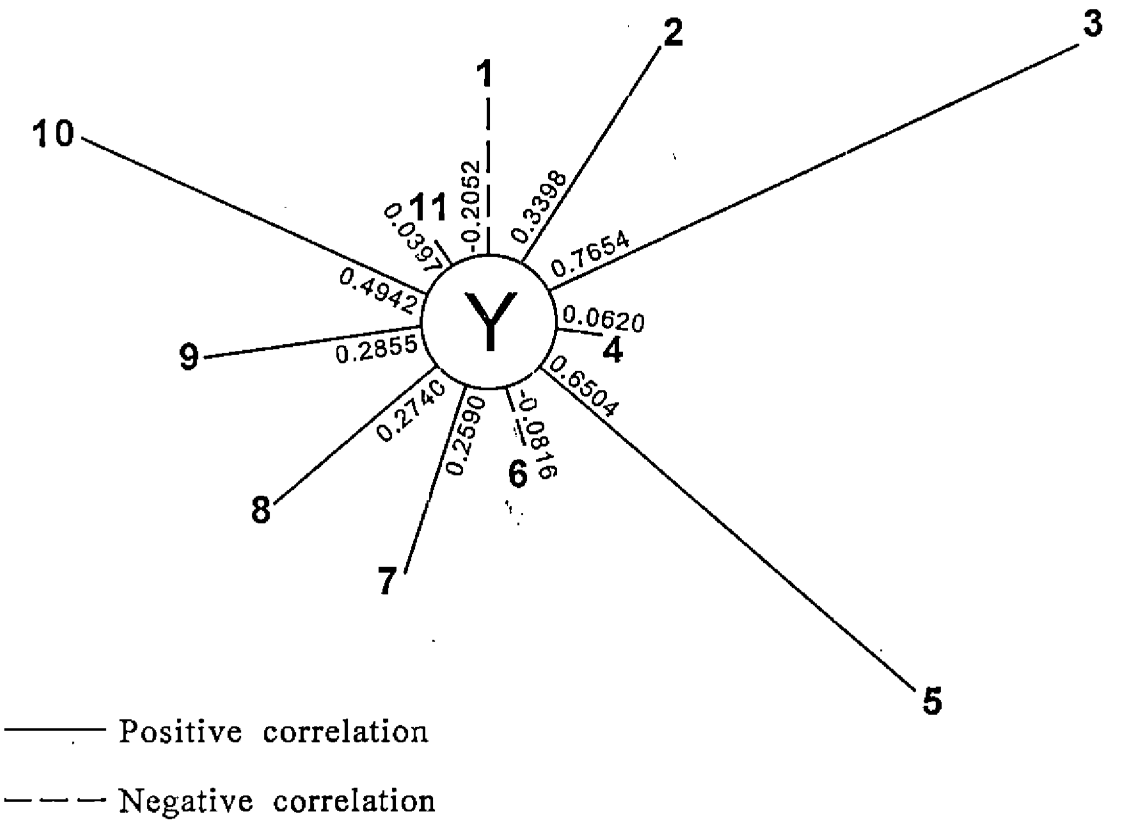
The genotypic correlation of yield with all the characters except days to first flowering, length of main stem, number of inflorescences per plant and number of seeds per pod were found to be significant and positive. Number of pods per plant had the highest positive correlation with pod yield per plant (0.7654) followed by number of pods per inflorescence (0.6504), pod weight (0.4942), length of harvesting period (0.3398), pod girth (0.2855), pod length (0.2740) and number of primary branches (0.2590).

While considering the environmental correlation of yield with other characters, number of pods per plant had the highest correlation coefficient (0.8759) followed by number of pods per inflorescence (0.7359), number of inflorescences per plant (0.7228) and pod weight (0.3689).

Table 7. Phenotypic, genotypic and environmental correlation coefficients between vegetable pod yield per plant and other characters

Sl.No.	Characters	Correlation coefficients		
		Phenotypic	Genotypic	Environmental
1.	Days to first flowering	-0.2124^{*}	-0.2052	-0.2877
2.	Length of harvesting period	0.3277^{**}	0.3398^{**}	0.2797
3.	Number of pods per plant	0.7766^{**}	0.7654^{**}	0.8759
4.	Number of inflorescences per plant	0.1241	0.0620	0.7228
5.	Number of pods per inflorescence	0.6543^{**}	0.6504^{**}	0.7359
6.	Length of main stem (cm)	-0.0788	-0.0816	-0.0449
7.	Number of primary branches	0.2246^{*}	0.2590^{*}	-0.0393
8.	Pod length (cm)	0.2456^{*}	0.2740^{**}	-0.0450
9.	Pod girth (mm)	0.2601^{*}	0.2855^{**}	0.0570
10.	Pod weight (g)	0.4836^{**}	0.4942^{**}	0.3689
11.	Number of seeds per pod	0.0000	0.0397	-0.2095

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



1 - Days to first flowering
2 - Length of harvesting period
3 - Number of pods per plant
4 - Number of inflorescences per plant
5 - Number of pods per inflorescence
6 - Length of main stem
7 - Number of primary branches
8 - Pod length
9 - Pod girth
10 - Pod weight
11 - Number of seeds per pod

Fig. 3. Genotypic correlation of yield with other characters

b) Correlation among the yield component characters

The phenotypic, genotypic and environmental correlation coefficients among the yield components are presented in Tables 8, 9 and 10 respectively.

1. Days to first flowering

Number of days to first flowering recorded significant negative phenotypic correlation with length of harvesting period (-0.5687), number of pods per plant (-0.3814) and number of pods per inflorescence (-0.3263). Positive genotypic correlation was observed with pod weight (0.2311), pod length (0.2147) and pod girth (0.1931). Length of harvesting period recorded significant negative genotypic correlation (-0.4870) followed by number of pods per plant (-0.4308) and number of pods per inflorescence (-0.3601). Environmental correlation was highly significant and negative for length of harvesting period (-0.8373).

2. Length of harvesting period

At phenotypic level, significant positive correlation was observed with number of pods per plant (0.3411) and number of inflorescences per plant (0.3144) while days to first flowering (-0.5687) and length of main stem (-0.2616) recorded significant negative correlation. Genotypic correlation was significant and positive with number of pods per plant (0.3655), and number of inflorescences per plant (0.3148) while days to

Table 8. Phenotypic correlation coefficients among the yield component characters

Characters	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod
Days to first flowering	1.0000										
Length of harvesting period	-0.5687**	1.0000									
No. of pods/plant	-0.3814**	0.3411**	1.0000								
No. of inflorescences/plant	-0.0557	0.3144**	0.0651	1.0000							
No. of pods/inflorescence	-0.3263**	0.1962	0.8682**	-0.3840**	1.0000						
Length of main stem	0.1831	-0.2616*	-0.1966	-0.0086	-0.1713	1.0000					
No. of primary branches	0.1008	0.0302	0.2923**	-0.0746	0.2834**	0.0830	1.0000				
Pod length	0.1564	-0.0091	-0.0393	0.2952**	-0.1705	0.2397*	-0.1851	1.0000			
Pod girth	0.1395	-0.0173	-0.0683	0.2646*	-0.2040	0.0541	-0.0406	0.4033**	1.0000		
Pod weight	0.1697	0.0529	-0.1496	0.1477	-0.1837	0.1002	-0.0633	0.4206**	0.4640**	1.0000	
No. of seeds/pod	0.1099	0.1009	0.0751	-0.0519	0.0892	0.0352	0.0751	0.0665	-0.2591*	-0.1511	1.0000

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

Table 9. Genotypic correlation coefficients among the yield component characters

Characters	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod
Days to first flowering	1.0000										
Length of harvesting period	-0.4870**	1.0000									
No. of pods/plant	-0.4308**	0.3655**	1.0000								
No. of inflorescences/plant	-0.0158	0.3148**	-0.0166	1.0000							
No. of pods/inflorescence	-0.3601**	0.2001	0.8808**	-0.4549**	1.0000						
Length of main stem	0.2071	-0.2847**	-0.2117*	-0.0053	-0.1794	1.0000					
No. of primary branches	0.1301	0.0440	0.3521**	-0.0699	0.3212**	0.0973	1.0000				
Pod length	0.2147*	-0.0383	-0.0494	0.3165**	-0.1780	0.2569*	-0.2102*	1.0000			
Pod girth	0.1931	-0.0349	-0.0938	0.2775**	-0.2322*	0.0631	-0.0554	0.4445**	1.0000		
Pod weight	0.2311*	0.0432	-0.1570	0.1585	-0.1948	0.1108	-0.0845	0.4675**	0.5241**	1.0000	
No. of seeds/pod	0.1383	0.1534	0.1386	-0.0451	0.1268	0.0315	0.1100	0.0586	-0.3070**	-0.1712	1.0000

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

Table 10. Error correlation coefficients among the yield component characters

Characters	Days to first flowering	Length of harvesting period	No. of pods/ plant	No. of inflore-scences/ plant	No. of pods/ inflore-scence	Length of main stem (cm)	No. of primary branches	Pod length (cm)	Pod girth (mm)	Pod weight (g)	No. of seeds/ pod
Days to first flowering	1.0000										
Length of harvesting period	-0.8373**	1.0000									
No. of pods/plant	-0.2169*	0.2213*	1.0000								
No. of inflorescences/plant	-0.2638*	0.3399**	0.7759**	1.0000							
No. of pods/inflorescence	-0.2486*	0.2145*	0.7926**	0.5408**	1.0000						
Length of main stem	0.1109	-0.1363	-0.0225	-0.0597	-0.0062	1.0000					
No. of primary branches	-0.0066	-0.0390	-0.1268	-0.1130	-0.0878	-0.0750	1.0000				
Pod length	-0.1112	0.1839	0.0534	0.0729	-0.0679	-0.0202	0.0204	1.0000			
Pod girth	-0.0672	0.0745	0.1185	0.1616	0.0889	-0.0513	0.0582	0.0506	1.0000		
Pod weight	-0.1640	0.1494	-0.0752	0.0095	0.0171	-0.1148	0.1580	-0.2327*	-0.1589	1.0000	
No. of seeds/pod	0.0336	-0.0780	-0.2199*	-0.0968	-0.1507	0.0831	-0.0719	0.1250	-0.0620	-0.0613	1.0000

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

first flowering (-0.4870) and length of main stem (-0.2847) showed significant negative correlation. Days to first flowering recorded highest significant negative environmental correlation (-0.8373) while number of inflorescences per plant (0.3399) recorded significant positive environmental correlation.

3. Number of pods per plant

Number of pods per inflorescence showed significant positive correlation (0.8682) at phenotypic level followed by length of harvesting period (0.3411) and number of primary branches (0.2923) while significant negative correlation was observed for days to first flowering (-0.3814). At genotypic level, number of pods per inflorescence (0.8808) showed significant positive correlation followed by length of harvesting period (0.3655) and number of primary branches (0.3521). Days to first flowering (-0.4308) recorded significant negative genotypic correlation along with length of main stem (-0.2117). Environmental correlation was significant and positive for number of pods per inflorescence (0.7926) followed by number of inflorescences per plant (0.7759) and length of harvesting period (0.2213).

4. Number of inflorescences per plant

This character showed significant positive phenotypic correlation with length of harvesting period (0.3144), pod length (0.2952) and pod girth (0.2646). Number of pods per inflorescence showed significant negative phenotypic correlation (-0.3840). Genotypic correlation was positive and significant for length of harvesting period (0.3148), pod length (0.3165) and pod girth (0.2775) while number of pods per inflorescence (-0.4549) showed significant negative correlation. Environmental correlation was significant and positive for number of pods per plant (0.7759), number of pods per inflorescence (0.5408) and length of harvesting period (0.3399) while days to first flowering showed significant negative correlation (-0.2638).

5. Number of pods per inflorescence

Phenotypic correlation was significant and positive for number of pods per plant (0.8682) and number of primary branches (0.2834) while number of inflorescences per plant (-0.3840) and days to first flowering (-0.3263) recorded significant negative correlation. Number of pods per plant (0.8808) and number of primary branches (0.3212) recorded significant and positive genotypic correlation while number of inflorescences per plant (-0.4549) and days to first flowering (-0.3601) showed significant negative correlation. Environmental correlation was significant and positive for number of pods per plant (0.7926) and number of inflorescences per plant (0.5408).

6. Length of main stem

Pod length alone showed significant positive phenotypic correlation while length of harvesting period had negative correlation with length of main stem. Genotypic correlation was positive and significant for pod length (0.2569) while length of harvesting period (-0.2847) and number of pods per plant (-0.2117) showed significant negative correlation. Environmental correlation of length of main stem with other characters were not significant.

7. Number of primary branches

Significant phenotypic correlation was observed for number of pods per plant (0.2923) and number of pods per inflorescence (0.2834). Number of pods per plant (0.3521) and number of pods per inflorescence (0.3212) showed positive and significant genotypic correlation while pod length (-0.2102) showed significant negative correlation. None of the characters showed significant environmental correlation.

8. Pod length

At phenotypic level, pod girth (0.4033), pod weight (0.4206) number of inflorescences per plant (0.2952) and length of main stem (0.2397) recorded significant positive correlation with pod length. This character had maximum positive and significant genotypic correlation with pod weight (0.4675) followed by pod girth (0.4445), number of inflorescences per plant (0.3165) and length of main stem (0.2569). Only pod weight (-0.2327) recorded significant negative environmental correlation with pod length.

9. Pod girth

Pod girth recorded significant positive phenotypic correlation with pod weight (0.4640) and pod length (0.4033) while number of seeds per pod showed significant negative correlation (-0.2591). Pod weight (0.5241) showed significant and positive genotypic correlation followed by pod length (0.4445) and number of inflorescences per plant (0.2775) while number of seeds per pod (-0.3070) and number of pods per inflorescence (-0.2322) recorded significant negative correlation. None of the characters showed significant environmental correlation with pod girth.

10. Pod weight

Significant positive phenotypic correlation was recorded for pod girth (0.4640) and pod length (0.4206). Genotypic correlation was significant and positive for pod girth (0.5241), pod length (0.4675) and days to first flowering (0.2311). The only character showing significant environmental correlation (negative) with pod weight was pod length (-0.2327).

11. Number of seeds per pod

Phenotypic correlation was negative and significant (-0.2591) for pod girth only. At genotypic level, maximum positive correlation was observed for length of harvesting period (0.1534) while pod girth recorded significant negative correlation (-0.3070). Number of pods per plant recorded significant negative environmental correlation (-0.2199) with number of seeds per pod.

4.1.6. Path analysis

In path coefficient analysis, the genotypic correlation coefficients among yield and its component characters were partitioned into different components to find the direct and indirect contribution of each character to pod yield (Table 11). The characters *viz.*, length of harvesting period, number of pods per plant, number of pods per inflorescence, pod length, pod girth and pod weight were selected for path coefficient analysis. These component characters had highly significant genotypic correlation with yield. Path diagram showing the direct and indirect effects of the component characters on yield is provided in Fig. 4.

The maximum direct effect on yield was shown by number of pods per plant (0.7613) followed by pod weight (0.5884) and number of pods per inflorescence (0.1105)

Length of harvesting period recorded the lowest direct effect (0.0173) on yield. But its indirect effect through number of pods per plant (0.2783) was high which accounted for its high genotypic correlation with yield (0.3398). The indirect effects of length of harvesting period via other characters were negligible.

Number of pods per plant had the highest direct effect (0.7613) as well as highest positive correlation (0.7654) with yield. The indirect

Table 11. Direct and indirect effects of yield components on pod yield in yard-long bean

Characters	Length of harvesting period	No. of pods per plant	No. of pods/ inflorescence	Pod length	Pod girth	Pod weight	Total genotypic correlation
Length of harvesting period	0.0173	0.2783	0.0221	-0.0011	-0.0022	0.0254	0.3398
Number of pods per plant	0.0063	0.7613	0.0974	-0.0015	-0.0058	-0.0924	0.7654
Number of pods/inflorescence	0.0035	0.6706	0.1105	-0.0052	-0.0143	-0.1146	0.6504
Pod length	-0.0007	-0.0376	-0.0197	0.0294	0.0274	0.2751	0.2740
Pod girth	-0.0006	-0.0714	-0.0257	0.0131	0.0617	0.3084	0.2855
Pod weight	0.0007	-0.1195	-0.0215	0.0138	0.0323	0.5884	0.4942

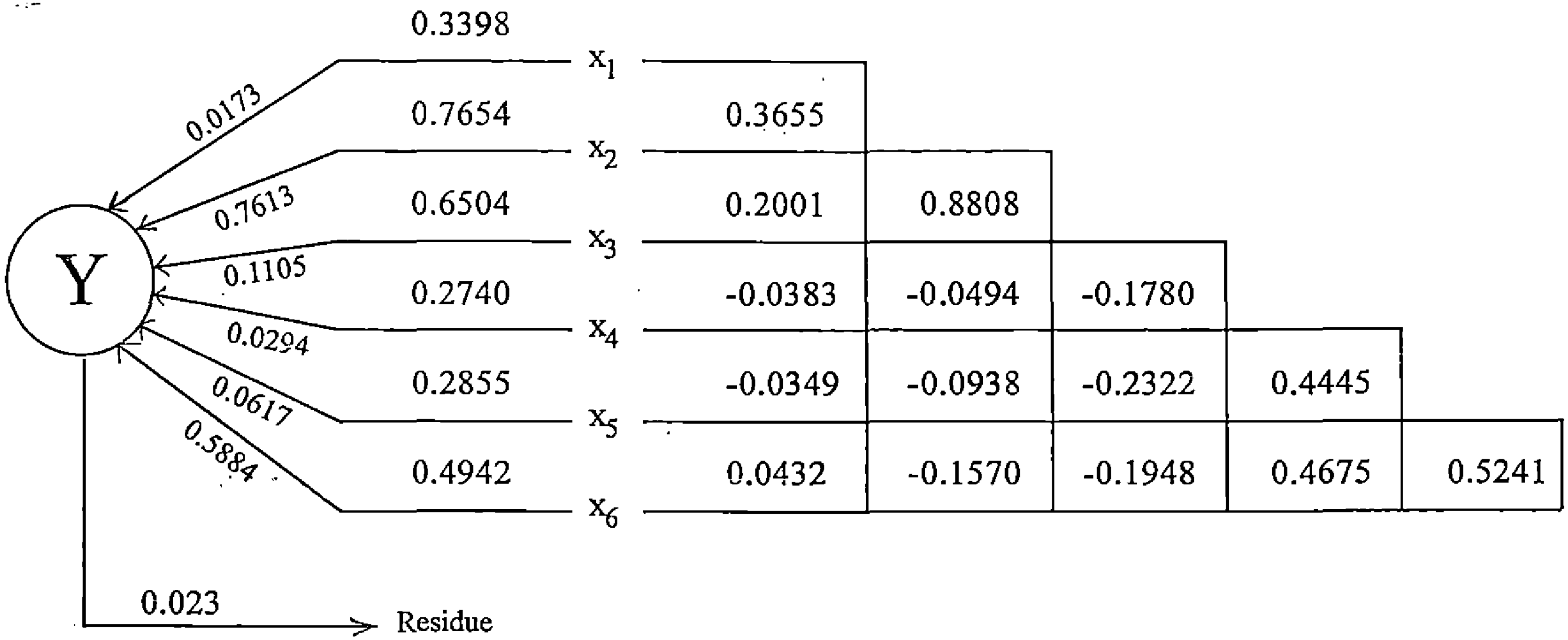
R = 0.023 Underlined figures are direct effects effect through other characters on yield was negligible. So this correlation explained the true relationship of number of pods per plant and yield.

The direct effect of number of pods per inflorescence was low (0.1105) but its total correlation was high (0.6504). This may be due to the high indirect effect via number of pods per plant (0.6706). Pod weight (-0.1146) exerted low but negative indirect effect on pod yield via number of pods per inflorescence. The indirect effects via other characters were negligible.

Pod length recorded low but positive direct effect (0.0294) on pod yield but its indirect effect via pod weight was high and positive (0.2751) which is almost equal to its total correlation (0.2740) with yield. The indirect effect via other characters is almost nullified.

The direct effect of pod girth on pod yield was low and positive (0.0617) but its indirect effect via pod weight was high (0.3084) which accounted for the positive correlation (0.2855) of pod girth on yield. Other characters have not contributed towards yield via pod girth.

Pod weight recorded high and positive direct effect (0.5884) on yield as well as high total correlation (0.4942). But its indirect effect vià number of pods per plant (-0.1195) was negative. Other characters showed negligible indirect effect on yield via pod weight.



Direct effects shown in arrows. Inter-relationships shown in the steps.

x_1	- Length of harvesting period	x_4	- Pod length
x_2	- Number of pods per plant	x_5	- Pod girth
x_3	- Number of pods per inflorescence	x_6	- Pod weight

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

Number of pods per plant and pod weight are the main characters which influence yield directly and indirectly. Hence these characters can be considered during selection programmes for identifying high yielding vegetable cowpea genotypes. The residue obtained (0.023) indicated that 97.7 per cent of variation could be explained by the path coefficient model.

4.1.7. Genetic divergence analysis

Following Mahalanobis statistic, the 50 genotypes of yard-long bean were subjected to D^2 analysis based on the seven characters *viz.*, length of harvesting period, number of pods per plant, number of pods per inflorescence, pod length, pod girth, pod weight and yield of vegetable pods per plant.

The 50 genotypes fell under four clusters. The clustering pattern is furnished in Table 12. Cluster I was the largest with 28 genotypes followed by cluster II with 13 and cluster III with eight genotypes. Cluster IV had only one genotype.

The cluster means of the 12 characters are presented in Table 13. Cluster IV showed the highest cluster mean for the characters *viz.*, length of harvesting period, number of pods per plant, yield of vegetable pods per plant, number of inflorescences per plant, number of primary branches, pod girth, pod weight and number of seeds per pod and lowest cluster mean for days to first flowering.

Table 12. Clustering pattern of genotypes

Cluster No.	No. of genotypes	Genotypes
I	28	1, 3, 4, 6, 7, 9, 11, 15, 16, 17, 19, 21, 23, 24, 26, 28, 29, 32, 33, 34, 35, 36, 40, 41, 43, 44, 48, 50
II	13	2, 8, 10, 12, 13, 14, 18, 20, 22, 25, 31, 39, 46
III	8	5, 27, 30, 37, 38, 42, 45, 49
IV	1	47

Table 13. Cluster means of the 12 biometric characters

Sl.No.	Character	Clusters			
		I	II	III	IV
1.	Days to first flowering	47.55	47.67	46.27	45.13
2.	Length of harvesting period (days)	34.23	34.02	36.66	40.07
3.	Number of pods per plant	20.27	24.20	31.18	32.93
4.	Yield of vegetable pods per plant (g)	282.05	391.78	511.61	614.27
5.	Number of inflorescences per plant	16.86	19.45	15.92	20.47
6.	Number of pods per inflorescence	2.40	2.49	3.60	3.20
7.	Length of main stem (cm)	438.43	492.87	417.49	361.53
8.	Number of primary branches	4.22	4.24	4.61	5.13
9.	Pod length (cm)	41.05	45.91	41.86	45.47
10.	Pod girth (mm)	25.40	27.07	26.66	33.13
11.	Pod weight (g)	14.60	16.90	17.98	19.07
12.	Number of seeds per pod	18.65	18.33	18.88	19.33

The highest cluster mean for number of pods per inflorescence and second highest cluster mean for length of harvesting period, number of pods per plant, yield of vegetable pods per plant, number of primary branches, pod weight and number of seeds per pod were for cluster III. It also had lowest cluster mean for number of inflorescences per plant.

Cluster II had highest cluster mean for days to first flowering, length of main stem and pod length and second highest cluster mean for number of inflorescences per plant and pod girth. It also recorded lowest cluster mean for length of harvesting period and number of seeds per pod.

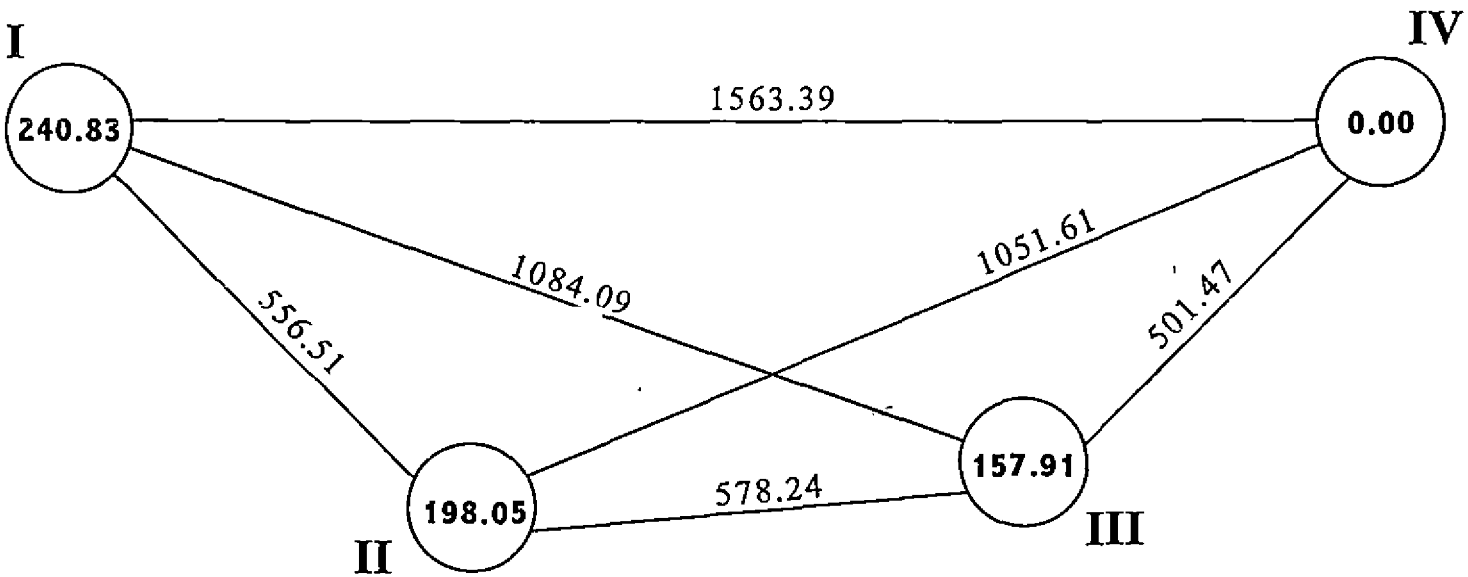
Cluster I had the lowest cluster mean for most of the characters including number of pods per plant, yield of vegetable pods per plant, number of pods per inflorescence, number of primary branches, pod length pod girth and pod weight.

The average inter and intracluster distances are presented in Table 14. The intercluster distance was maximum between cluster I and IV (1565.39) followed by cluster I and III (1084.09) and cluster II and IV (1051.61). The least intercluster distance was between cluster III and IV (501.47).

The intracluster distance was on the increase with increasing cluster size. Cluster I had the highest intracluster distance (240.83) followed by cluster II (198.05) and cluster III (157.91). The cluster diagram is provided in Fig. 5.

Table 14. Average inter and intracluster D^2 values among four clusters (D values in parenthesis)

	I	II	III	IV
I	57997.79	309698.91	1175253.63	2450445.89
	(240.83)	(556.51)	(1084.09)	(1565.39)
II		39224.81	334357.52	1105881.24
		(198.05)	(578.24)	(1051.61)
III			24934.51	251469.01
			(157.91)	(501.47)
IV				0.00



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

Fig. 5. Cluster diagram

4.2. Screening for legume pod borer resistance

The major feeding sites of legume pod borer larvae are the flowers, developing pods and seeds. Screening of cultivars based on the extent of damage to flowers, pods and seeds was attempted in the present study. Infested flowers could be easily recognised by the presence of larval entry - exit holes on them. Larvae of the pod borer were present in most of the infested flowers (Plate 7). Plate 8 shows the typical damage caused to the peduncle. Larval entry-exit holes would be present on infested pods. Plate 9 shows the infested pods with larval entry points covered with brownish frass. Webbing together of pods on the same peduncle is a common symptom (Plate 10).

4.2.1. Damage parameters and resistance evaluation

The legume pod borer damage parameters and overall plant resistance index (Ipr) relating to 50 vegetable cowpea cultivars are present in Table 15.

The criteria employed for assessment of flower damage were the percentage of infested flowers and the number of larvae in 25 flowers. Vs 9 with 80 per cent infested flowers and more than 21 larvae in 25 flowers was the cultivar suffering most severe flower damage. Vs 19 and Vs 48 were on par with Vs 9 in flower damage in terms of both percentage of infested flowers and larval count in flowers. On the other hand, Vs 5, Vs 18, Vs 27, Vs 33 and Vs 50 showed significantly low

Plate 7. *Maruca vitrata* larva inside a cowpea flower

Plate 8. Typical damage symptom on peduncle

Plate 9. Larval entry holes on infested pods plugged with excreta

Plate 10. Webbing together of pods on the same peduncle

flower damage irrespective of the criterion employed for damage assessment. Other varieties deserving mention are Vs 25 with lesser flower infestation and Vs 29 with lower count of larvae in flowers.

Percentage pod infestation and pod damage severity were the two crietria employed for pod damage assessment, the latter being the number of larval entry / exit holes per pod. Percentage of infested pods ranged from 34 (Vs 34) to 66 (Vs 28, Vs 45 and Vs 46). The cultivars statistically on par with Vs 34 were Vs 23, Vs 29, Vs 39 and Vs 42. Apart from the three varieties mentioned above, high degree of pod infestation also occured in nine other cultivars, *viz.*, Vs 9, Vs 10, Vs 16, Vs 24, Vs 25, Vs 26, Vs 31, Vs 38 and Vs 48. Pod damage severity was least (0.46) for Vs 39. Other cultivars with statistically equivalent low pod damage severity were Vs 34 and Vs 42. Most severe pod damage was observed for Vs 24 (2.00) and none of the varieties was statistically on par with it.

The attack of a pod often leads to infestation of pods developing subsequently from the same peduncle. So simultaneous infestation of more than one pod on a peduncle, referred here as multiple pod infestation is a commonly observed feature. The cultivars Vs 9, Vs 24 and Vs 28 recorded the highest percentage of infested peduncles with multiple pod damage (92.5 per cent). Vs 10, Vs 45 and Vs 46 also suffered high multiple pod damage. Relative low multiple pod damage could be observed for several varieties. Three varieties among them were Vs 34, Vs 39

Table 15. Legume pod borer damage measurements and plant resistance indices of 50 yard-long bean cultivars

Acc. No.	Percentage infestation of flowers	Number of larvae per 25 flowers	Percentage pod infestation	Pod damage severity	Percentage of infested peduncles with multiple pod damage	Seed damage index	Plant resistance index
Vs1	50	14.0	46	0.88	72.5	44	29.67
Vs2	50	13.0	42	0.78	67.5	34	26.17
Vs3	44	13.5	54	1.12	82.5	42	31.75
Vs4	60	17.0	46	0.92	72.5	44	31.17
Vs5	34	10.0	42	0.70	67.5	54	28.00
Vs6	50	15.0	54	0.90	82.5	66	36.50
Vs7	48	13.5	58	0.94	85.0	46	33.75
Vs8	54	16.0	48	0.60	72.5	38	30.34
Vs9	80	21.5	64	1.20	92.5	46	39.75
Vs10	66	16.5	62	1.04	87.5	66	39.92
Vs11	44	12.0	46	0.90	72.5	40	28.00
Vs12	66	17.0	42	0.70	67.5	38	28.83
Vs13	48	14.0	50	1.16	72.5	48	31.67
Vs14	66	18.0	44	0.86	72.5	58	33.34

Table 15. (Contd...)

Acc. No.	Percentage infestation of flowers	Number of larvae per 25 flowers	Percentage pod infestation	Pod damage severity	Percentage of infested peduncles with multiple pod damage	Seed damage index	Plant resistance index
Vs15	48	12.0	58	1.06	82.5	74	37.67
Vs16	62	16.0	60	1.20	85.0	74	40.34
Vs17	50	13.0	48	0.66	67.5	52	31.17
Vs18	38	10.5	52	0.88	72.5	54	31.59
Vs19	76	20.0	46	0.86	72.5	46	33.00
Vs20	58	15.0	42	0.78	67.5	48	29.50
Vs21	66	16.5	50	0.88	72.5	58	34.58
Vs22	62	17.0	54	1.02	77.5	66	37.50
Vs23	58	15.5	40	0.88	62.5	54	30.08
Vs24	54	15.0	64	2.00	92.5	92	44.17
Vs25	36	11.5	62	1.08	82.5	86	40.75
Vs26	46	11.5	64	0.76	85.0	56	36.42
Vs27	38	10.0	44	0.90	67.5	64	30.34
Vs28	58	18.5	66	1.68	92.5	70	42.92

Table 15. (Contd...)

Acc. No.	Percentage infestation of flowers	Number of larvae per 25 flowers	Percentage pod infestation	Pod damage severity	Percentage of infested peduncles with multiple pod damage	Seed damage index	Plant resistance index
Vs29	42	11.0	38	0.76	62.5	50	26.50
Vs30	70	18.5	54	0.70	82.5	48	35.25
Vs31.	44	12.0	62	0.80	82.5	56	36.00
Vs32	50	12.5	54	1.10	82.5	70	35.92
Vs33	34	8.5	50	1.04	72.5	54	29.92
Vs34	46	12.0	34	0.56	62.5	42	24.33
Vs35	58	15.0	50	0.86	72.5	50	32.50
Vs36	60	15.5	42	0.78	62.5	50	30.08
Vs37	42	12.0	42	0.76	62.5	50	28.34
Vs38	52	14.5	62	1.26	82.5	80	41.25
Vs39	60	15.5	36	0.46	62.5	42	26.75
Vs40	66	17.0	58	1.44	77.5	84	41.84
Vs41	72	18.5	42	0.98	62.5	50	31.59
Vs42	58	15.0	40	0.54	62.5	42	27.84

Table 15. (Contd...)

Acc. No.	Percentage infestation of flowers	Number of larvae per 25 flowers	Percentage pod infestation	Pod damage severity	Percentage of infested peduncles with multiple pod damage	Seed damage index	Plant resistance index
Vs43	56	14.5	44	0.84	65.0	52	30.59
Vs44	54	13.5	44	0.70	67.5	54	30.42
Vs45	62	16.0	66	1.52	87.5	82	43.67
Vs46	48	12.5	66	1.48	87.5	90	43.25
Vs47	58	15.5	48	0.88	70.0	52	32.42
Vs48	74	19.5	64	0.90	85.0	58	40.75
Vs49	54	13.5	44	0.58	65.0	52	30.08
Vs50	36	11.0	50	1.24	72.5	76	34.84
$F_{49,49}$	16.46**	8.61**	14.93**	75.17**	15.32**	10.08**	19.06**
$CD_{(0.05)}$	7.86	2.74	6.63	0.098	6.72	13.04	3.41

and Vs 42 which recorded low pod damage in terms of percentage pod infestation and pod damage severity.

The data on seed damage index showed that Vs 2 (34) had the lowest and Vs 24 (92) had the highest index values. Cultivars with seed damage index values not significantly different from Vs 2 included Vs 1, Vs 3, Vs 4, Vs 7, Vs 8, Vs 9, Vs 11, Vs 12, Vs 19, Vs 34, Vs 39 and Vs 42. On the other hand, Vs 25, Vs 38, Vs 40, Vs 45 and Vs 46 had seed damage high enough to be statistically on par with Vs 24.

There were significant differences among cultivars in plant resistance index (Ipr) computed using a combination of flower, pod and seed damage parameters. The Ipr values ranged from 24.33 to 44.17. Lower Ipr values indicate higher levels of plant resistance. Vs 34 with the lowest Ipr value was identified as the most resistant among the 50 cultivars. Varieties not significantly different from Vs 34 were Vs 2, Vs 29, Vs 39 and Vs 42. The most susceptible variety was Vs 24 with an Ipr value of 44.17. The cultivars with Ipr value on par with that of Vs 24 were Vs 25, Vs 28, Vs 38, Vs 40, Vs 45, Vs 46 and Vs 48.

4.2.2. Correlation among damage parameters

The correlation among the different parameters for the assessment of legume pod borer damage to flowers, pods and seeds were estimated and presented in Table 16.

Table 16. Correlation between various parameters of pod borer damage

Damage parameters	Percentage infestation of flowers	Number of larvae per 25 flowers	Percentage pod infestation	Pod damage severity	Percentage of infested peduncles with multiple pod damage	Seed damage index
Percentage infestation of flowers	1.0000					
Number of larvae per 25 flowers	0.9463**	1.0000				
Percentage pod infestation	0.0856	0.1329	1.0000			
Pod damage severity	0.0476	0.1325	0.6811**	1.0000		
Percentage of infested peduncles with multiple pod damage	0.1289	0.1984	0.9476**	0.6372**	1.0000	
Seed damage index	-0.0961	-0.0814	0.6340**	0.7210**	0.5478**	1.0000

Percentage infestation of flowers showed significant and high positive correlation with number of larvae per 25 flowers (r = 0.9463). But the results suggested that there was no relationship between percentage infestation of flowers and other damage parameters *viz.*, percentage pod infestation, pod damage severity, percentage of infested peduncles with multiple pod damage and seed damage index. Similarly, larval count in flowers was not correlated with any of the damage parameters except percentage infestation of flowers.

There was significant and positive correlation between percentage pod infestation and pod damage severity (r = 0.6811). Both these pod damage parameters in turn, were found to be correlated with percentage of infested peduncles with multiple pod damage and seed damage index.

Percentage of infested peduncles with multiple pod damage showed positive and significant correlation with percentage pod infestation (r = 0.9476) followed by pod damage severity (r = 0.6372) and seed damage index (r = 0.5478).

Seed damage index showed significant positive correlation with pod damage severity (r = 0.7210), percentage pod infestation (r = 0.6340) and percentage of infested peduncles with multiple pod damage (r = 0.5478).

4.2.3. D^2 analysis

Employing the Mahalanobis D^2 statistic, the 50 yard-long bean varieties were grouped into seven clusters based on the different legume pod borer damage parameters *viz.*, percentage infestation of flowers, number of larvae per 25 flowers, seed damage index, number of larval entry / exit holes per pod, percentage of infested peduncles with multiple pod damage and plant resistance index. The clustering pattern is provided in Table 17.

Cluster I was the largest with 18 genotypes followed by cluster III with 12, cluster IV with 11 and cluster II with six genotypes. Cluster V, cluster VI and cluster VII had one genotype each.

The average intra and intercluster distances are provided in Table 18. The intracluster distance was least for cluster III (16.79) followed by cluster I (16.99), cluster II (17.51) and cluster IV (19.06).

The highest intercluster distance was observed between clusters IV and VII (79.26) followed by clusters IV and V (67.71), cluster IV and VI (65.68) and clusters III and VI (63.49). The least intercluster distance was between clusters V and VI (22.42). The cluster diagram is provided in Fig. 6.

The cluster means of different clusters based on the different legume pod borer damage parameters are provided in Table 19.

Table 17. Clustering pattern of genotypes

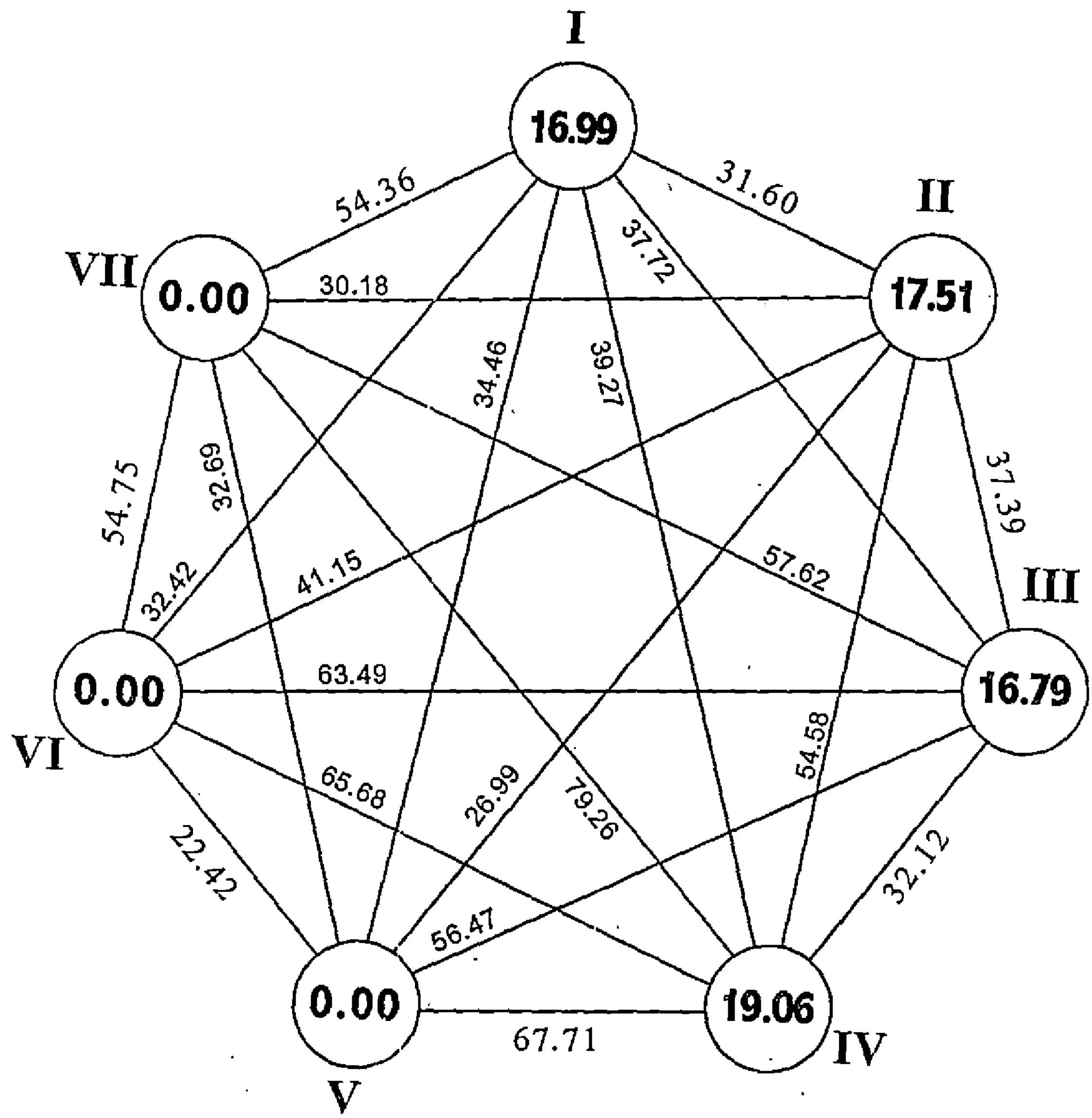
Clusters	Number of genotypes	Genotypes
I	18	2,4,8, 12,14,17,20,21,22,23,35,36,39,42,43,44,47,49
II	6	10,16,30,40,45,48
III	12	1,3,6,7,15,24,26,28;31,32,38,46
IV	11	5,11,13,18,25,27,29,33,34,37,50
V	1	19
VI	1	41
VII	1	9

Table 18. Average intra and inter D^2 values among seven clusters of genotypes in yard-long bean (D values in parenthesis)

	I	II	III	IV	V	VI	VII
I	288.68 (16.99)	998.71 (31.60)	1423.02 (37.72)	1542.41 (39.27)	1187.18 (34.46)	1051.21 (32.42)	2954.55 (54.36)
II		306.75 (17.51)	1398.12 (37.39)	2978.78 (54.58)	728.32 (26.99)	1693.14 (41.15)	910.73 (30.18)
III			282.01 (16.79)	1031.65 (32.12)	3189.30 (56.47)	4030.42 (63.49)	3320.42 (57.62)
IV				363.42 (19.06)	4583.98 (67.71)	4314.30 (65.68)	6282.50 (79.26)
V					0.00	502.56 (22.42)	1068.80 (32.69)
VI						0.00	2997.73 (54.75)
VII							0.00

Table 19. Cluster means for the various pod borer damage parameters

Damage parameters	Clusters						
	I	II	III	IV	V	VI	VII
Percentage infestation of flowers	58.22	66.67	49.33	39.82	76.0	72.0	80.0
Number of larvae per 25 flowers	15.33	17.25	13.71	11.14	20.0	18.5	21.5
Percentage pod infestation	44.67	60.67	59.0	46.36	46.0	42.0	64.0
Pod damage severity	0.76	1.13	1.17	0.91	0.86	0.98	1.20
Percentage of infested peduncles with multiple pod damage	68.19	84.17	84.17	69.77	72.5	62.5	92.5
Seed damage index	49.11	68.67	65.5	56.18	46.0	50.0	46.0
Plant resistance index	30.74	40.3	37.47	30.39	33.0	31.59	39.75



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

Fig. 6. Cluster diagram

Cluster IV showed the least cluster mean for percentage infestation of flower buds (39.82) and number of larvae per 25 flowers (11.14). The plant resistance index value was also lowest in this cluster (30.39)

The least cluster means for percentage pod infestation (42.0) and percentage of infested peduncles with multiple pod damage (62.5) was least for cluster VI. But this cluster had high mean values for flower damage parameters *viz.*, percentage infestation of flowers and number of larvae per 25 flowers.

Cluster I had the least cluster mean for pod damage severity (0.76) and also the second least cluster mean for percentage pod infestation (44.67), percentage of infested peduncles with multiple pod damage (68.19), plant resistance index (30.74) and seed damage index (49.11).

The highest cluster mean for all the damage parameters *viz.*, percentage flower infestation (80.0), number of larvae per 25 flowers (21.5), percentage pod infestation (64.0), pod damage severity (1.2) and percentage of infested peduncles with multiple pod damage (92.5) except seed damage index was observed for cluster VII. Fig. 7 shows the cluster means of flower, pod and seed damage measurements of the seven clusters.

In resistance breeding against legume pod borer, genotypes from cluster IV with low flower damage parameters and genotypes from cluster I with low pod damage parameters can be utilized as parents in hybridization programmes.

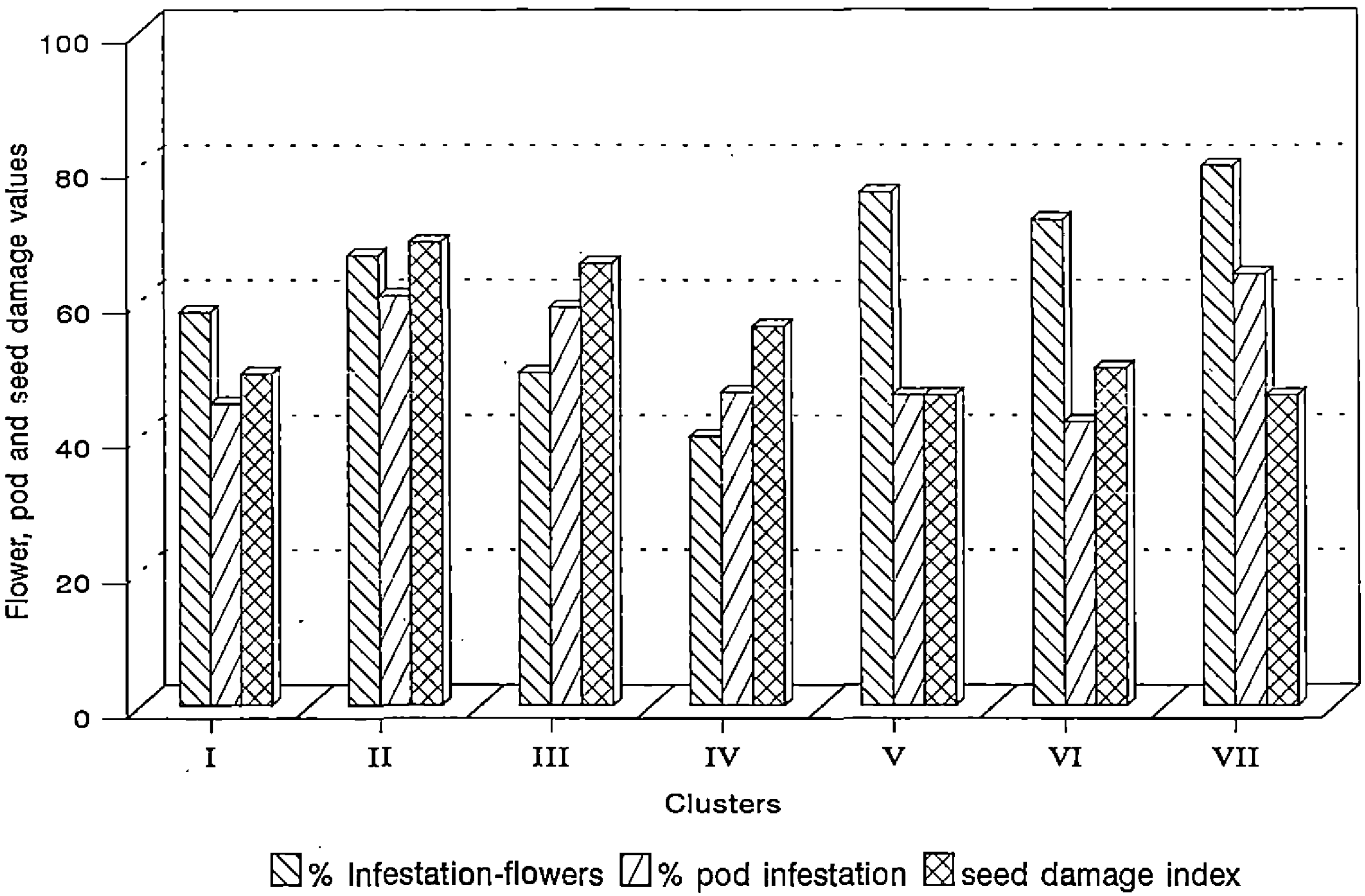


Fig. 7. Cluster means of flower, pod and seed damage measurements

Table 20. Contingency table of pod wall thickness with percentage pod infestation

Pod infestation	Pod wall thickness		Total
	Thin	Thick	
High	8	13	21
Low	8	21	29
Total	16	34	50

Calculated χ^2 value = 0.6182

Table value at 1 d.f. = 3.841

Table 21. Contingency table of pod wall thickness with pod damage severity

Pod damage severity	Pod wall thickness		Total
	Thin	Thick	
High	8	10	18
Low	8	24	32
Total	16	34	50

Calculated χ^2 value = 2.0016

Table value at 1 d.f. = 3.841

Table 22. Percentage pod infestation, pod damage severity and fibre content of 10 selected varieties

Varieties	Vs 5	Vs 33	Vs 27	Vs 18	Vs 41	Vs 19	Vs 26	Vs 9	Vs 48	Vs 28
Percentage pod infestation	42:0	50.0	44.0	52.0	42.0	46.0	64.0	64.0	64.0	66.0
Pod damage severity	0.68	1.04	0.90	0.88	0.98	0.86	1.76	1.20	0.90	1.68
Fibre content of pods	1.92	2.06	2.13	1.94	2.20	2.21	2.01	2.15	2.11	1.99

Varieties are arranged in the ascending order of Ipr values

4.2.4. Relationship of pod characters with pod damage parameters

The association of pod wall thickness and pod damage was studied employing Chi-square test. This involved categorisation of varieties into thick and thin pod walled based on visual assessment of pod wall thickness and grouping them into varieties suffering high and low pod damage using overall mean (below and above overall mean) of damage measurement as the basis for categorisation (Tables 20, 21). The Chi-square values worked out with the pod damage parameters *viz.*, percentage pod infestation and pod damage severity were 0.6182 and 2.0016 respectively. Both the Chi-square values were not significant suggesting the independence of pod wall thickness and pod damage due to legume pod borer.

Data on the fibre content and pod damage parameters of 10 varieties are given in Table 22. The correlation coefficients of fibre content with percentage pod infestation (r=-0.1500) and pod damage severity (r = 0.0410) were not significant suggesting that pod damage was least influenced by fibre content of pods.

DISCUSSION

5. DISCUSSION

Field experiments were conducted to study varietal variation in yard-long bean for yield and legume pod borer resistance. The experimental results are discussed under different headings.

5.1 Evaluation of yield and yield component characters

Crop improvement seeks alteration in the genetic make up of the existing varieties. The choice of breeding methods to achieve improvement in yield and its components mainly depends on the available variability, heritability of the character, genetic advance under selection and the association among characters. Selection for yield to be efficient, should take into account, yield as well as its components (Evans, 1978). The genetic analysis of yield and component characters is therefore indispensable. 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 studies

The magnitude of variability present in a crop species is of utmost importance as it provides the basis for effective selection. Since the observed variability in a population is the sum of variation arising due to genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential (Allard, 1960).

In the present investigation, analysis of variance revealed highly significant differences among the 50 yard-long bean varieties for all the 12 characters studied. Similarly the existence of high variability for several characters in vegetable cowpea was reported by Yap (1983), Sobha (1994), Resmi (1998), Vardhan and Savithramma (1998), Sharma (1999) and Pournami (2000).

Variation in vegetative characters was remarkable with length of main stem ranging from 324.13 cm to 652.47 cm and number of primary branches from 3.2 to 5.4. The results obtained by Hazra *et al.* (1996) and Resmi (1998) also indicated high variability for these characters in vegetable cowpea.

Wide variation was evident for the days taken for first flowering and length of harvesting period. The reports by Hazra *et al.* (1996), Resmi (1998) and Pournami (2000) supports this finding.

Characters like number of pods per plant, number of inflorescences per plant and number of pods per inflorescence also showed notable varietal variation. The range in pod count per plant (14.13 to 45.53) was impressive. This observation was in agreement with earlier reports by several workers in vegetable cowpea (Ramachandran *et al.*, 1980; Hazra *et al.*, 1996; Resmi, 1998; Pournami, 2000).

Remarkable variation in pod characters viz., pod length, pod girth, pod weight and number of seeds per pod was evident in the present study. Wide variation in pod length was also reported by Hazra *et al.* (1996), Wang YanFeng *et al.* (1997), Resmi (1998) and Pournami (2000). Reports of high variability for pod weight (Ramachandran *et al.*, 1980; Hazra *et al.*, 1996; Wang YanFeng *et al.*, 1997; Resmi, 1998; Pournami, 2000) and number of seeds per pod (Ramachandran *et al.*, 1980; Hazra *et al.*, 1996; Resmi, 1998) in vegetable cowpea supports this finding.

Yield of vegetable pods per plant also showed wide variation ranging from 614.27 g (Vs 47) to 208.37g (Vs 24). Vs 47 was identified as the top yielder. Existence of high variability for pod yield in vegetable cowpea was also reported by Ramachandran *et al.* (1980), Sobha (1994), Hazra *et al.* (1996), Resmi (1998) and Pournami (2000).

Coefficient of variation is another means of expressing the amount of variability. In the present study, PCV ranged from 6.01 to 28.95. Highest PCV was recorded for yield of vegetable pods per plant followed by number of pods per plant and number of pods per inflorescence. High PCV for vegetable pod yield and number of pods per plant were reported by Rajaravindran and Das (1997), Resmi (1998), Vardhan and Savithramma

(1998a) and Pournami (2000). Days to first flowering recorded the least PCV in the present study. Similarly Resmi (1998) reported low PCV for this character.

Phenotypic value being the aggregate of genotypic value and environmental deviation, selection based on phenotypic performance could be misleading. The GCV provides a precise measure of genetic variability. GCV ranged from 5.07 (days to first flowering) to 27.53 (yield of vegetable pods per plant). High GCV was also observed for number of pods per inflorescence, number of pods per plant and pod weight. High estimates of GCV for vegetable pod yield as well as number of pods per plant were reported by Jana *et al.* (1982), Sharma *et al.* (1988), Sobha (1994), Sreekumar *et al.* (1996), Rajaravindran and Das (1997), Resmi (1998), Vardhan and Savithramma (1998a) and Pournami (2000) as in the present investigation. High values of GCV for number of pods per inflorescence and pod weight were reported by Resmi (1998) and Pournami (2000) in yard-long bean. Low estimate of GCV for days to first flowering in the present study is supported by the findings of Resmi (1998) and Pournami (2000).

In this study, high values of PCV with correspondingly high values of GCV were observed for yield of vegetable pods per plant, number of pods per plant, number of pods per inflorescence and pod weight which indicated the presence of a great extent of genetic variability for these characters thus suggesting better scope for improvement through selection. High PCV and GCV values for both pod yield and number of pods per plant were reported by Rajaravindran and Das (1997), Resmi (1998), Vardhan and Savithramma (1998a) and Pournami (2000). So for these characters, phenotypic selection would be reliable.

5.1.2 Heritability and genetic advance

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

In the present study, all the characters showed high heritability estimates (71.16 to 95.85 per cent). Heritability was maximum for length of main stem followed by pod weight, number of pods per inflorescence, pod length, number of inflorescences per plant, yield of vegetable pods per plant and number of pods per plant.

High heritability for vegetable pod yield per plant in the present study was in agreement with the findings of Sobha (1994), Rajaravindran and Das (1997), Ram and Singh (1997), Resmi (1998), Vardhan and Savithramma (1998a) and Pournami (2000).

On the contrary low heritability for pod yield was reported by Yap (1983) and Sharma *et al.* (1988). High heritability for number of pods per plant has been reported earlier by Resmi (1998), Vardhan and Savithramma (1998a) and Pournami (2000). High heritability for pod weight was reported by Sobha (1994), Resmi (1998) and Pournami (2000) and for pod length by Ye and Zhang (1987), Savithramma (1992), Sreekumar *et al.* (1996), Rajaravindran and Das (1997), Resmi (1998) and Pournami (2000). Medium heritability was noticed for number of inflorescences per plant by Pournami (2000). As in the present study high heritability for number of inflorescence per plant was reported by Resmi (1998).

High values of genetic advance as percentage of mean were recorded for yield of vegetable pods per plant, number of pods per inflorescence, number of pods per plant, length of main stem, pod weight and number of inflorescences per plant in this study. Resmi (1998) and Pournami (2000) also reported high genetic advance for the above characters. The present findings are supported by earlier reports of high genetic advance for vegetable pod yield per plant (Sobha, 1994; Rajaravindran and Das, 1997; Ram and Singh, 1997; Resmi, 1998; Vardhan and Savithramma, 1998a; Pournami, 2000), number of pods per plant (Ramachandran *et al.*, 1980; Rajaravindran and Das, 1997; Resmi, 1998;

Vardhan and Savithramma, 1998a; Pournami, 2000) and pod weight (Sobha, 1994; Resmi, 1998; Pournami, 2000).

High heritability with high genetic advance of characters is indicative of additive gene action suggesting the possibility of genetic improvement of those characters through selection (Panse, 1957). In the present study, high estimates of heritability in conjunction with high genetic advance was observed for number of pods per plant, number of pods per inflorescence, yield of vegetable pods per plant, pod weight, length of main stem and number of inflorescences per plant. Similar results were earlier reported for number of pods per plant (Resmi, 1998; Vardhan and Savithramma, 1998a; Pournami, 2000), pod weight (Sobha, 1994; Resmi, 1998; Pournami, 2000) and pod yield per plant (Sobha, 1994; Rajaravindran and Das, 1997; Ram and Singh, 1997; Resmi, 1998; Vardhan and Savithramma, 1998a; Pournami, 2000).

5.1.3 Correlation studies

Yield is a complex character influenced by many characters either in positive or negative direction. So selection for yield should take into account related characters as well. Correlation provides information on the nature and extent of relationship between pairs of characters. Therefore analysis of yield in terms of genotypic and phenotypic correlation coefficients of component characters leads to the understanding of characters that can form the basis of selection. The genotypic correlation between characters provides a reliable measure of the genetic association between characters and helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1981).

5.1.3.1 Correlation between yield and other characters

In the present investigation, pod yield showed strong genotypic correlation with number of pods per plant (r = 0.7654), number of pods per inflorescence (r=0.6504), pod weight (r=0.4942), length of harvesting period (r = 0.3398) and also with pod girth, pod length and number of primary branches. None of the characters showed significant negative correlation with yield whereas six characters showed high positive genotypic correlation with yield.

The positive association of pod yield with number of pods per plant was in line with the results reported by Sharma *et al.* (1988), Tewari and Gautam (1989), Samiullah and Imtiaz (1993), Sreekumar *et al.* (1996), Resmi (1998); Vardhan and Savithramma (1998) and Pournami (2000). Correlations of pod yield with number of pods per inflorescence and length of harvesting period were reported by Pournami (2000). The earlier reports of high positive correlation of pod yield with pod weight (Sobha, 1994; Chattopadhyay *et al.*, 1997; Resmi, 1998; Pournami, 2000), pod length (Sobha, 1994; Sreekumar *et al.*, 1996; Chattopadhyay *et al.*, 1997: Resmi, 1998; Vardhan and Savithramma, 1998; Pournami, 2000) and number of primary branches (Kumar *et al.*, 1976; Jana *et al.*, 1982; Tewari and Gautam, 1989) also supports the present findings.

Significant positive phenotypic and genotypic correlations of pod yield with number of pods per plant, number of pods per inflorescence, pod weight and length of harvesting period imply that selection for these characters would lead to simultaneous improvement of pod yield in yard-long bean. High heritability of the above mentioned characters further support this notion, since for highly heritable characters, the phenotypic value of a genotype tend to reflect its genotypic worth. The other characters worthy of consideration in indirect selection for yield include number of primary branches, pod length and pod girth.

In general, the magnitude of genotypic correlation coefficients was higher than the corresponding phenotypic correlation coefficients for most of the characters positively correlated with yield indicating low environmental influence in these characters.

5.1.3.2 Correlation among the yield component characters

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

Days to first flowering showed significant negative genotypic correlation with length of harvesting period (r=-0.4870), number of pods per plant (r=-0.4308) and number of pods per inflorescence (r=-0.3601). Corroborative reports of significant negative correlation of days to first flowering with number of pods per plant (Sreekumar *et al*, 1996; Resmi, 1998; Pournami, 2000), length of harvesting period (Pournami, 2000) and number of pods per inflorescence (Resmi, 1998) support these findings.

Number of pods per plant showed highly significant positive genotypic correlation with number of pods per inflorecence (r=0.8808), length of harvesting period (r=0.3655) and number of primary branches (r=0.3521). Number of pods per inflorescence was negatively correlated with number of inflorescences per plant (r=-0.4549). This was similar to the findings of Pournami (2000).

Pod length was significantly and positively associated with pod weight (r=0.4675), pod girth (r=0.4445) and number of inflorescences per plant (r=0.3165) while pod weight showed significant positive correlation with pod girth (r=0.5244) at genotypic level. Similar results were obtained by Resmi (1998) and Pournami (2000). Number of seeds per pod recorded significant negative correlation (r = -0.3070) with pod girth.

The number of pods per plant and pod weight are not correlated with each other inspite of their significant positive correlation with pod yield. Further considering their relationship with other charaters correlated with pod yield it is suggested that selection for these characters would lead to worthwhile improvement in pod yield. High heritability coupled with high genetic advance for these characters indicate that phenotypic selection would be effective.

5.1.4 Path analysis

Plant breeders have to deal mostly with correlated characters during crop improvement programmes. Although correlation studies between yield and its components are useful, it does not give an exact picture of the relative importance of the various yield attributes. Rate of improvement is expected to be rapid if differential emphasis is laid on the component characters during selection. The basis of differential emphasis could be the degree of influence of component characters on the economic character of interest. Path coefficient analysis helps in partitioning the genotypic correlation coefficients into direct and indirect effects of the component characters on yield on the basis of which improvement programmes can be devised effectively.

In the present study, the maximum direct effect on yield was shown by number of pods per plant (0.7613) followed by pod weight (0.5884) and number of pods per inflorescence (0.1115). Number of pods per plant also exerted positive indirect effect through length of harvesting period and number of pods per inflorescence while pod weight exerted positive indirect effect *via* pod length and pod girth and negative indirect effect *via* number of pods per plant.

Both pod weight and number of pods per plant had high direct effect along with high genetic correlation. The contribution of other characters viz., length of harvesting period, pod length and pod girth *via* number of pods per plant and pod weight was negligible. A low residual effect (0.023) was also noticed in the present study. High direct effect of number of pods per plant was earlier reported by Jana *et al.* (1983), Chattopadhyay *et al.* (1997), Resmi (1998), Vardhan and Savithramma (1998a) and Pournami (2000). Several studies identified pod weight as one of the major contributors to pod yield (Sobha, 1994; Chattopadhyay *et al.*, 1997 and Resmi, 1998).

Hence, number of pods per plant and pod weight can be identified as the major characters contributing towards pod yield and selection based on these characters can be effective for developing high yielding varieties of yard-long bean.

5.1.5 Genetic divergence analysis

Breeding of crop plants adopting hybridisation as a tool is one of the most important crop improvement methods. The success of hybridisation programme is mainly dependent on the genetic diversity of the parents chosen for the purpose. Crosses between genetically diverse parents are likely to produce high heterotic effects. However, maximum heterosis generally occurs at an optimal or intermediate level of genetic diversity. Mahalanobis D^2 statistic (Mahalanobis, 1936) is one of the potent techniques of measuring genetic divergence. This technique measures the force of differentiation at the intracluster and intercluster levels and thus provides a basis for selection of genetically divergent parents in breeding programmes. It permits precise comparison among all possible pairs of genotypes in any population.

On the basis of D^2 values, the 50 genotypes of yard-long bean were grouped into four clusters. The maximum number of genotypes (28) were included in cluster I. The cluster II and III had 13 and eight genotypes respectively. Cluster IV had only one genotype in it.

Considering the cluster means for the various characters studied, cluster IV showed the highest cluster mean for several characters including length of harvesting period, number of pods per plant, yield of vegetable pods per plant, number of inflorescences per plant, number of primary branches and for pod girth, pod weight and number of seeds per pod while it had the lowest cluster mean for days to first flowering. Cluster III showed highest cluster mean for number of pods per inflorescence and the lowest mean value for number of inflorescences per plant. While cluster II exhibited highest cluster mean for length of main stem, pod length and days to first flowering, it record the lowest cluster mean for length of harvesting period and number of seeds per pod. Cluster I had the lowest cluster means for most of the characters including number of pods per plant and yield of vegetable pods per plant. For crop improvement programmes, intercrossing of genotypes with outstanding mean performance from these clusters would be effective.

Maximum divergence would be shown by the clusters which have maximum intercluster distance between them. Cluster I and IV recorded the highest intercluster distance while the least intercluster distance was observed between cluster III and IV. The intracluster distance was maximum for cluster I which had the maximum number of genotypes. The clustering pattern showed that the genotype Vs 47 was genetically divergent from the rest of the genotypes and formed the most divergent single genotypic cluster (Cluster IV).

The cultivar Vs 47 forming cluster IV was identified as the highest yielder of green pods. Hybridisation of this variety with varieties from other clusters having high pod number per plant or pod weight would be worthwhile. The cultivars Vs 45 and Vs 49 possessed the highest pod weight and pod number per plant respectively. So these varieties belonging to cluster III deserves mention in this respect.

5.2 Screening for legume pod borer resistance

The crop loss in yard-long bean in the event of serious infestation by legume pod borer is tremendous as the larvae of the pest feed on flowers and developing pods. Widespread occurence of the pest in the recent past has become a threat to yard-long bean cultivation in Kerala. Host plant resistance is an economic and eco-friendly pest control tactic. Varieties suffering lesser damage in comparison with others can be considered relatively resistant. Hence a varietal screening programme to identify yard-long bean varieties suffering lesser damage from legume pod borer attack was taken up.

5.2.1 Variation in damage parameters and overall plant resistance indices

Tingey (1986) suggested that assessment of plant resistance through measurement of insect damage should be made employing damage criteria closely associated with the ultimate loss in crop yield and quality. Jackai (1982) suggested that flower, pod and seed damage should be considered while evaluating cowpea varieties for legume pod borer resistance. In the present study, resistance evaluation was based on the plant resistance index (Ipr) computed using a combination of flower, pod and seed damage parameters.

There were significant differences among the varieties for all the damage parameters studied viz., percentage infestation of flowers, number of larvae per 25 flowers, percentage pod infestation, pod damage severity, percentage of infested peduncles with multiple pod damage and seed damage index. Significant differences among yard-long bean varieties in flower, pod and seed damages by legume pod borer was also reported by Pournami (2000).

The cultivar which recorded the highest degree of flower damage in terms of both percentage flower infestation and larval count in flowers was Vs9. It suffered more than twice flower damage compared to the least affected cultivars Vs 5 and Vs 33. Jackai (1982) reported wide differences in larval population in flowers of cowpea varieties in a legume pod borer screening programme. He opined that information on larval count in flowers provides an insight on the pest population intensity in each cultivar since larvae tend to migrate from one flower to the other. Oghiake *et al.* (1992b) reported significantly high pod borer larval counts in flowers of susceptible cultivars compared to resistant ones.

The two criteria employed for pod damage assessment were percentage pod infestation and pod damage severity. Irrespective of the criteria of damage assessment cultivars Vs 34, Vs 39 and Vs 42 were found to suffer low pod damage. Cultivars Vs 23 and Vs 29 also registered low level of percentage pod infestation. Pod damage severity was significantly high for Vs 24 while percentage pod infestation was very high for Vs 28, Vs 45 and Vs 46 along with nine other cultivars including Vs 24.

Since the legume pod borer larvae tend to migrate from one pod to other, simultaneous infestation of more than one pod on the same peduncle is a most commonly noticed symptom. The cultivars Vs 9, Vs 24 and Vs 28 recorded the highest percentage of infested peduncles with multiple pod damage. Relatively low multiple pod damage could be observed in several varieties of which the cultivars Vs 34, Vs 39 and Vs 42 also recorded low pod damage in terms of percentage pod infestation and pod damage severity.

Seed damage index values ranged from 34 to 92. Vs 2 showed the lowest seed damage. Low level of seed damage was also expressed by 12 other cultivars. Vs 24 suffered the highest seed damage and only five other cultivars were statistically on par with it.

In the present study, field screening for legume pod borer resistance was based on the computation of plant resistance index (Ipr) based on flower, pod and seed damage in terms of larval count in flowers, percentage pod infestation and seed damage index respectively. Vs 34 with the lowest Ipr value of 24.33 was identified as the most resistant cultivar among the 50 varieties. Cultivars with Ipr value not significantly different from Vs 34 were Vs 2, Vs 29, Vs 39 and Vs 42. The most susceptible cultivar was Vs 24 with an Ipr value of 44.17. Seven other cultivars statistically on par with Vs24 regarding resistance index values were Vs 25, Vs 28, Vs 38, Vs 40, Vs 45, Vs 46 and Vs 48.

5.2.2. Correlation among parameters of damage

The percentage of infested flowers and larval count in flowers showed good correlation (r=0.9463) suggesting that essentially similar results would be obtained when either of the criteria is employed for flower damage assessment.

Flower damage, both in terms of percentage of infested flowers and larval count in flowers was not correlated with any of the pod damage measurements viz., percentage pod infestation, pod damage severity and percentage of infested peduncles with multiple pod damage. The result is to be viewed in light of the flowering and fruiting habits of yard-long bean. The crop has protracted and overlapping flowering and fruiting phases. This offers the opportunity for the larvae to choose between flowers and fruits as feeding sites. The absence of any relationship between flower and pod damage suggests that larval preference for flower or pod as feeding sites differ among varieties. Pod characters conferring resistance to attack by the pest may be the reason for preferential attack of flowers in some varieties. Oghiakke *et al.* (1992a) identified trichome density (count per unit area) on pod wall surface as an important factor deciding pod damage in cowpea by legume pod borer. Pournami (2000) found negative correlation between pod damage and density of non-glandular trichomes on pod wall in yard-long bean.

Flower damage parameters viz., percentage infestation of flowers and larval count in flowers did not show any significant correlation with seed damage index also. Jackai (1982) reported that there was no correlation between the number of larvae in flowers and seed damage index as in the present study. However he reported positive correlation between larval count in flowers and pod damage parameters. But Pournami (2000) reported that there was no correlation between larval count in flowers and pod or seed damage.

Percentage infestation of pods, pod damage severity and percentage of infested peduncles with multiple pod damage showed significant positive correlation among themselves. Maximum correlation was observed between percentage pod infestation and multiple pod damage (r=0.9476). High correlation between percentage pod infestation and pod damage severity was also reported by Pournami (2000).

Seed damage index was found to be significantly correlated with pod damage. In contrast to this, Jackai (1982) reported the absence of any relationship between pod damage and seed damage by legume pod borer in cowpea. Pournami (2000) reported significant correlation between pod damage and seed damage as in the present study.

5.2.3 D^2 analysis

Based on the different legume pod borer damage parameters and plant resistance index, the 50 genotypes of yard-long bean were grouped into seven clusters employing Mahalanobis D^2 statistic. Cluster I with 18 genotypes formed the largest cluster followed by cluster III with 12, cluster IV with 11 and cluster II with six genotypes respectively. Cluster V, VI and VII were single genotype clusters.

The intracluster distance was least for cluster III (16.79) and maximum for cluster IV (19.06). The highest intercluster distance was observed between cluster IV and VII (79.26) and lowest between cluster V and VI (22.42).

The cluster mean values for the various damage parameters studied showed that cluster IV had the least cluster mean for flower damage and plant resistance index values. Percentage pod infestation and percentage of infested peduncles with multiple pod damage was least for cluster VI, but it showed high cluster means for flower damage parameters. Lowest cluster mean for pod damage severity and also low mean values for other pod damage parameters, seed damage index as well as plant resistance index was seen for cluster I. Highest cluster mean for all the flower and pod damage parameters was observed in cluster VII with a single cultivar which was identified as the most susceptible one.

In combination breeding programmes to develop varieties resistant to legume pod borer, genotypes from cluster IV with low flower damage and from cluster I with low pod damage can be utilised.

5.2.4 Relationship between pod characters and pod damage parameters

The association between pod wall thickness and pod damage based on percentage pod infestation and pod damage severity was attempted employing chi-square analysis. The insignificant chi-square values of both the pod damage parameters with pod wall thickness indicated that pod damage due to legume pod borer is independent of thickness of pod wall. Oghiakhe *et al.* (1992c) measured pod wall toughness of cowpea varieties with differing levels of resistance to legume pod borer and found that there was no relationship between pod damage and pod wall toughness.

The correlation between fibre content of pods with pod damage parameters viz., percentage pod infestation and pod damage severity was determined using 10 selected varieties of yard-long bean. The results showed that there was no correlation between fibre content of pods and pod damage parameters suggesting that pod damage due to legume pod borer was not related to fibre content of pods.

5.3. Promising cultivars identified on the basis of yield performance and resistance to legume pod borer

In the present study, Vs 47 was identified as the top yielder. Several other genotypes including Vs 5, Vs 37, Vs 38, Vs 42 and Vs 49 were also found to be good yielding though not on par with Vs 47. Based on Ipr values, Vs 34 was identified as the most resistant one among the 50 cultivars. Vs 2, Vs 29, Vs 39 and Vs 42 also had low Ipr values statistically on par with Vs 34. Vs 42 with good yield performance and high level of legume pod borer resistance was identified as a cultivar suitable for cultivation in legume pod borer endemic areas.

Flowers and developing pods are the major feeding sites of legume pod borer larvae. Damage to flowers and pods together would ideally reflect the ultimate crop loss due to the pest in yard-long bean. The present study clearly demonstrated that the flower damage and pod damage in yard-long bean varieties consequent to the pest infestation are not correlated. Combination breeding using a variety showing lower flower infestation and another suffering lesser pod damage as parents appears to be a rational breeding approach for the evolution of varieties with low flower damage as well as low pod damage and consequently possess better resistance to legume pod borer. The varietal screening programme undertaken as a part of the present study identified the cultivars Vs 5 and Vs 33 as those with least flower infestation and Vs 34, Vs 39 and Vs 42 as those suffering least pod damage among the 50 cultivars evaluated. These varieties are worthy of consideration as parents in legume pod borer resistance breeding programmes.

Most of the varieties with high level of legume pod borer resistance were found to be low yielding while several high yielding cultivars were found to be susceptible to legume pod borer. Vs 34 identified as the most resistant among the 50 cultivars was found to be a low yielder. Vs 38 though a better yielder having high pod length and pod weight was found to be a susceptible cultivar. So combination breeding using the high yielding varieties and legume pod borer resistant ones identified in the present study as parents is recommended for developing legume pod borer resistant varieties with high yield.

SUMMARY

6. SUMMARY

The present study entitled "Legume pod borer resistance and genetic divergence in domestic germplasm of yard-long bean (*Vigna unguiculata* ssp. sesquipedalis (L.) Verdc.)" was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 1999-2000. The data for the investigations were collected from two field experiments.

In experiment I, 48 local cultivars collected from different parts of Kerala along with two improved varieties *viz.*, Sharika and Malika were evaluated for yield and yield component characters in a field experiment in randomised block design with three replications. Observations were recorded on 12 characters viz., 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 number of seeds per pod.

Analysis of variance revealed significant differences among the varieties for all the twelve characters studied. The cultivar Vs 47 recorded the highest vegetable pod yield (614.27g). Vs 24 was the lowest yielder

(208.37g). Number of pods per plant was highest for Vs 49 (45.53) while pod weight was maximum for Vs 48 (28.6g).

The genotypic variance made up the major portion of phenotypic variance for all the characters studied. PCV and GCV were high for yield of vegetable pods per plant, number of pods per plant, number of pods per inflorescence, length of main stem and pod weight while both were low for days to first flowering.

The heritability estimates were high for all the twelve characters and it ranged from 71.16 to 95.85 per cent. High values of heritability coupled with high genetic advance were 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.

At genotypic level, pod yield per plant showed high positive correlation with number of pods per plant, number of pods per inflorescence, pod weight, length of harvesting period, pod girth, pod length and number of primary branches. Number of pods per plant had the highest genotypic correlation with yield.

Path coefficient analysis revealed number of pods per plant and pod weight as the characters with high direct effect as well as indirect effect through other characters on pod yield. The genotypic correlation of these characters on yield was also very high. The low residue obtained

(0.023) indicated that the major portion of variation in yield could be explained by the characters considered in path analysis.

Genetic diversity studies using Mahalanobis D^2 statistic indicated considerable diversity among the 50 varieties of yard-long bean. The clustering pattern indicated that cluster I was the largest with 28 genotypes followed by cluster II with 13 and cluster III with eight genotypes respectively. Cluster IV consisted of only a single genotype. Intercluster distance was maximum between clusters I and IV (1565.39) while the intracluster distance was maximum in cluster I (240.83). Based on the cluster mean values, cluster IV with the single variety Vs 47 was identified as the highest yielder of green pods. The cultivars Vs 45 and Vs 49 belonging to cluster III has the highest pod weight and pod number per plant respectively. So hybridisation programmes with these cultivars may be helpful in developing high yielding yard-long bean varieties.

In experiment II, the 50 yard-long bean genotypes were screened for legume pod borer resistance in a field experiment in randomised block design with two replications. Data were collected on the various damage parameters viz., percentage infestation of flowers, number of larvae per 25 flowers, percentage pod infestation, pod damage severity, percentage of infested peduncles with multiple pod damage and number of damaged seeds in a sample of 25 pods. Assessment of hostplant resistance was done based on the overall plant resistance index (Ipr) values computed using a combination of flower, pod and seed damage parameters.

Significant differences were observed among the cultivars for all the above mentioned damage parameters. Flower damage in terms of both percentage infestation of flowers and larval count in flowers was highest for Vs 9 and lowest for Vs 5 and Vs 33. The cultivars Vs 34, Vs 39 and Vs 42 recorded the lowest pod damage in terms of percentage pod infestation, pod damage severity and percentage of infested peduncles with multiple pod damage. Highest percentage pod infestation was observed for Vs 28, Vs 45 and Vs 46. Most severe pod damage was for Vs 24 while Vs 9, Vs 24 and Vs 28 suffered high multiple pod damage. The seed damage index value was lowest for Vs 2 and highest for Vs 24. Lower Ipr values indicate higher levels of plant resistance. Vs 34 with the lowest Ipr value was identified as the most resistant among the 50 cultivars. The most susceptible variety was Vs 24.

Correlation analysis of the damage parameters showed that flower damage was not correlated with pod damage or seed damage parameters. However, percentage infestation of flowers showed high correlation with larval count in flowers, showing that essentially similar results would be obtained when either of the criterion is chosen for flower damage assessment. The pod damage parameters were highly correlated with seed damage. High correlation was also observed among the pod damage parameters viz. percentage pod infestation, pod damage severity and percentage of infested peduncles with multiple pod damage.

Clustering of the 50 yard-long bean genotypes based on the legume pod borer damage parameters was done using Mahalanobis D^2 statistic. Of the seven clusters formed, cluster I with 18 genotypes formed the largest cluster followed by cluster III with 12, cluster IV with 11 and cluster II with six genotypes respectively. Cluster V, VI and VII had only one genotype each. Intracluster distance was maximum for cluster IV while intercluster distance was maximum between clusters IV and VII. Cluster means on the various damage parameters indicated that cluster IV had the least flower damage and cluster I had the least pod damage. Cluster VII with highest flower and pod damage was identified as the most susceptible cluster. For developing pod borer resistant varieties, the following parents of cluster I viz., Vs 2, Vs 39 and Vs 42 and the parents of cluster IV viz., Vs 5, Vs 29, Vs 33, Vs 34 and Vs 37 will be of better use in combination breeding programmes.

The relationship of pod characters viz., pod wall thickness and fibre content of pods with pod damage was studied and the results indicated that there was no association between pod damage and pod wall thickness or fibre content of pods.

Considering both yield performance and resistance to legume pod borer, it is suggested that the cultivar Vs 42 would be useful for cultivation in pod borer endemic areas. Further, better yielding varieties (Vs 47, Vs 49, Vs 5 and Vs 37) and pod borer resistant ones (Vs 34, Vs 39, Vs 29 and Vs 2) identified in the present study deserve consideration as parents in combination breeding programmes for developing high yielding and legume pod borer resistant varieties in yard-long bean.

REFERENCES

REFERENCES

Allard, R.W. 1960. *Principles of Plant Breeding.* John Wiley and Sons, Inc. New York, p. 485

Angadi, S.P., Subramani, A. and Kulkarni, R.S. 1978. Genetic variability for some quantitative traits in cowpea. *Agric. Res. J. Kerala* 16(1): 60-62

Anithakumari. 1992. Host resistance in cowpea (*Vigna unguiculata* L. Walp.) to pod borer, *Maruca testulalis* (Geyer). *M.Sc. (Ag.) Thesis.* Kerala Agric. Univ., Thrissur

*Attachi, P. and Djihou, Z.C. 1994. Record of host-plants of *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae) in Republic of Benin. *Annales de la Societe Entomologique de France* 30(2): 169-174

Backiyarani, S. and Nadarajan, N. 1996. Variability studies in cowpea. *Legume Research* 19(1): 59-61

Bottenberg, H., Tamo, M., Arodokoun, D., Jackai, L.E.N., Singh, B.B. and Youm, O. 1997. Population dynamics and migration of cowpea pests in northern Nigeria : implications for integrated pest management. *Advances in cowpea research.* (Eds. B. B. Singh, D.R. Mohan Raj, Dashiell, K.E. and Jackai, L.E.N.). IITA, Ibadan, Nigeria, pp. 271-284

*Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassland Congr.* 1: 277-283

Chakraborty, A.K. 1986. Cowpea. *Vegetable Crops In India.* Bose, T.K. and Som, M.G. (Eds.). Naya Prokash, Calcutta, pp. 515-523

Chandrika, P. 1979. Genetic studies in cowpea. *M.Sc. (Ag.) Thesis.* Kerala Agric. Univ., Thrissur

Chattopadhyay, A., Dasgupta, T., Hazra, P. and Som, M.G. 1997. Character association and path analysis in vegetable cowpea. *Madras Agric. J.* 84(3): 153-156

Chauhan, G.S. and Joshi, R.K. 1980. Path analysis in cowpea. *Tropical Grain Legume Bull.* **20**: 5-8

Chiang, H.S. and Jackai, L.E.N. 1988. Tough pod wall : a factor involved in cowpea resistance to pod sucking bugs. *Insect Sci. Appl.* 9: 389-393

Chikkadyavaiah. 1985. Genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.). *Mysore J. Agric. Sci.* 19(2): 131-132

Dabrowski, Z.T., Bungu, D.O.M. and Ochieng, R.S. 1983. Studies on the legume pod-borer, *Maruca testulalis* (Geyer) - III. Methods used in cowpea screening for resistance. *Insect Sci. Appl.* 4: 141-145

Damarany, A.M. 1994. Estimation of genotypic and phenotypic correlation, heritability and potence of gene set in cowpea (*Vigna unguiculata* (L.) Walp.). *Assiut J. Agric. Sci.* 25(4): 1-8

De Mooy, B.E. 1985. Variability of different characteristics in Botswana cowpea germplasm. *Tropical Grain Legume Bull.* **31**: 1-4

Dent, D.R. 1995. *Integrated Pest Management.* Chapman and Hall, London, p. 356

Dewey, D.R. and Lu, K.H. 1959. *Agron. J.* **51**: 515-518

Dharmalingam, V. and Kadambavanasundaram, M. 1984. Genetic variability in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J.* **71**(10): 640-643

Dharmalingam, V. and Kadambavanasundaram, M. 1989. Genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J.* **76**(7): 394-399

van Emden, H.F. 1989. *Pest Control.* Edward Arnold, London, p. 117

*Evans, L.T. 1978. *Crop Physiology.* Cambridge University Press, Cambridge, London, p. 355

Eveleens, K.G., van den Bosch, R. and Ehler, L.E. 1973. Secondary outbreak induction of beet armyworm by experimental insecticide applications in cotton in California. *Environ. Entomol.* **2**: 497-503

Falconer, D.S. 1981. *Introduction to Quantitative Genetics* (3rd Edn.). Longman, New York, p. 438

Hazra, P., Das, P.K. and Som, M.G. 1993. Genetic divergence for pod yield and its components in cowpea. *Haryana J. Hort. Sci.* **22**(4): 296-302

Hazra, P., Som, M.G. and Das, P.K. 1996. Selection of parents for vegetable cowpea breeding by multivariate analysis. *Veg. Sci.* **23**(1): 57-63

Hussein, H.A. and Farghali, M.A. 1995. Genetic and environmental variation, heritability and response to selection in cowpea. *Assiut J. Agric. Sci.* **26**(4): 205-216

Jackai, L.E.N. 1982. A field screening technique for resistance of cowpea (*Vigna unguiculata*) to the pod-borer *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae). *Bull. Ent. Res.* 72: 145-156

Jackai, L.E.N. 1983. Efficacy of insecticide application at different times of day against legume pod borer, *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae) on cowpea in Nigeria. *Protection Ecology* 5: 245-251

Jackai, L.E.N. and Adalla, C.B. 1997. Pest management practices in cowpea : a review. *Advances in cowpea research.* (Eds. B.B. Singh, D.R. Mohan Raj, Dashiell, K.E. and Jackai, L.E.N.). IITA, Nigeria, pp. 240-258

Jackai, L.E.N. and Singh, S.R. 1988. Screening techniques for host plant resistance to cowpea insect pests. *Trop. Grain legume Bull.* 35: 2-18

Jackai, L.E.N., Pannizzi, A.R., Kundu, G.G. and Srivastava, K.P. 1990. Insect pests of soyabean in the tropics. *Insect pests of tropical food legumes.* (Ed. S.R.Singh). John Wiley and Sons, Chichester, U.K. pp. 91-156

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

Jana, S., Som, M.G. and Das, M.D. 1982. Genetic variability and correlation studies in cowpea. *Veg. Sci.* 9(2): 96-107

Jana, S., Som, M.G. and Das, M.D. 1983. Correlation and path analysis of vegetable pod yield components in cowpea (*Vigna unguiculata* var. *sesquipedalis*). *Haryana J. Hort. Sci.* 12(3/4): 224-227

Jindal, S.K. 1985. Genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.) under rainfed conditions. *Genetica Agraria* **39**(1): 19-24

Johnson, H.W., Robinson, H.D. and Comstock, R.E. 1955. Estimates of genetical and environmental variability in soyabeans. *Agron. J.* **47**: 314-318

Kar, N., Dasgupta, T., Hazra, P. and Som, M.G. 1995. Association of pod yield and its components in vegetable cowpea. *Indian Agriculturist* **39**(4): 231-238

Kumar, A., Misra, S.N. and Verma, J.S. 1982. Studies on genetic diversity in cowpea. *Crop Improvement* **9**(2): 160-163

Kumar, P., Prakash, R. and Haque, M.F. 1976. Inter-relationships between yield and yield components in cowpea (*Vigna sinensis* L.). *Proc. Bihar Acad. Agric. Sci.* **24**(2): 13-16

Lakshmi, P.V. and Goud, V. 1977. Variability in cowpea (*Vigna sinensis* L.). *Mysore J. Agric. Sci.* **11**: 144-147

*Mahalanobis, P.C. 1936. 1936. On the generalized distance in statistic. *J. Genet.* **41**: 159-193

Marangappanavar, L.R. 1986. Genetic diversity, gene action and character association in cowpea (*Vigna unguiculata* (L.) Walp.). *Mysore J. Agric. Sci.* **20**(3): 231

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

Naidu, N.V., Satyanarayana, A. and Seenaiah, P. 1996. Inter relationships between yield and yield attributes in cowpea (*Vigna unguiculata* (L.) Walp.). *Annals of Agric. Res.* 17(4): 337-341

Oghiakhe, S. 1992. The relationship between leaf chlorophyll and cowpea resistance to the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *J. Plant Protection in the Tropics* 9(3): 201-207

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W.A. 1991. Cowpea plant architecture in relation to infestation and damage by legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae) : 1. Effect of canopy structure and position. *Insect Sci. Appl.* **12**: 193-200

Oghiakhe, S., Jackai, L.E.N., Makanjuola, W.A. and Hodgson, C.J. 1992a. Morphology, distribution and role of trichomes in cowpea (*Vigna unguiculata*) resistance to legume pod borer, *Maruca testulalis* (Geyer) (Lepidoptera : Pyralidae). *Bull. Ent. Res.* **82**: 499-505

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W.A. 1992b. A rapid visual screening technique for resistance of cowpea (*Vigna unguiculata*) to legume pod borer *Maruca testulalis* (Lepidoptera : Pyralidae). *Bull. Ent. Res.* **82**: 507-512

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W.A. 1992c. Pod wall toughness has no effect on cowpea resistance to the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *Insect Sci. Appl.* 13(3): 345-349

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W.A. 1992d. Cowpea plant architecture in relation to infestation and damage by legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae): 2. Effect of pod angle. *Insect Sci. Appl.* **13**: 339-344

Oghiakhe, S., Makanjuola, W.A. and Jackai, L.E.N. 1993. The relationship between the concentration of phenol in cowpea and field resistance to legume pod borer, *Maruca testulalis* Geyer (Lepidoptera : Pyralidae). *Int. J. Pest Management* **39**: 261-264

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

Patil, R.B. and Baviskar, A.P. 1987. Variability studies in cowpea. *J. Maharashtra Agric. Univ.* **12**(1): 63-66

Patil, R.B. and Bhapkar, D.G. 1987a. Correlation studies in cowpea. *J. Maharashtra Agric. Univ.* **12**(1): 56-59

Patil, R.B. and Bhapkar, D.G. 1987. Genetic divergence among 49 cowpea strains. *J. Maharashtra Agric. Univ.* **12**(3): 283-285

Pournami, R.P. 2000. Evaluation of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) for legume pod borer, *Maruca vitrata* (Fab.) resistance and yield. *M.Sc. (Ag.) Thesis.* Kerala Agric. Univ., Thrissur

Radhakrishnan, T. and Jebaraj, S. 1982. Genetic variability in cowpea (*Vigna unguiculata* (L.) Walp.) *Madras Agric. J.* 69(4): 216-219

Rajaravindran, R. and Das, L.D.V. 1997. Variability, heritability and genetic advance in vegetable cowpea. *Madras Agric. J.* **84**(11/12): 702-703

Rajendran, R., Biswas, S.R., Ramachander, P.R., Satyanarayana, A., Anand, N. and Srinivasan, K. 1979. Genetic improvement of cowpea (*Vigna unguiculata* (L.) Walp) for seed yield. *Agric. Res. J. Kerala* 17(1): 60-66

Ram, T., Ansari, M.M. and Sharma, T.V.R.S. 1994. Relative performance of cowpea genotypes in rainfed conditions in Andaman and their genetic parameter analysis for seed yield. *Indian J. Pulses Res.* 7(1): 72-75

Ram, D. and Singh, K.P. 1997. Variation and character association studies in cowpea (*Vigna unguiculata* (L.) Walp.). *Hort. J.* **10**(2): 93-99

Ramachandran, C., Peter, K.V. and Gopalakrishnan, P.K. 1980. Variability in selected varieties of cowpea (*Vigna unguiculata* (L.) Walp.). *Agric. Res. J. Kerala* **18**(1): 94-97

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

Renganayaki, K. and Rangaswamy, S.R. 1991. Genetic divergence in *Vigna* species. *Indian J. of Pulses Res.* **4**(2): 159-164

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

Resmi, P.S. 1998. Genetic variability in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt). *M.Sc. (Ag.) Thesis.* Kerala Agric. Univ., Thrissur

Rewale, A.P., Birari, S.P. and Apte, U.B. 1996. Genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.). *Indian J. Agric. Res.* 30(2): 73-79

Rewale, A.P., Birari, S.P. and Jamadagni, B.M. 1995. Genetic variability and heritability in cowpea. *Agricultural Science Digest* 15(1/2): 73-76

Roquib, M.A. and Patnaik, R.K. 1990. Genetic variability in grain yield and its components in cowpea, *Vigna unguiculata*. *Environment and Ecology*. 8(1A): 197-200

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences*. Wiley Eastern Ltd., New Delhi, pp. 20-21

Samiullah, R., Imtiaz, S.H., Chikkadyavaiah, R.A., Shereff, Sadiqullakhan and Bhargava, B.S. 1993. Association analysis in vegetable cowpea. *Report of Golden Jubilee Symposium, Horticultural Research - Changing Scenario*. UAS, Bangalore. May 24-28

Savithramma, D.L. 1992. Genetic variability in cowpea. *Agric. Res. J. Kerala* **31**: 50-52

Sawant, D.S. 1994. Association and path analysis in cowpea. *Annals of Agric. Res.* 15(2): 134-139

Saxena, R.C. and Khan, Z.R. 1991. Genetics of insect - host plant interactions : Concepts, old and new. *Advances in Plant Breeding* Vol. I (Eds. Mandal, A.K., Ganguli, P.K. and Banerjee, S.P.). CBS Publishers and Distributors, Delhi, pp. 111-120

Shakarad, M.N., Arathi, H.S., Gangappa, E. and Ramesh, S. 1995. Gene action for yield and yield attributes in cowpea (*Vigna unguiculata* (L.) Walp.). *Mysore J. Agric. Sci.* 29(4): 289-292

Sharma, P.C., Mishra, S.N., Amarjit Singh and Verma, J.S. 1988. Genetic variation and correlation in cowpea. *Annals of Agric. Res.* 9(1): 101-105

Sharma, T.R. 1999. Genetic variability studies in cowpea. *Legume Research* 22(1): 65-66

Shepard, M., Carner, G.R. and Turnipseed, S.G. 1977. Colonization and resurgence of insect pests of soybean in response to insecticides and field isolation. *Environ. Entomol.* 6: 501-506

Siddique, A.K.M.A.R. and Gupta, S.N. 1991. Genotypic and phenotypic variability for seed yield and other traits in cowpea (*Vigna unguiculata* (L.) Walp.). *Int. J. Tropical Agric.* 9: 144-148

Singh, S.R. 1978. Resistance to pests of cowpea in Nigeria. *Pests of Grain Legumes : Ecology and Control.* Singh, S.R., van Emden, H.F. and Taylor, T.A. (Eds.). Academic Press, London, pp. 267-280

Singh, R.K. and Choudhary, B.D. 1979. *Biometrical Methods in Quantitative Genetic Analysis.* Kalyani Publishers, New Delhi, pp. 39-79

Singh, R.B. and Gupta, M.B. 1968. Multivariate analysis of divergence in upland cotton. *Indian J. Genet.* 28: 151-157

Sobha, P.P. 1994. Variability and heterosis in bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *M.Sc. (Ag.) Thesis.* Kerala Agric. Univ., Thrissur

Sreekumar, K. 1995. Genetic analysis of biological nitrogen fixation traits and yield components in cowpea (*Vigna unguiculata* (L.) Walp.). *Ph.D Thesis.* Kerala Agric. Univ., Thrissur

Sreekumar, K., Inasi, K.A., Alice Antony and Nair, R.R. 1996. Genetic variability, heritability and correlation studies in vegetable cowpea (*Vigna unguiculata* var. *sesquipedalis*). *South Indian Hort.* 44(1&2): 15-18

Sudhakumari, J.S. and Gopimony, R. 1994. Genetic divergence in cowpea. *Proc. 6th Kerala Sci. Congress.* January, 1994, Thiruvananthapuram, p. 164

Tamilselvam, A. and Das, L.D.V. 1994. Correlation studies in cowpea (*Vigna unguiculata* (L.) Walp.) for seed yield. *Madras Agric. J.* 81(8): 445-446

Tamo, M., Bottenberg, H., Arodokoun, D. and Adeoti, R. 1997. The feasibility of classical biological control of two major cowpea insect pests. *Advances in Cowpea Research.* IITA, Ibadan, Nigeria, pp. 259-270

Tewari, A.K. and Gautam, N.C. 1989. Correlation and path coefficient analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Indian J. Hort.* 46(4): 516-521

Thiagarajan, K., Rathinaswamy, R. and Rajasekaran, S. 1988. Genetic divergence in cowpea. *Madras Agric. J.* 75(3-4): 125-128

Thiyagarajan, K. 1989. Genetic variability of yield and component characters in cowpea (*Vigna unguiculata* (L.) (Walp.). *Madras Agric. J.* 76(10): 564-567

Thiyagarajan, K., Natarajan, C. and Rathinaswamy, R. 1989. Variability in Nigerian cowpeas. *Madras Agric. J.* 76(12): 719-720

Tingey, W.M. 1986. Techniques for evaluating plant resistance to insects. *Insect - Plant Interactions.* J.A. Miller and T.A. Miller (Eds.). Springer - Verlag, New York, pp. 251-284

Vardhan, P.N.H. and Savithramma, D.L. 1998a. Variability, character association, path analysis and assessment of quality parameters in cowpea (*Vigna unguiculata*) germplasm for vegetable traits. *ACIAR Food Legume Newsletter* **28**: 7-8

Vardhan, P.N.H. and Savithramma, D.L. 1998. Evaluation of cowpea genotypes for vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *ACIAR Food Legume Newsletter* **28**: 5-6

*Wang Yan Feng, Zhang Wei Zhang and Gao DiMing. 1997. Agronomic character analysis of yard long bean genetic resources. *China Vegetables* **2**: 15-18

Wolley, J.N. and Evans, A.M. 1979. Screening for resistance to *Maruca testulalis* (Geyer) in Cowpea (*Vigna unguiculata* (L.) Walp). *J. Agric. Sci.*, Camb. **92**: 417-425

Wright, S. 1921. Correlation and causation. *J. Agric. Res.* **20**: 557-585

Yap, T.C. 1983. Genetic studies and improvement of long bean (*Vigna unguiculata* (L.) Walp.) in Malaysia. *Crop Improvement* 295-302

Ye, Z.B. and Zhang, W.B. 1987. Inheritance studies and correlations between quantitative characters in *Vigna sesquipedalis*. *Acta Horticulturae Sinica* **14**(4): 257-264

* Originals not seen

LEGUME POD BORER RESISTANCE AND GENETIC DIVERGENCE IN DOMESTIC GERMPLASM OF YARD-LONG BEAN (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.)

By

VIDYA. C.

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(PLANT BREEDING AND GENETICS)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

2000

ABSTRACT

The present study aimed at the evaluation of variability in domestic germplasm of yard-long bean for yield and legume pod borer resistance was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani. Data for the investigation was collected from two field experiments conducted during the period 1998-2000.

Fifty diverse genotypes of yard-long bean were 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 varieties for all the twelve characters studied. High PCV and GCV were observed for yield of vegetable pods per plant, number of pods per plant, number of pods per inflorescence, length of main stem and pod weight. High heritability coupled with high genetic advance were also observed for these characters.

Pod yield per plant showed high positive correlation with number of pods per plant, number of pods per inflorescence, pod weight and length of harvesting period at genotypic level. Path analysis revealed that number of pods per plant and pod weight were the primary yield contributing characters owing to their high direct effect on pod yield.

So selection based on these characters will result in improvement of yield in yard-long bean.

Based on Mahalanobis D^2 statistic, the 50 cultivars were grouped into four clusters. Cluster I formed the largest cluster with 28 varieties while cluster IV had only a single cultivar. The genetic distance was maximum between clusters I and IV and minimum between clusters III and IV. Cluster I had the highest intracluster distance. The single variety Vs 47 of cluster IV was identified as the highest yielder of green pods. Hybridisation of this variety with varieties having high pod number per plant or pod weight would be beneficial. The cultivars Vs 45 and Vs 49 belonging to cluster III possessed the highest pod weight and pod number per plant respectively. So hybridisation programmes utilising these varieties as parents is worthy of consideration for developing high yielding varieties in yard-long bean.

In the field screening programme for legume pod borer resistance all the 50 yard-long bean cultivars were evaluated on the basis of overall plant resistance index (Ipr) computed using a combination of flower, pod and seed damage measurements *viz.*, number of larvae in 25 flowers, percentage pod infestation and seed damage index (computed based on the number of damaged seeds in a sample of 25 pods) respectively. Cultivars showed significant differences among them for these damage parameters as well as for resistance index computed based on them.

The cultivars suffering least flower damage were Vs 5 and Vs 33. Lowest pod damage were recorded for the cultivars Vs 34, Vs 39 and Vs 42. Seed damage index value was the lowest for cultivar Vs 2.

Vs 34 with the lowest Ipr value was identified as the most resistant among the 50 yard-long bean varieties. The cultivars Vs 2, Vs 29, Vs 39 and Vs 42 were on par with Vs 34.

Correlation analysis of the different damage parameters did not suggest any relationship between flower damage and pod damage or seed damage. However pod damage showed high positive correlation with seed damage.

Cluster analysis based on the different damage parameters enabled to group varieties into seven clusters. Based on cluster means of the various damage parameters, cluster IV and I were those suffering least flower and pod damage respectively. So hybridisation programmes utilising varieties from these two clusters could lead to the production of varieties with higher level of legume pod borer resistance.

Studies on relationship between pod damage and two pod characters *viz.*, pod wall thickness and fibre content of pods indicated that these pod characters did not influence infestation and damage by legume pod borer.

Based on superior yield performance and high level of resistance to legume pod borer, the cultivar Vs 42 is identified as a variety suitable for cultivation in legume pod borer endemic areas. Further, breeding programmes utilising the varieties with high yield and legume pod borer resistance identified in this study could help in evolving better yielding varieties with resistance to pod borer in yard-long bean.