SCREENING OF VEGETABLE COWPEA (*Vigna unguiculata* (L) Walp) GERMPLASM FOR YIELD, QUALITY AND RESISTANCE TO COLLAR ROT AND WEB BLIGHT

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Screening of vegetable cowpea (*Vigna unguiculata* (L) Walp) germplasm for yield, quality and resistance to collar rot and web blight"** is bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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DEDICATED TO

MY FAMILY

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LIST OF ABREVIATIONS

%	-	per cent
>	-	Greater than
<	-	Less than
µg	-	microgram
μm^2	-	micro square metre
CD	-	Critical difference
cm	-	Centimetre
cm^2	-	square centimetre
et al	-	And others
Fig.	-	Figure
G	-	Gram
GA	-	Genetic advance
GCV	-	Genotypic Coefficient of Variation
h	-	Hour
H^2	-	Heritability
ha	-	Hectare
i.e.	-	That is
IPGRI	-	International Plant Genetic Resources Institute
KAU	-	Kerala Agricultural University
Kg	-	Kilogram
m	-	metre
mg	-	milligram
min	-	minutes
ml	-	millilitre
mm	-	millimetre
mm^2	-	square millimetre
nm	-	Nanometre
No. of	-	Number of

°C	-	Degree Celsius
PCV	-	Phenotypic Coefficient of Variation
S	-	Seconds
SE	-	Standard error
Var.	-	Variety
WAI	-	Week after inoculation

INTRODUCTION

1. INTRODUCTION

Vegetable cowpea (*Vigna unguiculata* (L) Walp.) is one of the most popular and cosmopolitan vegetable crop grown in many parts of India and elsewhere in the world. It is a rich and inexpensive source of vegetable protein. It enriches soil fertility by fixing atmospheric nitrogen. Because of its quick growth habit it has become an essential component of sustainable agriculture in marginal lands of the tropics.

Verdcourt (1970) identified five subspecies of *Vigna unguiculata* of which *V.unguiculata* subsp. *unguiculata* (bush cowpea) is the most common species found in all areas of cultivation and *V. unguiculata* subsp. *Sesquipedalis* (yard long bean) is common in the peninsular India and the Far East. This crop was introduced from Africa which is considered as the primary centre of origin.

In Kerala, vegetable cowpea is one of the most favourite crops as it ensures a stable market throughout the year. The traditional vernaculars *viz.*, 'Achingapayar', 'Kurutholapayar', 'Vallipayar', 'Pathinettumaniyan' etc., used to refer yard long bean indicate that Kerala is the lad of this crop. Perhaps it is the only vegetable evenly distributed and preferred in all the 14 districts of Kerala.

Over several decades of cultivation genetically diverse types of the crop gets evolved and maintained in Kerala by farmers. Despite genetic diversity in the crop, the variability utilized for crop improvement in general is quite restricted. This may be due to poor characterization of germplasm and lack of understanding of the relation existing among cultivars.

The productivity of vegetable cowpea is limited by a complexity of biotic and abiotic interactions. Incidence of pests and diseases is considered to be a major limiting factor affecting the productivity of vegetable cowpea. The growing demand for the vegetable cowpea has led to large scale intensive cultivation. This in turn, resulted in enhanced incidence of pest and diseases inflicting heavy crop loss.

Among the diseases, collar rot and web blight caused by *Rhizoctonia solani* Kuhn is an important soil borne disease of cowpea particularly under high temperature and humidity causing severe yield loss. The collar rot phase of the disease is more severe and wide spread than the web blight phase under field conditions.

Collar rot is initially manifested in the collar region of the plants right from the seedling stage. It begins as brownish – black lesions at soil level near collar region girdling the base of the stem resulting in yellowing and drooping of leaves and rotting of roots. White mycelial growth often studded with small sclerotia is characteristically seen on the affected regions. Web blight appears as small circular light greyish-brown spots on leaf lamina which enlarges to oblong or irregular water soaked areas. Later shot hole symptoms are produced or the spots coalesce to cover entire leaf area resulting in shedding of leaves.

R. solani is a ubiquitous soil inhabiting plant pathogen with great diversity, wide host range and lack of sharp differentiation among its strains. Prolific growth and ability of pathogen to produce large number of sclerotia that may persist in the soil for several years and resistant to microbial attack makes the elimination of this difficult soil borne pathogen. Although this disease can be controlled with biological control and cultural practices like crop rotation, tillage, use of seeds from healthy plants, etc., these methods may not be effective in all conditions. This disease can also be controlled by using different fungicides, but they cause environmental pollution and finally affecting health of human beings and other animals. Therefore the most economical and environment friendly method of controlling collar rot in cowpea appears to be the use of resistant varieties.

Breeding for disease resistance is an excellent approach to overcome economic losses caused by pathogen in plants. To initiate the search for resistance to disease, identification of sources of resistance is needed and the development of a technique to screen putative lines is the first step.

Investigations into the morphological, anatomical and biochemical basis of resistance would help the breeder to locate resistant types based on these characters.

Under these circumstances, the present study was undertaken with the following objectives

1. To assess the genetic variability present in vegetable cowpea germplasm.
2. To study correlation and path analysis of different characters.
3. To evaluate them for yield, quality and resistance to collar rot and web blight caused by *Rhizoctonia solani* Kuhn.
4. To confirm the resistance under artificial epiphytotic conditions.
5. To study the morphological, anatomical and biochemical basis of resistance to R. solani.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most important leguminous vegetable crops of Kerala. Verdcourt (1970) identified five subspecies of *Vigna unguiculata* namely, *V. unguiculata* subsp. *cylindrica* (grain cowpea), *V. unguiculata* subsp. *unguiculata (*Bush cowpea*)*, *V. unguiculata* subsp. *sesquipedalis* (yard long bean), *V. unguiculata* subsp. *dekindtiana* (black eyed pea), and *V. unguiculata* subsp. *stenophylla.* Among these, three sub species *viz., V. unguiculata* subsp. *unguiculata, V. unguiculata* subsp. *sesquipedalis* and *V. unguiculata* subsp. *cylindrica* are cultivated in India whereas, *V. unguiculata* subsp. *dekindtiana* is cultivated in Africa and some parts of USA. Even though a lot of work has been done on grain cowpea, very little attention has been paid to the improvement of vegetable types.

The available literature on vegetable cowpea related to the present study is reviewed under the following heads:

2. 1. Variability studies

2.2. Screening vegetable cowpea for collar rot and web blight resistance

2.3. Screening for other pest and diseases

2.1 Variability studies

2.1.1 Germplasm evaluation

Classification of cultivars into three subspecies based on various growth and reproductive characters were attempted by Hazra et *al.* (1993).

Uguru (1996) described Nigerian vegetable cowpea (*V. unguiculata* subsp. *unguiculata*) germplasm based on morphological characters.

Thirty yard long bean genotypes were scored for morphological characters using IPGRI descriptor by Resmi (1998). The cowpea gene pool is characterized by its unusually large size with wide morphological variations (Pasquet, 2000).

Padi (2003) studied the genetic control of pigmentation in different parts of cowpea (*V. unguiculata* (L.) Walp.). A monogenic control for colour expression was found in node pigmentation, flower colour, immature pod colour, seed coat colour, seed eye colour and seed eye colour pattern.

Association was found for flower colour with stem pigmentation, pod pigmentation and seed colour. Wide variability was noticed upon cataloguing 330 vegetable cowpea accessions (Gopalakrishnan, 2004).

Manju (2006) described sixty six accessions of vegetable cowpea collected from various sources upon cataloguing pointed out wide variation for various morphological characters.

Futuless *et al.* (2010) evaluated five cowpea varieties for plant height, number of leaves per plant, number of branches per plant, number of days to flowering, pod filling period, days to physiological maturity, pods per plant, pod length, number of seeds per pods, number of seeds per plant, and yield per hectare.

Sanjeev *et al.* (2010) evaluated 225 germplasm collections of cowpea including local types for high test weight, desirable seed and pod features, earliness and resistance to cowpea rust, Cowpea Mosaic Virus (CMV) and cercospora leaf spot. The results about 15 gerplasm accessions were found to be highly resistant to rust, 10 accessions displayed HR reaction to CMV and about 5 accessions showed highly resistant reaction against leafspot.

2.1.2 Genetic parameters

i. Variability

Rejatha (1992) reported high variability among different genotypes of cowpea for days to flowering, number of pods per cluster, pod length and number of seeds per pod. Significant variability was noticed among different cowpea cultivars for days to flowering, plant height, number of pods per plant, number of seeds per pod, pod length, 100 seed weight and yield per plant (Sudhakumari, 1993).

Wide range of genetic variability was reported for protein content in cowpea by Aghora *et al.* (1994)

High variation for number of clusters per plant, number of pods per plant and 100 seed weight in cowpea was reported by Backiyarani and Nadarajan (1996). Hazra *et al.* (1996) observed wide range of genetic variability for plant height, number of pods per plant, pod length, number of seeds per pod, 100 seed weight and yield per plant.

Mehta and Zaveri (1998) noticed high magnitude of genetic variability in segregating generations of cowpea for number of branches, number of clusters, number of pods and seed yield. Resmi (1998) reported high range of variability for all important yield traits among different genotypes of cowpea. Significant variability was noticed for days to 50 per cent flowering, plant height, number of branches per plant, pod length, number of pods per plant, number of seeds per pod, 100 seed weight and yield per plant by Sobha and Vahab (1998) in bush cowpea.

Harshavardhan and Savithramma (1998b) noted significant variation in 102 accessions of vegetable cowpea genotypes for all characters studied except for dry pod yield.

Wide range of genetic variability for number of pod clusters per plant, number of pods per cluster, peduncle length, number of pods per plant, number of seeds per pod, 100 seed weight and seed yield per plant was observed in cowpea by Dwivedi *et al.* (1999).

Considerable variation for several yield related characters in cowpea was reported by Kumar and Sangwan (2000). Significant variability among 32 genotypes of cowpea was reported by Backiyarani *et al.,* (2000) for days to 50 per cent flowering, plant height, yield per plant and total chlorophyll content. Panicker (2000) observed high variability for days to flowering, number of inflorescence per plant, number of pods per inflorescence, number of pods per plant, pod length and peduncle length. Wide range of variation for plant height was reported by Anbuselvam *et al.*, (2000); Rangaiah and Mahadevu (2000) and Singh and Verma (2002).

Tyagi *et al.* (2000) reported days to 50 per cent flowering, plant height, pod length, number of pods per plant, 100 seed weight and seed yield per plant recorded high genetic variability. High variability was noticed among 50 cultivars of cowpea for days to flowering, number of pods per plant, number of inflorescence per plant, number of pods per inflorescence, plant height, pod length, number of branches per plant and number of seeds per pod (Vidya, 2000).

Wide range of genetic variability was reported for protein content in cowpea by De *et al.* (2001); Kalaiyarasi and Palanisamy, (2001).

Ajith (2001) reported that the characters, days to 50 per cent flowering, plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod and yield per plant exhibited high range of variability. High range of genetic variability was recorded for days to 50 per cent flowering, plant height, number of branches per plant, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, 100 seed weight and yield per plant in 50 genotypes of cowpea (Anbuselvam *et al.*, 2001).

Jyothi (2001) noticed broad spectrum of variability for number of branches per plant, plant height, number of inflorescence per plant, number of pods per plant, number of seeds per pod, 100 seed weight and yield per plant in cowpea. Significant variation in plant height was observed by Purushotham *et al.* (2001) in cowpea.

Arunachalam *et al.* (2002) reported high variability for several yield contributing characters in cowpea. In cowpea, Kavita *et al.* (2003) reported high range of genetic variability for days to 50 per cent flowering. A wide range of variation was observed in almost all the characters studied in a set of 740 germplasm accessions of cowpea including both indigenous and exotic origin when evaluated for 25 descriptors (Mishra *et al.*, 2003).

All the ten yield related characters *viz.,* days to 50 per cent flowering, pods per plant, inflorescence per plant, pods per inflorescence, plant height, primary branches, pod length, seeds per pod, grain yield per plant and 100 seed weight exhibited wide range of variation among the 50 genotypes of cowpea studied by Philip (2004). High genetic variability was observed for pods per cluster, yield per plant, pod weight, pods per plant and clusters per plant in yard long bean by Lovely (2005).

Jithesh (2009) reported that high genetic variability for pod length, pod weight, pods per plant, pod clusters per plant, pod yield per plant and 100-seed weight in yard long bean. Variability studies indicated that all the characters were predominantly governed by additive gene action (Nehru *et al.,* 2009).

Manggoel *et al.* (2012) studied ten cowpea accessions, and reported significant variability for days to 50% flowering, number of peduncles per plant, flowers per plant, pods plant per plant, seeds per pod , pod length and 100-seed weight.

Udensi *et al.* (2012a) reported that high and wide genetic variability for number of leaves per plant, leaf area, number of flowers per plant, days to 50% maturity and seed yield.

ii. Heritability (H^2) and genetic advance (GA)

Heritability and genetic advance are important selection parameters. The ratio of genetic variance to phenotypic variance is known as heritability. Heritability (%) was categorized into low (0-30%), moderate (30-60%) and high (above 60%) as suggested by Robinson *et al.* (1949). Higher H^2 indicates the least environmental influence on the characters. The difference between the mean phenotypic value of the progeny of selected plants and the base or parental population is called as the genetic advance. The genetic advance was categorized into low (<20%) and high (>20%) as suggested by Robinson *et al.* (1949). High GA indicates that additive genes govern the character and low GA shows that non-additive gene action is involved. Heritability along with GA helps us in predicting the gene action and the method of breeding to be practiced.

Sreekumar *et al.* (1996) observed high heritability and low genetic advance for days to flowering. In vegetable cowpea, high heritability and genetic advance was recorded for pods per plant and yield by Tikka *et al.* (1997). Umaharan *et al.* (1997) reported high heritability for pod weight and can be effectively selected for in the early generations of improvement of the crop.

In yard long bean, vine length, primary branches, petiole length, length and breadth of terminal and lateral leaflets were reported to have high heritability and low genetic advance, by Resmi (1998).

In case of pod characters, Panicker (2000) reported high heritability and low genetic advance for pod length.

Tyagi *et al.* (2000) reported high heritability and high genetic advance for days to flowering. Peduncle length was found to have high heritability along with high genetic advance by Panicker (2000) and Pal *et al.* (2003).

Vine length had high heritability and low genetic advance by Vidya (2000). High heritability and high genetic advance for primary branches per plant and high heritability low genetic advance for pod girth was reported by Ajith (2001) in bush type vegetable cowpea.

High heritability coupled with high genetic advance for several characters was reported by Philip (2004) in bush type of vegetable cowpea.

Anbumalarmathi *et al.* (2005) reported high heritability and genetic advance for days to 50% flowering, plant height, primary branches per plant and pod clusters per plant.

High heritability and medium genetic advance for days to 50% flowering was reported by Awopetu and Aliyu (2006). Girish *et al.* (2006) reported high heritability and genetic advance for plant height and pods per plant. He also reported high heritability and low genetic advance for days to 50% flowering.

Suganthi and Murugan (2007), reported high heritability and genetic advance for plant height, pods per plant, pod clusters per plant, pod length, seeds per pod and 100 seed weight in cowpea. They also reported high heritability and low genetic advance for days to 50% flowering.

In yard long bean, Jithesh (2009) reported high heritability for all the characters of yard long bean except crude fiber content. He also reported that the characters peduncle length, trichome number and protein content of pods showing high genetic advance.

High heritability coupled with high genetic advance was observed for pod clusters per plant, pods per plant, pod yield per plant, pods per cluster and pod weight, indicating the additive gene action and suggesting the possibility of genetic improvement through selection (Kumar and Devi, 2009).

iii. Coefficients of variance

The efficiency of selection in crop improvement programmes largely depends on the extent of genetic variability present in the population. The variation present in the plant population is of three types *viz.*, phenotypic, genotypic and environmental. Of these the genetic variance can be further partitioned to additive, dominance and epistatic variance components.

Variance component analysis is used to assess the variability present in populations. The phenotypic, genotypic and environmental coefficient of variation (PCV, GCV and ECV respectively) gives an idea about the magnitude of variability present in the population.

PCV and GCV were high for plant height, seed yield per plant, pods per plant and 100 seed weight in cowpea (Sawant, 1994).

High values of GCV and PCV, heritability and genetic advance were obtained in cowpea for pod length and seeds per pod (Sreekumar *et al.*, 1996) indicating additive gene action. Backiyarani and Nadarajan (1996) reported high GCV and PCV for pods per plant, clusters per plant and 100 seed weight in cowpea.

Genotypic coefficient of variation was maximum for pod length in cowpea followed by total seed weight and number of pods per plant and lowest for number of clusters per plant (Rangaiah, 1997).

A wide range of PCV was reported in genetic variability studies conducted in 31 genotypes of vegetable cowpea by Sobha and Vahab (1998). High GCV was observed for pod weight and pod yield per plant. Harshavardhan and Savithramma (1998a) recorded high PCV and GCV for green pod yield, pods per plant and plant height in cowpea.

In cowpea characters such as plant height, pod weight, pod length and pod yield per plant showed high PCV and GCV (Hazra *et al.*, 1999). Rangaiah and Mahadevu (2000) reported narrow difference between PCV and GCV resulting in high heritability coupled with high genetic advance for number of seeds per pod in cowpea.

Panicker (2000) reported high PCV and GCV for pods per plant followed by yield of vegetable cowpea. Yield per plant, pods per plant, pods per inflorescence, main stem length and pod weight recorded high PCV and GCV, which it was low for days to first flowering (Vidya, 2000).

High phenotypic and genotypic coefficients of variation were reported for main stem length, number of primary branches and pod weight by Ajith (2001). The PCV was highest for pods per plant followed by cluster, primary branches and yield per plant by Nehru and Manjunath (2001). Jyothi (2001) reported high PCV and GCV for pods per plant, pods per cluster and yield per plant in cowpea.

High PCV and GCV were reported for number of pods per plant by Malarvizhi (2002). High GCV and PCV were observed for plant height and moderate PCV and GCV were reported for number of pods per by Venkatesan *et al.* (2003).

Lovely (2005) observed high GCV for pods per cluster, yield per plant, pod weight, pods per plant and clusters per plant. Pod weight and yield per plant had the highest PCV and GCV among different characters studied (Manju, 2006). Girish *et al.* (2006) reported high GCV and PCV for plant height and pods per plant.

The characters *viz.,* plant height, days to 50 per cent flowering, 100 seed weight and seed yield per plant showed moderately high GCV, thereby suggesting the scope for improvement of these characters. The relative magnitude of PCV and GCV indicated the presence of environmental influence in the expression of the characters studied (Eswaran *et al.* 2007).

Suganthi and Murugan (2008) reported that thirty genotypes of cowpea (*Vigna unguiculata* L.) exhibited high genotypic coefficient of variation than phenotypic coefficient of variation for all the characters.

High GCV was observed for pod length, pod weight, pods per plant, pod clusters per plant, pod yield per plant and 100-seed weight, which indicate that there exists high genetic variability and better scope for improvements of these characters through selection (Jithesh, 2009).

iv. Correlation and path coefficient analysis

Selection of desirable genotypes is the principal step of crop improvement. Most of the economically important characters like yield is an extremely complex trait and is the result of many growth functions of the plant. An estimation of inter-relationship of yield with other traits is of immense help in any crop improvement programme. Correlation studies would facilitate effective selection for simultaneous improvement of one or many yield contributing components. Certain characters contribute indirectly to yield through other components. They may not have significant direct effect on yield. Path coefficient analysis is used to separate the correlation coefficients into components of direct and indirect effects (Dewey and Lu, 1959).

Days to flowering were not associated with seed yield per plant. Number of pods per plant and number of seeds per pod were negatively and significantly correlated with 100 seed weight. Path coefficient analysis indicated that number of pods per plant was the most important yield contributing character affecting seed yield per plant followed by number of seeds per pod. Sudhakumari (1993) observed strong positive correlation for yield per plant with number of seeds per pod, pod length and 100 seed weight. High positive correlation between days to flowering and maturity was noticed by Perrino *et al.* (1993). Peduncle length was not correlated with any other character.

Misra *et al.* (1994) observed that pod weight was positively correlated with green pod yield per plant in cowpea. Path coefficient analysis indicated that pod length had the greatest direct effect on pod yield, followed by pod diameter, while direct but negative effects were observed for average pod weight. Seed yield was significantly and positively correlated with branches per plant, inflorescence per plant, pods per plant, pod length, seeds per pod and 100 seed weight (Sawant, 1994). Path analysis revealed that the pods per plant had the highest positive direct effect on seed yield followed by 100 seed weight, seeds per pod, days to 50 per cent flowering, inflorescences per plant, plant height and pod length.

In cowpea Sobha (1994) reported that yield per plant was significantly and positively correlated with pod weight, pod length, number of seeds per pod and 100 seed weight. Pod weight and 100 seed weight had high direct influence on yield. Sudhakumari and Gopimony (1994) noticed high positive correlation between number of pods per plant and seed yield per plant.

Positive correlation for plant height with days to 50 per cent flowering, number of clusters per plant, pod length and 100 seed weight were observed by Tamilselvam and Das (1994) in cowpea. Number of seeds per pod and 100 seed weight were positively correlated with each other and with pod length. Number of pods per plant was positively correlated with number of clusters per plant and negatively correlated with pod length and 100 seed weight.

Ofori and Djagbletey (1995) reported that seed yield in cowpea depended mainly on seeds per plant, number of fruiting branches and seeds per pod. Pod yield was strongly associated with seeds per pod (Kar *et al.* 1995). Path analysis showed that pod length was the main determinants of pod yield. Sreekumar (1995) noted highly significant negative correlation between 100 seed weight and protein content of seeds.

In cowpea, Sreekumar *et al.* (1996) observed that the yield of green pods was positively correlated with fruiting points per plant, pods per plant, pod length and seeds per pod. Naidu *et al.* (1996) noticed significant positive correlation between number of clusters per plant and number of pods per plant.

Chattopadhyay *et al.* (1997) reported that yield per plant was significantly and positively correlated with pod length, number of seeds per pod and 100 seed weight and negatively correlated with days to flowering. Number of pods per plant was negatively correlated to pod length. Path coefficient analysis revealed that number of pods per plant and number of seeds per plant had high direct effect on yield per plant. Days to flowering had negative direct effect on yield.

Character association studies in cowpea indicated a very high positive association of green pod yield with pods per plant (Harshavardhan and Savithramma, 1998b). Path coefficient analysis for green pod yield indicated that green pods per plant, pod length, pod width and number of primary branches were major traits contributing to yield. Singh *et al.* (1998) conducted a correlation study which revealed that grain yield per plant was positively and significantly associated with clusters per plant and pods per plant. Based on path coefficient analysis, pods per plant was the most important component character.

High positive correlation was reported for pod weight, pod length, pods per kg and pods per plant with pod yield per plant in yard long bean (Resmi, 1998). Path analysis revealed maximum positive direct effect for pods per plant followed by pod weight on yield per plant. Pods per kilogram exerted negative direct effect on yield. Number of pods per plant had maximum positive direct effect on yield. Mehta and Zaveri (1998) reported that grain yield per plant was significantly and positively correlated with number of branches per plant, number of clusters per plant and number of pods per plant.

In cowpea, Vardhan and Savithramma (1998) observed that yield per plant was significantly and positively correlated with pod length and number of pods per plant. Number of pods per plant, pod length and number of primary branches were the major traits which had positive direct effect with yield per plant. Branches per plant, pods per plant and plant height had positive correlation with seed yield both at genotypic and phenotypic levels (Kalaiyarasi and Palanisamy, 1999). Path analysis showed positive direct effects of branches per plant, plant height, pod length and 100 seed weight on seed yield.

Rangaiah and Mahadevu (2000) noted highly significant and positive association of yield in cowpea with clusters per plant, pods per plant and pod weight. Path analysis indicated a very high direct effect of pod weight. Pods per plant exhibited high indirect effect via pod weight on total seed weight.

In cowpea, Panicker (2000) reported that pod yield per plant was positively correlated with seeds per pod, pods per plant, length of harvest period, pods per inflorescence, pod weight and pod length. Yield per plant in cowpea showed high positive correlation with pods per plant, pods per inflorescence, pod weight, length of harvest period, pod girth, pod length and number of primary branches (Vidya, 2000). Path analysis revealed high direct effect for pods per plant and pod weight and indirect effect through other characters on yield.

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

Kalaiyarasi and Palanisamy (2000a) reported that pod length, seeds per pod, 100 seed weight and crude protein content had strong positive correlation with seed yield. High positive direct effect on seed yield was observed for pod length (Bastian *et al.*, 2001).

Ajith (2001) reported high positive genotypic correlation for pods per plant, pod weight, pods per cluster, pod clusters per plant and pod girth with pod yield per plant in cowpea. Pods per plant and pod weight had high direct effect on pod yield. Pods per plant exerted positive indirect effect via pod weight and pod weight exerted positive indirect effect via pods per plant.

In cowpea, plant height, branches per plant, pod yield, number of pods and pod length registered positive direct effect on grain yield while grains per pod had negative direct effect (Neema and Palanisamy, 2003). The highest positive direct effect was recorded by pod yield and the lowest by pod length. The indirect effect was maximum for pod length via pod yield.

Stoilova and Lozanov (2001) reported that high positive correlation were found in cowpea between the weight of plants without pods and pods per plant. Pod weight per plant was also strongly correlated with seeds per plant. Path analysis indicated that seeds per pod, pods per plant and plant height had high positive direct effects on seed yield while pod length 100 seed weight and branches per plant had negative direct effects (Kalaiyarasi and Palanisamy, 2002). Pod length and 100 seed weight had positive indirect effects on seed yield through pods per plant and seeds per pod.

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

Grain yield in cowpea showed significant positive association with clusters per plant and pods per plant (Parmar *et al.,* 2003). Other significant positive correlations were found between days to flower with days to maturity and plant height; days to maturity with plant height, pod length with seeds per pod, branches per plant with clusters per plant, clusters per plant with pods per plant and pods per cluster with pods per plant. Pods per plant registered the highest direct effect on seed yield, followed by clusters per plant and seeds per pod. The indirect effect of branches per plant via seeds per pod was also positive and high.

In cowpea, Kutty *et al.* (2003) observed that pods per plant, pod weight and pod length were positively and significantly correlated with yield per plant. Number of days to first picking showed significant negative correlation with seeds per plant and number of pods per plant. Path analysis indicated that the pods per plant, followed by pod weight had the greatest positive direct effect on yield.

Subbiah *et al.* (2003) studied the cause and effect relationship among the different quantitative traits of cowpea. Number of pods per plant, number of branches per plant, pod length, number of seeds per pod, plant height and 100 seed weight had positive direct effect on yield per plant. Number of pods per plant had positive indirect effect on yield per plant through days to flowering, number of branches per plant, pod length and number of seeds per pod.

In cowpea, Venkatesan *et al.* (2003) observed that number of branches per plant, number of pods per cluster, number of pods per plant and pod yield had significant positive phenotypic and genotypic correlation with grain yield. Path coefficient analysis revealed positive direct effect of grain yield with number of pods per plant, pod length, number of clusters per plant, number of seeds per pod and 100 seed weight. Number of pods per plant, pod length and number of clusters per plant were the most important yield determinants.

Lovely (2005) reported that yield per plant showed strong positive genotypic correlation with pods per cluster, pods per plant, pod weight, pod length, pod breadth and seeds per pod. A negative correlation was noted for days to 50 per cent flowering, days to first harvest and primary branches per plant. The characters pods per cluster, pods per plant, pod weight, pod length, pod breadth, seeds per pod and main stem length had positive direct effects while length of harvest period had negative direct effect.

Correlation studies revealed that characters like pod length, pod girth, pod weight, pods per plant, seeds per pod, 100 seed weight, number of harvests and pod protein observed high positive correlation with yield, whereas peduncle length was negatively correlated with yield (Manju, 2006). Path coefficient analysis indicated that pods per plant exerted the highest positive direct effect on yield, while pod weight and vine length had high indirect effects on pod yield.

Madhukumar (2006) noticed that pod yield per plant in cowpea showed significant positive correlation with pods per plant, pod clusters per plant, days to first harvest, pod weight, days to 50 per cent flowering, seeds per pod, pod length, and 100 seed weight at genotypic level. Path analysis revealed that number of pods per plant and pod weight were the primary yield contributing characters due to their high direct effect on pod yield.

Seed yield per plant had high significant positive correlation with harvest index at phenotypic and genotypic levels. The path coefficient analysis indicated that plant height at the time of first flowering, plant height at the time of 50 per cent flowering, plant height at the time of 50 per cent maturity and total dry matter production are important for effecting selection (Eswaran *et al.*, 2007). Suganthi and Murugan (2008) reported high positive correlation between seeds per pod and pod length.

In yard long bean, Jithesh (2009) reported that yield per plant showed strong positive correlation with pod weight, pod length, pod breadth, seeds per pod and 100-seed weight. The characters pod weight, pods per plant, 100-seed weight, seeds per pod and pod clusters per plant had positive direct effect.

Manggoel *et al.* (2012) reported that positive correlation were noticed between grain yield and number of peduncles per plant, flowers per plant, pods per plant and 100-seed weight. Path analysis showed high positive direct effects of number of peduncles per plant, flowers per plant and 100-seed weight.

Udensi *et al.* (2012b) reported correlation coefficient and path coefficients on yield and yield contributing traits. Results obtained revealed that significant relationship between on yield and yield contributing traits existed which could be indices for selection. Genotypic correlation coefficient was high and more significant than phenotypic and environment correlation coefficient. Path coefficient analysis shows that number of pods per plant had the highest direct effect to cowpea yield.

2.1.3 Selection index

The economic worth of a plant depends upon several characters so while selecting a desirable plant from a segregating population the plant breeder has to give due consideration to characters of economic importance. Selection index is one such method of selecting plants for crop improvement based on several characters of importance. This method was proposed by Smith (1937) using discriminant function of Fisher (1936).

In yard long bean, Resmi (1998) worked out the selection indices using thirteen characters and found that the genotype VS 6 had the maximum index value followed by VS 11. Superior genotypes were identified by constructing selection indices using the characters namely vine length, primary branches, petiole length, length and breadth of lateral leaflets, days to flowering, pod length, pod girth, pod weight, pods per inflorescence, pods per kilogram, pods per plant and yield.

Philip (2004) worked out selection indices for 50 genotypes of cowpea on the basis of pods per plant, number of inflorescence per plant, pods per inflorescence, pod length, seeds per pod and 100 seed weight. Five superior genotypes were selected for hybridization programme as female parents to develop F_1 hybrids.

Selection index for the genotype was computed based on the nine characters having significant genotypic correlation coefficients namely pods per cluster, pods per plant, pod yield per plant, pod weight, pod length, pod breadth, seeds per pod, length of harvest period and main stem length. The maximum selection index value was obtained for VS 41, while the least value was for VS 7 (Lovely, 2005).

Selection index analysis done by Madhukumar (2006) in yard long bean revealed that genotype VS 86 attained the maximum selection index value followed by Tvm-1, Vellavalli payar and the minimum estimates were recorded for Kayamkulam local, Malappuram local-2 and Kollengode local.

Manju (2006) worked out selection indices involving the characters, peduncle length, pod length, pod girth, pod weight, pods per plant, seeds per pod, 100 seed weight, number of harvests, pod protein and yield per plant. Based on selection index, VS 27 was ranked first followed by VS 8 and VS 19.

The selection index for the genotypes were computed on the basis of nine characters namely harvest period, primary branches per plant, pods per plant, pod weight, pod length, pod breadth, seeds per pod, 100-seed weight and pod yield per plant by Jithesh (2009).

2.2. Screening vegetable cowpea for collar rot and web blight resistance

2.2.1 Collar rot and web blight

Cowpea is subjected to a number of diseases of which collar rot is the most common one distribution causing severe economic losses in India (Shahina *et al.*, 2003).

Dubey and Mishra (1990) observed that web blight caused by *Rhizoctonia solani* on horse gram (*Macrotyloma uniflorum*) that caused 10-60 per cent reduction in yield. Mishra and Dubey (1991) reported the incidence of web blight disease on soybean, yard long bean and field bean during kharif season. The disease manifested in different stages on all the aerial parts and pods. Widespread occurrence of web blight disease caused by *R. solani* in *Albizia falcatoria*, a fast growing leguminous tree was reported in 1982 (Sharma and Sankaran, 1991).

Rhizoctonia solani Kühn [teleomorph: *Thanatephorus cucumeris* (Frank) Donk] is reported to cause economic losses in soybean [*Glycine max* (L.) Merril] crops throughout the world (Naito *et al.*, 1995).

High rainfall coupled with high soil moisture, relative humidity and soil temperature (21-25°C) favoured the development of the disease in French bean (Mathew and Gupta, 1996). They further reported that severity of web blight of french bean caused by *R. solani* ranged from 4.3 to 62.1 per cent.

The soil borne inoculants of the pathogen results in damping off or seedling blight or later as collar rot or foot rot. Web blight is caused by aerial types of the pathogen which is also soil borne. Web blight symptoms are noticed on the leaves and young stem tissues causing irregular water soaked areas that gradually turn straw coloured with dark margins under humid conditions, lesion progresses rapidly and cause extensive foliar blight, web blight and defoliation (Allen and lenn, 1998).

Web blight disease causes 30 per cent yield loss in urdbean (Sharma, 1999). *R. solani* isolates from urdbean was able to cause typical web blight symptoms on members of family Leguminosae (Sharma and Tripathi, 2001). They also reported that high rainfall coupled with high soil moisture, relative humidity and soil temperature (21-25°C) favoured the development of the disease

Gupta and Singh (2002) reported *R. solani* causing foliar blight of mung bean at early stage of crop growth causing premature defoliation and reduction in size of pods and grains with a disease intensity ranging from 6.66 to 75.35 per cent.

Safrankova (2003) studied the effects of *R. solani* strain AG-4 on the hypocotyl length of cultivars of *Phaseolus vulgaris* and pea. They reported that *R. solani* significantly reduced the length of hypocotyls of all cultivars tested.

In beans, root rot and web blight caused by *R. solani* is one of the most economically important root and hypocotyl diseases in the world (Sikora, 2004).

Upmanyu and Gupta (2005) reported that, high soil moisture (80%) and a temperature of 25°C were the most favourable for root rot development in French bean, while web blight development was optimum at >85% relative humidity coupled with 25°C temperature.

Singh and Sinha (2005) reported that the disease caused by *R. solani* due to the seed and soil borne nature needs constant monitoring. Thies *et al.* (2006) reported that cowpeas are more susceptible to seedling diseases caused by *R. solani* when planted in cold, moist, spring soils.

Gutierrez *et al.* (2009) evaluated 18 haricot bean cultivars and they were reported severe leaf blight caused by *R.solani*. They were also reported that here is a wide variation in disease symptoms.

Cowpea seedlngs in cool, moist spring soils are very susceptible to seedling damping-off and root rot caused by a soil-borne fungus, *R. solani*. This ubiquitous fungus is highly virulent to cowpea causing stand losses and subsequent yield losses (Berland *et al.*, 2009).

Symptomology

Thanatephorus cucumeris (Frank) Donk and its anamorphic state, *Rhizoctonia solani* Kuhn, are soil borne and widely distributed in native as causal agents for two distinctly different yet related diseases of cowpea collar rot & web blight (Emechebe and McDonald, 1979).

Lakshmanan *et al.* (1979) gave a detailed description of the symptoms of collar rot and web blight of cowpea caused by *R. solani*. Under field conditions, collar rot phase of the disease was more common than the web blight phase. Collar rot began as brownish – black lesions at soil level near collar region girdling the basal portion of the stem. White mycelial growth, often studded with small sclerotia was noticed in the affected area. The leaves turned yellow and finally dropped off. Symptoms of rotting were noticed and the root development was affected. Web blight symptoms appeared on leaves as small circular, light-greyish-brown spots surrounded by irregular water soaked area that enlarged to oblong or irregular shapes. Under congenial conditions, the spots coalesced covering major portion or entire leaf with mycelial growth, leading to shedding of affected leaves.

Collar rot symptoms of cowpea caused by *R. solani* were described by Viswanathan and Viswambharan (1979). They recorded the first visible symptom of the disease as occurrence of water soaked lesions in the leaves accompanied by rotting of stem in collar region. With the advancement of the disease, enlargement of lesions along with white cottony mycelial web and numerous creamy white globular sclerotial bodies appeared on the affected region. The final stages of infection witnessed yellowing of leaves with withering and drying off of the whole plant.

Sharma and Sohi (1980) found that *R. solani* caused pre-emergence and post-emergence mortality, collar rot, stem canker and pod rot symptoms in French bean.

The soil borne inoculants of the pathogen results in damping off/seedling blight or later as collar rot or foot rot. Web blight is caused by aerial types of the pathogen which also have soil borne in nature. Web blight symptoms are noticed on the leaves and young stem tissues causing irregular water soaked areas that gradually turn straw coloured with dark margins under humid conditions, lesion progresses rapidly and cause external blight, web blight & defoliation.(Allen and lenn, 1998).

Rhizoctonia solani causes pre- and post-emergence damping-off, root and hypocotyl rot and foliar blight in soybean. Foliar blight has resulted in yield losses of 31–60% (Fenille, 2002).

The severity of the symptoms of Rhizoctonia disease in potato depends on inoculum potential, i.e., the amount of pathogen in the soil and on seed tubers along with local climatic conditions. (Campion *et al.* 2003; Justesen *et al.* 2003)

The first symptoms of *R. solani* on snap bean were small, circular, water soaked spots on stems, pods and foliage, later tan-brown with a dark border, up to 2 cm across. Irregular, light brown sclerotia and fine mycelium develop as plants become seriously blighted (Yang *et al.*, 2007).

Sources of resistance

Mligo (1989) reported resistance to web blight caused by *R. solani* in the variety Vuli-1. Sources of resistance were located in IITA's (International Institute of Tropical Agriculture) world collection of cowpea germplasm. Using these sources IITA has developed many resistant varieties to fungal diseases including multiple disease resistant varieties (Singh, 1993).

Nassir and Oshunlaja (2003) identified the cowpea accession 'IT 86D 716' as the most likely source of resistance to web blight.

Upmanyu *et al.*(2004) reported that 'ET 8396' of French bean was completely free of web blight and was affected only by 2 isolates, i.e. RS 14 and RS18 while, fourteen cultivars or lines were moderately susceptible.

The prostrate cultivars, BRS-Amapa, BR03-Tracuateua, BR17-Gurgueia, BR14-Mulato and Canapuzinho, and erect cultivars, BRS-Mazagao, Pitiuba and BR03-Braganca, were most resistant to web blight and can be recommended for planting in areas where the disease is known to occur (Nechet and Halfeld-Vieira 2007).

Resistance to collar rot in chickpea was reported by Abida Akram *et al.* (2008). Singh *et al.* (2008) evaluated 85 mung bean accessions for *R. solani* resistance. None of the accessions were free from infection. Only 7 accessions, namely NDM 92-2, ML 406, EC 12431-1, EC 27130, EC 5551, IC 73362 and IC 39338 showed resistance with disease severity of 0.1-20% ,while 18 accessions showed moderate resistance and 28 were moderately susceptible to the pathogen. The rest of the accessions were susceptible to web blight disease having more than 60% disease severity.

Pamela (2010) reported that the common bean genotypes *viz.,* Western Nebraska and Fortuna have moderate tolerance to *Rhizoctonia solani,* in Mexico. The entries NE-08-95, NE-08, NE14-08-176, Ur 3 and *Ur 6* as well also partial resistance to Rhizoctonia Root Rot.

2.2.2. Basis of resistance to collar rot and web blight

2.2.2.1 Morphological and Anatomical basis of resistance

Different morphological and biochemical characteristics of crop varieties often play a crucial role in providing biotic stress resistance to plants (Norris and Kogan, 1980).

Morphological and anatomical characters such as cuticle thickness, number of stomata and number of hairs per unit area of stem and leaf have been correlated with blight resistance in chickpea (Ahmad *et al.*, 1952; Hafiz, 1952).

Iqbal *et al.*, (2002) reported that morphological and anatomical traits *viz.*, number of hairs on dorsal and ventral sides of leaves, number and size of stomata, guard cells and stomatal aperture of six chickpea cultivars consisting of two each resistant (NIFA-88, Dasht), tolerant (C-44, Punjab-91), and susceptible (C-727, ILC-263), and their relationship with *Ascochyta* blight resistance.

2.2.2.2 Biochemical basis of resistance

Several biochemical reactions take place inside the host plants to ward off the invading pathogens. Presence of high concentration of phenolics in cells of plants contributes to disease resistance.

i. Phenols

Mitter *et al.* (1997) reported that in both resistant and susceptible genotypes of chickpea on inoculation with *Botrytis cinerea* causing grey mould of chickpea there was reduction in phenol content. Kalim *et al.* (2000) reported higher amounts of total phenols in cowpea plants susceptible to *Rhizoctonia* spp. raised from seeds treated with 0.2 per cent bavistin.

Tiwari and Khare (2001) reported that, the phenolic compounds inhibited the growth of *R. solani* in mung bean.

Beckmann (2002) related physiological aspect of disease resistance and phenol as due to rapid oxidation of phenolic compounds which resulted in lignification and suberisation of cells and cell death that sealed off further infection at the site of cellular penetration by pathogen.

Priyadarsini (2003) observed significant increase in total phenol content by soil application of *Trichoderma* and also its foliar spray for Amaranthus leaf blight caused by *R. solani.* Saravankumar *et al.* (2005) reported increased accumulation of phenolics in *Bacillus* amended with chitin bioformulation pretreated plants challenge inoculated with *Macrophomina phaseolina.* Prakash and Mohan (2005) reported that in all bacterial treated plants appreciable amount of phenol was noticed when compared to control. Todkar *et al.* (2005) reported that the roots of cotton cultivars resistant to *Fusarium oxysporum* f. sp. *vasinfectum* causing wilt of cotton were found to contain higher levels of total phenols. Thakker *et al.* (2005) reported greater production of phenols in banana plantlets with Fusarium wilt disease treated with elicitors of *Fusarium oxysporum* f. sp. *cubense.*

Lozoya-Saldana *et al.* (2007) reported that there was a direct positive correlation between the percentage of infection and the presence of phenols under presence or absence of fungicides in potato for late blight (*Phytophthora infestans*)

Prabhu *et al.* (2009) investigated the biochemical basis of host plant resistance for shoot and fruit borer of brinjal using selected genotypes from the back crosses involving cultivated brinjal varieties and *Solanum viarum.* The different levels of biochemical constituents namely peroxidase, poly phenol oxidase, total phenols and solasodine contents were observed in genotypes derived from interspecific crosses and their parents. A higher level of polyphenol oxidase activity was observed in interspecific cross F_6 EP65 x *S. viarum.* There was a clear correlation exists between the levels of biochemical constituents of superior genotypes and resistance to fruit and shoot borer.

Khorsheduzzaman *et al.* (2010) reported that lignin content of all the genotypes was higher in fruits compared to shoots. The genotype containing the highest quantities of lignin showed the lowest shoot and fruit infestation by the borer. Lignin is a phenolic compound, which increases un-palatability of the food materials. This may be the possible reason for receiving lowest infestation in that genotype.

Khare *et al.* (2011) conducted studies to determine the role of phenols in rice cultivars tested for bacterial leaf blight (*Xanthomomas oryzae pv. oryzae*; BLB) resistance. The phenol contents of 21 resistant rice cultivars and one susceptible control T (N1) were determined. Results showed that the total phenol content in resistant rice cultivars varied from 1.60-2.46 mg/g varying from 4.4 to 0.6% correspondingly as against 1.21 mg/g in TN1 with a percent infection of 79.0. These results indicated that only the total phenol content in the rice cultivars imparted resistance against BLB.

ii. Proline

Feng Ming and Zhong (2005) studied biochemical characters in cotton seedlings for disease resistance to *F. oxysporum f.sp. vasinfectum.* They reported that the level of proline in leaves, stems and roots of healthy seedlings of the resistant cv. Zhongmian 12 was higher than that in the susceptible line 6037.

Proline accumulation may be part of the stress signal influencing adaptive responses (Maggio *et al.* 2002). In many plants, under various forms of stress, proline concentration increases up to 80 percent of the amino acid pool (Matysik *et al.*, 2002).

Geetha (2004) studied the variation in proline content in response to shade on various vegetables like chilli (217.52 to 281.53 $\mu g\ g^{-1}$), tomato (44.53 to 81.77 $\mu g\ g^{-1}$) and sword bean (35.71 to 77.92 $\mu g\ g^{-1}$).

Verbruggen and Hermans(2008) reported that accumulation of proline is a common physiological response in many plants in response to a wide range of biotic and abiotic stresses.

2.3 Screening for other pests and diseases

2.3.1 Legume pod borer [*Maruca vitrata* (Fab.)]

Legume pod borer [*Maruca vitrata* (Fab.) (Syn. *Maruca testulalis,* Geyer)] is a major limitation to successful cultivation of cowpea in many countries (Singh and Jackai, 1998). The crop loss caused by the pest is tremendous since the larvae feed on flowers and developing pods (Jackai and Adalla, 1997). The moth lays eggs on the flower buds, flowers and young pods and the first instar larvae start feeding at the oviposition sites. It then bores into the pods and devours ripening seeds one after another. The larval burrow is marked by a mass of brownish excrement at the entry of the gallery (Panicker, 2000).

Source of resistance

Screening of cowpea (*Vigna unguiculata* (L.) Walp.) germplasm for pod borer resistance resulted in the identification of tolerant lines / varieties (Singh, 1978). A field screening technique for locating resistance in cowpea to pod borer, *M.vitrata* was developed by Jackai (1982). Based on this technique, TVu 946 was the most resistant cowpea cultivar. Veeranna *et al.* (2000) screened Forty five genotypes of cowpea for the resistance against cowpea pod borer, *Maruca testulalis* and found that genotype TVX-7 is more resistant to pod borer .

A large number of selected wild *Vigna* accessions were evaluated by Jackai *et al.* (1996) and found that *V.vexillata* had the most resistant accession. Both antibiosis and antixenosis modalities were expected to be involved.

In yard long bean, screening for legume pod borer resistance was done by Panicker (2000), who observed a plant susceptibility index ranging from 33.13 to 109.37. Larval count and positive correlation was found among percentage pod infestation, pod damage severity and seed damage index. No significant correlation was noted between pod fiber content and percent pod infestation.

Employing Mahalanobi's D^2 statistic, 50 yard long bean varieties were grouped into seven clusters base on the different legume pod borer damage parameters (Vidya, 2000). In grain cowpea Philip (2004) observed a seed damage index of 40 to 192 and plant susceptibility index of 16.09 to 66.50. Flower damage was positively correlated with pod damage parameters and negatively with peduncle length.

Screening of all the 66 accessions for legume pod borer resistance was done by working out plant susceptibility indices based on flower, pod and seed damage parameters. VS 19 was the most tolerant with least damage to flowers, pods and seeds, while VS 42 was the most susceptible. On comparing the accessions for various characters VS 27, VS 8 and VS 19 were found to be promising based on their superiority in yield, quality and tolerance to legume pod borer (Manju, 2006).

Kooner and Cheema (2006) screened eighty nine genotypes of pigeon pea in the field to isolate sources of resistance to pod borers. The pod borer complex comprises of *Maruca testulalis, Lampedes boeticus* and *Helicoverpa armigera*. On the basis of per cent pod damage and Pest Susceptibility Rating (PSR), entries AL 1498, AL 1502 and AL 1340 were found promising with mean pod damage of 11.21 to 13.71% (PSR 3-3.50) as compared to 17.67 to 26.25% (PSR 4.00 to 5.50) on the check varieties (AL 15, AL 20 and T21) and 28.21% (PSR 6.00) on the infester. Therefore, genotypes AL 1498, AL 1502 and AL 1340 may be used as resistant donors in the crossing programme to evolve pod borer resistant / tolerant varieties of pigeon pea.

Jithesh (2009) reported three genotypes with low plant resistant indices namely Kurappunthara local (T_1), Kanichar local (T_2) and KMV-1 (T_3) were selected as testers in the line x tester analysis.

Role of plant characters in host plant resistance to pod borer

Oghiakhe *et al.* (1992a) found a negative and significant correlation between pod wall trichome density and pod damage by legume pod borer in cowpea and highlighted the role of trichome density in reducing pod damage. Pubescence (trichome) in wild and cultivated cowpea adversely affected oviposition, mobility, food consumption and utilization by the pod borer (Oghiakhe, 1995). Veeranna and

Hussain (1997) observed a trichome density of 24.41% 9 mm^2 in the resistance genotype (TVX-7), while the susceptible genotype DPCL-216 had a low trichome density of 12.82/9 mm^2.

Thick and compact collenchyma cells in the stems and fibrous tissues on the petal on the surface contributed to pod borer resistance in the resistant varieties TVNu 72, with trichome as the principal factors in the resistance (Oghiakhe *et al.* 1993).

Cowpea varieties with upright and long peduncles that hold 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* cultivar with pods held within the canopy suffered significantly more damage than cultivars with pods held above the canopy. They opined that larvae penetrate the pods more successfully when pods are in contact with each other or with the foliage. Pods with wide angles were damaged only on one and rarely on both pods. Selection and breeding for wide pod angle was suggested for reducing pod borer damage in cowpea pods (Oghiakhe *et al.*, 1992a).

Pod size and rate of pod growth are important factors in the susceptibility of cowpea to attack by pod borer (Tayo, 1988). Oghiakhe *et al.* (1992b) reported that even though the pressure required to penetrating pod wall increases with pod age, the correlation between pod damage severity and pod wall toughness was not significant.

Presence or absence of pubescence and type of cuticle waxes that affect oviposition, locomotion or feeding by insects, tissue toughness that influence feeding and such other characters that impede host feeding and / or utilization by insect pests. Pubescence on plant surface is made up of individual trichomes or hairs. When pubescence is present, the mechanism of resistance may depend upon one or more of the four characteristics of trichomes namely their density, erectness, length and shape (Manju, 2006). Also she reported that non glandular trichome density range of 1.87 to 6.03 mm^2 area of pod surface.

Jaydeep and Sreenivasan (2011) reported that highly susceptible cv. GC-9708 had least number of trichomes on stems (5.1) and leaves (4.8) as compared to highly tolerant cv. HC-270 which had 7.5 and 9.4 trichomes / mm^2, respectively and they also reported that highly susceptible cv. GC-9708 possessed lowest pod wall thickness (0.77 mm), least pod width (6.35 mm) and minimum pod angle (40^0) as compared to most tolerant cv. HC-270 (0,89 mm, 7.80 mm & 85^o, respectively). Similarly, highest pod length (15.55 cm) and maximum number of pods / cluster (2.8) were recorded from GC-9708 as compared to others.

2.3.2 Fusarium wilt

Fusarium wilt of cowpea caused by *Fusarium* spp. is a major to the cultivation of cowpea. The affected plants showed yellowing, wilting and drooping of leaves, blackening and drying of veins and abnormal flattening of the stem along the growing tip. Occasionally the flower produced becomes reduced in size and sterile resulting in severe yield reduction (Gokulapalan *et al.*, 2006).

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

Fusarium wilt is characterized by yellowing of leaves followed by defoliation, drying of vines and root decay. Sometimes there is also swelling of the basal part of the plant including the lower part of the stem and upper part of the tap root forming a tuber like structure which later gets disintegrated.

The wilt of cowpea was noticed in farmers' field in Thiruvananthapuram district of Kerala (Reghunath *et al.*, 1995). Schneider and Kelley (2000) studied Fusarium root rot in bean. The genetic resistance to the pathogen (*Fusarium oxysporum* f. sp. *phaseoli*) is considered quantitative and strongly influenced by environmental factors. They observed correlation coefficient between the greenhouse and field ratings were significant for the screening of Fusarium root rot resistance.

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

The response of 23 bean cultivars to four physiological races of Fusarium wilt (caused by *Fusarium oxysporum* f.sp. *phaseoli*) was evaluated by Sala *et al.* (2001).

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

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

Eloy and Michereff (2003) reported that Fusarium wilt caused by *Fusarium oxysporum* f. sp. *tracheiphilum*, is an important cowpea disease in the Brazilian

Northeast. Fusarium severity ranged between 3.2 and 93.3 per cent, while the yield loss ranged between 2.2 and 98.1 per cent.

2.3.3 Aphid

Joseph and Peter (2010) reported that the tender most shoot tips of the resistant cowpea lines were densely pubescent with mixed types of trichomes. Anatomical studies showed that lignification of the schlerenchymatous pericycle was more in susceptible lines, indicating that resistance is more of physiological nature rather than anatomical.

Ansari *et al.* (2011) screened 181 accessions to find genetic sources of resistance to *Aphis craccivora*, a major pest of cowpea, *Vigna unguiculata*. Zero aphids were found on three accessions (310,408-P2 and 801); another six accessions had populations of less than 30, compared with 200–400 on susceptible varieties. The other accessions showed only partial antibiosis and/or tolerance.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Screening of vegetable cowpea (*Vigna unguiculata* (L) Walp.) germplasm for yield, quality and resistance to collar rot and web blight" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2011-12. The experimental site was located at $8^o\ 5'$ N latitude and $77^o\ 1'$ E longitude at an altitude of 29 m above mean sea level. Predominant soil type of the experimental site was red loam belonging to Vellayani series, texturally classified as sandy clay loam.

The study was conducted in two separate experiments.

Experiment 1: Evaluation of vegetable cowpea germplasm for genetic variability, yield, quality and tolerance to pests and diseases.

Experiment 2: Screening vegetable cowpea germplasm for collar rot and web blight resistance under artificial conditions and basis of resistance also studied.

3.1 Experiment 1:

3.1.1 Materials

The experimental material comprised of 44 yard long bean (vine type) and 22 bush cowpea (bush type) accessions collected from different parts of Kerala, State Agricultural Universities and the available germplasm of the Department of Olericulture, College of Agriculture, Vellayani. The details of both yard long bean and bush cowpea accessions used for the experiment are given in table 1 and 2 respectively.

3.1.2 Methods

3.1.2.1 Design and layout

Separate experiments were laid out for yard long bean and bush cowpea.

Yard long bean

Design: RBD

Treatments: 44

Replications: 3

Spacing: 1.50 m X 0.45 m

Table1. Details of yard long bean (vine type) accessions used for evaluation

Sl. No.	Accession Number	Accession Name	Source
1	VS 1	Local	College of Horticulture, Vellanikkara
2	VS2	Local	Payannur, Kannur
3	VS 3	Local	College of Agriculture, Vellayani
4	VS 4	Kanjikuzhi Payar	College of Agriculture, Vellayani
5	VS5	Local	Hosdurg, Kasargode
6	VS 6	Local	Kumarapuram, Trivandrum
7	VS 7	Vyjayanthi	College of Horticulture, Vellanikkara
8	VS 8	Sarika	College of Agriculture, Vellayani
9	VS 9	Local	Aryanad, Trivandrum
10	VS 10	Local	Kuttipuram, Malapuram
11	VS 11	Lola	College of Horticulture, Vellanikkara
12	VS 12	Malika	College of Agriculture, Vellayani
13	VS 13	Local	Neyyattinkara, Trivandrum
14	VS 14	Local	Sreekaryam, Trivandrum
15	VS 15	Local	Mitraniketan, Vellayani
16	VS 16	Local	Pattom, Trivandrum
17	VS 18	Local	Pilicode, Kasargode
18	VS 19	Local	College of Horticulture, Vellanikkara
19	VS 20	Local	College of Horticulture, Vellanikkara
20	VS 21	Local	Thalasserry, Kannur
21	VS 22	IVRCP-1	College of Horticulture, Vellanikkara
22	VS 23	Local	Vengad, Kannur
23	VS 24	Local	Pattambi, Palakkad
24	VS 27	Local	Aripra, Malapuram
25	VS 28	Local	College of Agriculture, Vellayani
26	VS 29	Local	Aripra, Malapuram
27	VS 30	Local	College of Agriculture, Vellayani

Table 1. Continued...

Sl. No.	Accession	Accession Name	Source
30	VS 33	Local	Haritha Agrofarm, Trivandrum
31	VS 34	Vellayani Local	IF, College of Agriculture, Vellayani
32	VS 35	Local	Periya, Kasargode
33	VS 36	Local	Periya, Kasargode
34	VS 37	Local	Kanjhangad, Kasargode
35	VS 38	Local	Palayam, Trivandrum
36	VS 39	Local	Kanjhangad, Kasargode
37	VS 40	Meter payar	Pilicode, Kasargode
38	VS 41	Local	Pilicode, Kasargode
39	VS 42	Vellayani Jyothika	College of Agriculture, Vellayani
40	VS 43	Local	Ettumanoor, Kottayam
41	VS 44	Local	Kanakkary, Kottayam
42	VS 45	Super Green	Cherthala, Alleppey
43	VS 46	YLB-7	ARS, Thruvalla
44	VS47	NKRA Local	ARS, Thruvalla

Table 2. List of bush cowpea accessions used for the evaluation

Sl. No.	Accession Number	Accession Name	Source
1	VU 1	Anaswara	College of Horticulture, Vellanikkara
2	VU 2	Local	Kollam
3	VU 3	Bhagyalakshmi	College of Agriculture, Vellayani
4	VU 4	Local	Haritha Agrofarm, Trivandrum
5	VU 5	Arka Suman	IIHR, Bangalore
6	VU 6	Arka Garima	IIHR, Bangalore
7	VU 7	Local	Thodupuzha
8	VU 8	Pusa Phalguni	IARI, New Delhi
9	VU 9	Co-26	TNAU, Coimbatore
10	VU 10	Kanakamony	RARS, Pattambi, Palakkad
11	VU 11	Local	Kottamangalam, Ernakulam
12	VU 13	Local	College of Agriculture, Vellayani
13	VU 14	Local	College of Agriculture, Vellayani
14	VU 15	GC-9732	RARS, Pattombi, Palakkad
15	VU 16	CO-2	TNAU, Coimbatore
16	VU 17	Local	Brahmamangalam, Kottayam
17	VU 18	Local	College of Agriculture, Vellayani
18	VU 19	Local	Thrippunithura, Ernakulam
19	VU 20	Local	College of Agriculture, Vellayani
20	VU 21	GC-3	College of Agriculture, Vellayani
21	VU 22	Local	Pilicode, Kasargode
22	VU 24	Local	College of Horticulture, Vellanikkara

Bush cowpea

Design: RBD

Treatments: 44

Replications: 3

Spacing: 0.45 m X 0.30 m

The crop received timely management practices as per package of practices recommendations of Kerala Agricultural University (KAU, 2007). Since main thrust was given for screening of the accessions for collar rot and web blight under field conditions, fungicide application was avoided to allow natural infection.

3.1.2.2 Biometric observations

Five plants were selected randomly from both yard long bean and bush cowpea plots and tagged for recording the biometric observations.

3.1.2.2.1 Vegetative characters

3.1.2.2.1.1 Vine length (cm)

Vine length was recorded from the ground level to the top most leaf of the plants at the time of final harvest and presented in centimeters.

3.1.2.2.1.2 Primary branches per plant

Number of branches arising from the main stem was recorded from all the sample plants at the peak harvest stage and average was worked out.

3.1.2.2.1.3 Petiole length (cm)

Length of petiole of five leaves selected at random was measured in each observational plant.

3.1.2.2.1.4 Leaflet length (cm)

The fifth leaf from top of the selected plants was used for making the above observation. Both the length of terminal and lateral leaflet was measured as the distance from the base of the petiole to the top of the leaf and expressed in centimeters.

3.1.2.2.1.5 Leaflet width (cm)

The width of same leaf, used for recording the length was taken at the region of maximum width.

3.1.2.2.2 Flowering characters

3.1.2.2.2.1 Days to first flowering

Number of days from the date of sowing to the first flowering of observational plants was recorded and the average obtained.

3.1.2.2.2.2 Peduncle length (cm)

Length of peduncle was measured from five randomly selected inflorescences from each observational plant.

3.1.2.2.3 Pod and yield characters

3.1.2.2.3.1 Pod length (cm)

Five pods were selected at random from the observational plants. Length of the pods was measured as the distance from pedicel attachment of the pod to the apex using twine and scale. Average was taken and expressed in centimeters.

3.1.2.2.3.2 Pod girth (cm)

Girth of the pods was taken at the broadest part from the same pods used for recording the pod length. Average was taken and expressed in centimeters.

3.1.2.2.3.3 Pod weight (g)

Weight of pods used for recording pod length was measured and average was found out and expressed in grams.

3.1.2.2.3.4 Pods per plant

Total number of pods produced per plant till last harvest was counted.

3.1.2.2.3.5 Yield per plant (g)

Weight of all pods harvested from selected plants was recorded, average worked out and expressed in grams per plant.

3.1.2.2.3.6 Seeds per pod

Seeds from each pod were extracted, counted and average was worked out.

3.1.2.2.3.7 100 seed weight (g)

The dry weights of randomly selected hundred seeds were weighed using an electronic balance and presented in grams.

3.1.2.2.4 Morphological Characters

3.1.2.2.4.1 Pigmentation on stem and leaf

Pigmentation on stem and leaf of each variety was observed

3.1.2.2.4.2 Flower colour

Colour on flower of each variety was observed.

3.1.2.2.4.3 Pod colour

Colour on pods of each variety was observed.

3.1.2.2.4.4 Pod colour

Colour on seeds of each variety was observed.

3.1.2.3 Quality characters

i. Protein

Protein was estimated by Bradford method (Sadasivam and Manickam, 1996).

1. Dye concentrate: 100mg of coomasie brilliant blue G 250 was dissolved in 50 ml of 95 per cent ethanol. 100ml of concentrated orthophosphoric acid was added and final volume was made up to 200 ml with distilled water. It was stored under refrigerated conditions in amber bottles. 1 volume of concentrated dye solution was mixed with 4 volumes distilled water for use. This was filtered with Whatman No. 1 filter paper if any precipitate occurred.

2. Phosphate-buffer saline (PBS)

3. Protein solution (Stock standard): 50 mg of bovine serum albumin was accurately weighed and dissolved in distilled water and made up to 50 ml in a standard flask.

4. Working standard: 10 ml of the stock solution was diluted to 50 ml with distilled water in a standard flask. One ml of this solution contained 200 μg protein.

Procedure

500 mg of the sample was weighed and ground well with a pestle and mortar in 5-10 ml of the buffer. This was centrifuged and the supernant was used for protein estimation.

0.2, 0.4, 0.6, 0.8, and 1 ml of the working standard was pipette out into a series of test tubes. 0.1 ml of the sample extract was pipetted out into 2 other test tubes. The volume was made up to 1 ml in all the test tubes. A tube with 1 ml of water is used as blank. 5 ml of diluted dye solution was added to each tube. This was mixed well and the colour was allowed to develop for five minutes, but not longer than 30 minutes. The absorbance was read at 595 nm. A standard curve was plotted using standard absorbance vs concentration. The protein in the sample was calculated using the standard curve.

ii. Keeping quality

The harvested pods kept under ordinary room conditions to study its shelf life and number of days, up to which the pods remained fresh for consumption without loss of colour and glossiness, were recorded.

3.1.2.4 Screening for incidence of pests and diseases

All accessions of yard long bean and bush cowpea were screened for incidence of pests and diseases under field conditions

i. Collar rot and web blight (*Rhizoctonia solani*)

Disease incidence (%)

Observations on collar rot incidence were taken from all plants until final harvest. Observations were taken at an interval of five days.

Disease incidence was calculated using the formula,

$$\text{Disease incidence (\%)} = \frac{\text{Number of plants affected}}{\text{Total number of plants}} \times 100$$

Disease intensity

Observations on web blight disease intensity were recorded from all the plants. Scoring of the disease was done using the disease scale developed for the purpose after careful study of the disease and disease development. The extent of infection was estimated based on the parts of the plants affected. Size of the lesion, yellowing and drying of infected leaves were taken into account for devising the scale. Based on this a 0-9 scale has been devised (Plate-1).

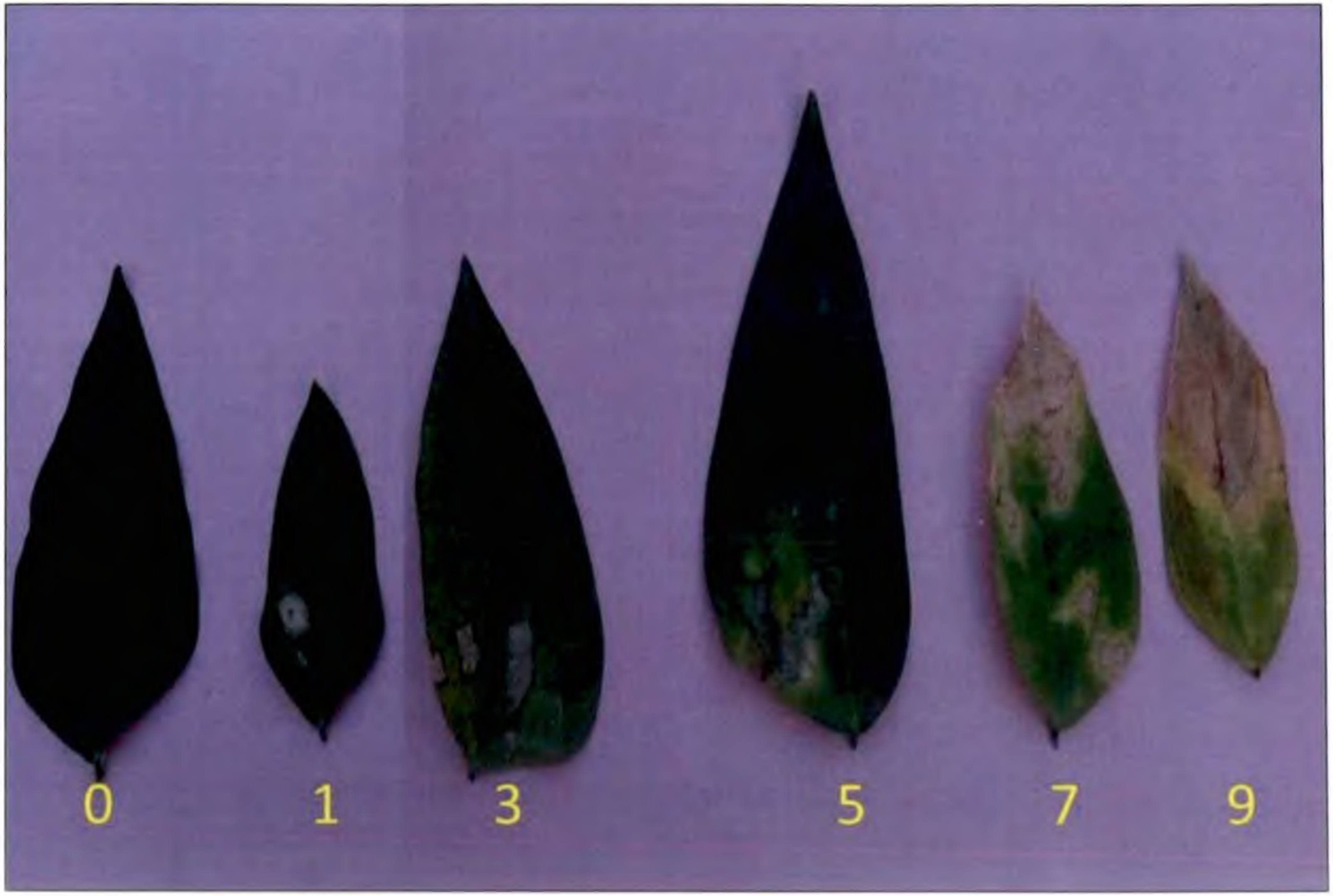


Plate 1. 0-9 scale for the scoring of web blight of cowpea

Grade	Description
0	No infection
1	1-10 % of leaf area infected
3	11-25 % of leaf area infected
5	26-50 % of leaf area infected
7	51-75 % of leaf area infected
9	> 75 % of leaf area infected

Percentage disease index (PDI) was calculated by using the formula:

$$PDI = \frac{\text{Sum of grades of each leaf}}{\text{Number of leaves assessed}} \times \frac{100}{\text{Maximum grade used}}$$

(Mayee and Dattar, 1986)

ii. Fusarium wilt (Fusarium oxysporum)

The percentage of wilt intensity was calculated. The individual plants in each genotype were scored by assigning score of 0-4 where,

0 —— Healthy plants

1 —— Slight yellowing of leaves

2 —— Yellowing and necrosis of leaves

3 —— Basal swelling, yellowing and necrosis of leaves

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

Percentage of disease intensity was calculated by using formula:

$$PDI = \frac{\text{Sum of grades of plants}}{\text{Number of plants assessed}} \times \frac{100}{\text{Maximum grade used}}$$

iii. Pod borer (*Maruca vitrata)*

Total number of infested pods was counted in each harvest from all observational plants and mean and percentage were calculated.

iv. Aphids (*Aphis craccivora*)

Total number of infested plants was counted from each line and scored in a 0-7 scale. The description for scale is as follow

Score	Descriptor	Severity of symptoms
0	No incidence	No symptoms
1	Low incidence	< 25% of plants attacked
3	Medium incidence	25-30% of plants attacked
5	High incidence	50-70% of plants attacked
7	Very high incidence	> 75% of plants attacked

3.1.3 Genetic cataloguing

The accessions were described morphologically using modified descriptor developed from the standard descriptor for cowpea by IPGRI (Appendix 1).

The cataloguing was done on appropriate scales ranging from 0-9.

Experiment 2:

The second experiment was screening vegetable cowpea germplasm for collar rot and web blight resistance under artificial conditions. To confirm the resistance of collar rot and web blight, all the accessions of both yard long bean and bush cowpea which were used in field experiment were screened under artificial conditions.

3.2.1 Materials

The experimental material comprised of the same 44 yard long bean and 22 bush cowpea accessions used for the first experiment.

3.2.2 Methods

3.2.2.1 Design and layout

The experiment was laid out as follow

Yard long bean

Design: CRD

Treatments: 44

Replications: 4

Bush cowpea

Design: CRD

Treatments: 22

Replications: 4

This experiment was done in the net house of the Department of Plant pathology, College of Agriculture, Vellayani.

3.2.2.2 Screening for collar rot and web blight

Isolation of the pathogen

Cowpea plants showing typical collar rot and web blight symptoms caused by *Rhizoctonia solani* were collected from the Crop Museum of College of Agriculture, Vellayani. The collar region and the leaves of infected cowpea plants showing rotting and blighting symptoms were washed with water and cut into small bits containing diseased portion along with some healthy tissue. The pieces were then surface sterilized in 0.1 per cent mercuric chloride solution for one minute followed by two to three washings in sterile water. The pieces were then transferred into sterile petridishes containing potato dextrose agar (PDA), under aseptic condition and incubated at room temperature. When fungal growth was visible, mycelial bits were transferred to PDA slants and labeled.

Purification

The two isolates obtained from collar region and the leaf was purified by hyphal tip method and pure culture was maintained on PDA slants by serial sub culturing for further studies.

Pathogenicity

Pathogenicity of the two isolates was proved following Koch's postulates. Cowpea seedlings were grown in disposable glasses. Ten to fifteen days old seedlings were inoculated with collar rot pathogen on collar region after giving injury by pin pricking. To provide moisture a thin layer of moisture cotton was placed over inoculated region. To ensure humidity the plant was covered with a polypropylene cover sprinkled with water and having sufficient holes. The pathogen isolated from leaf region was inoculated separately on leaves of 10 to 15 days old seedlings. For application on the leaves the mycelial suspension of *R. solani* was prepared by harvesting mycelial mats were suspended in sterile distilled water (SDW) and homogenized in warring blender for one minute and strained through a double layer muslin cloth and diluted with SDW in such a manner to contain 15-20 mycelial bits per microscopic field (200X). Then it was sprayed using a hand sprayer on the leaves. To ensure humidity the plant was covered with a polypropylene cover sprinkled with water and having sufficient holes. Four replications were maintained each. Both the isolates were capable of producing symptoms of disease on plants. Reisolation of pathogen was done from leaves and collar region showing typical web blight and collar rot symptoms and the identity of pathogen was established. These were used for further studies.

Disease incidence (%)

Observations on collar rot incidence were taken from the next day of inoculum application till the time of uprooting of the plants. Observations were taken at weekly interval.

Disease incidence was calculated using the formula as mentioned in 3.1.2.4.i.

Disease intensity

Observations on web blight disease intensity were recorded after inoculum application. Scoring of the disease was done using the disease scale developed for the purpose after careful study of the disease and disease development and it had given in 3.1.2.4.i.

3.2.2.3 Elucidation of basis of resistance

3.2.2.3.1 Anatomical Characters

All plants were analyzed for anatomical features like leaf trichome density, stomatal density, stem vascular bundle thickness and cuticle thickness.

i. Trichome density

Third leaf from tip was selected in each accession at random. The leaf observed under compound microscope with a magnification of 10X objective. The number of trichomes observed in a microscopic field was counted.. The area of microscopic field was calculated using stage micrometer. The mean value of trichome counts per mm^2 area of the leaf surface was calculated and expressed as trichome density on leaf.

ii. Stomatal density

A thin film of quick fix was applied over the adaxial surface of three randomly selected leaves in each selected accession. The film was peeled off after a few minutes and the number of stomatal impressions was counted using a compound microscope

(40X objectives) and the number of stomata per cm^2 was calculated by using the formulae given below

$$\text{No. of stomata/ } cm^2 = \frac{\text{No. of stomata under 40X}}{0.0086}$$

iii. Number of vascular bundles

A portion of the stem was cut off and thin sections of the stem were made with razor and slides were prepared. The slides were observed under compound microscope (10 X objectives) to count the number of vascular bundles.

iv. Cuticle thickness

The same stem sections taken for counting vascular bundles were used for measuring cuticle thickness also (40 X objective).

3.2.2.3.2 Biochemical characters

Biochemical characters governing disease resistance like phenol and proline were estimated from all plants of tolerant and susceptible categories.

i. Phenols

Total phenol content of leaf was estimated by using Folin-Ciocalteau reagent (Sadasivam and Manickam, 1996).

Reagents

- 80% ethanol
- Folin-Ciocalteau Reagent
- Na_2CO_3 20%
- Standard (100 mg Catechol in 100 ml water)
- Dilute 10 times for a working standard.

Procedure:

Weigh exactly 0.5 to 1.0 g of the sample and grind it with a pestle and mortar in 10-time volume of 80% ethanol. Centrifuge the homogenate at 10,000rpm for 20 min. Save the supernant. Reextract the residue with five times the volume of 80% ethanol, centrifuge and pool the supernants. Evaporate the supernant to dryness. Dissolve the residue in a known volume of distilled water (5 ml).

Pipette out different aliquots (0.2 to 2 ml) into test tubes. Make up the volume in each tube to 3mL with water. Add 0.5 ml of Folin-Ciocalteau reagent. After 3 minutes add 2 ml of 20 percent Na_2CO_3 solution to each test tube. Mix thoroughly, place the test tubes in boiling water for exactly one minute. Cool and measure the absorbance at 650nm against a reagent blank. Prepare a standard curve using different concentrations of catechol.

Calculation:

From the standard curve find out the concentration of phenols in the test sample and express as mg phenols/100 g material.

ii. Proline

Amount of proline in leaf is estimated using aqueous sulphosalicylic acid (Sadasivam and Manickam, 1996).

Reagents:

1. Acid Ninhydrin: Warm 1.25g ninhydrin in 30ml 6M phosphoric acid, with agitation until dissolved. Store at 4^0C and use within 24h.
2. 3% Aqueous Sulphosalicylic Acid
3. Glacial Acetic Acid
4. Toluene
5. Proline

Procedure

Extract 0.5g of plant material by homogenizing in 10ml of 3% aqueous sulphosalicylic acid. Filter the *homogenate* through Whatman No. 2 filter paper. Take 2 ml of filterate in a test tube and add 2 ml of glacial acetic acid and 2ml acid ninhydrin. Heat it in the boiling water bath for 1h. Terminate the reaction by placing the test tube in ice bath. Add 4 ml toluene to the reaction mixture and stir well for 20-30sec. Separate the toluene layer and warm to room temperature. Measure the red colour intensity at 520 nm. Run a series of standard with pure proline in a similar way and prepare a standard curve. Find out the amount of proline in the test sample from the standard curve.

Calculation

Express the proline content on fresh weight basis as follows:

$$\mu\text{moles per g tissue} = \frac{\mu\text{g proline per ml x ml toluene}}{115.5} \times \frac{5}{\text{g sample}}$$

Where 115.5 is the molecular weight of proline.

3.3 Statistical Analysis

The experimental data recorded were statistically analyzed. Analysis of variance and covariance were done:

a) To test significant difference among the genotypes and

b) To estimate variance components and other genetic parameters like correlation coefficients, heritability, genetic advance etc.

From the Table 3 and Table 4 other genetic parameters were estimated as follows:

3.3.1 Variance:

	X	Y
Environmental variance (σ^2_e)	$\sigma^2_{ex} = E_{xx}$	$\sigma^2_{ey} = E_{yy}$
Genotypic variance (σ^2_g)	$\sigma^2_{gx} = \frac{G_{xx} - E_{xx}}{r}$	$\sigma^2_{gy} = \frac{G_{yy} - E_{yy}}{r}$
Phenotypic variance (σ^2_p)	$\sigma^2_{px} = \sigma^2_{gx} + \sigma^2_{ex}$	$\sigma^2_{py} = \sigma^2_{py} + \sigma^2_{ey}$

3.3.2 Coefficient of variation

Phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated as

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

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

Table 3. Analysis of Variance / Covariance for RBD

Source	Df	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expected mean square YY
Block	(r-1)	B_{xx}		B_{xy}		B_{yy}	
Genotype	(v-1)	G_{xx}	$\sigma^2_{ex}+\sigma^2_{gx}$	G_{xy}	$\sigma^2_{exy}+r\sigma^2_{gxy}$	G_{yy}	$\Sigma^2_{ex}+r\sigma^2_{gx}$
Error	(v-1) (r-1)	E_{xx}	σ^2_{ex}	E_{xy}	σ^2_{exy}	E_{xy}	σ^2_{xy}
Total	Vr-1		T_{xx}			T_{yy}	

Table 4. Analysis of Variance / Covariance for CRD

Source	Df	Observed mean square XX	Expected mean square XX	Observed mean sum of products XY	Expected mean sum of products XY	Observed mean square YY	Expected mean square YY
Genotype	(v-1)	G_{xx}	$\sigma^2_{ex}+\sigma^2_{gx}$	G_{xy}	$\sigma^2_{exy}+r\sigma^2_{gxy}$	G_{yy}	$\Sigma^2_{ex}+r\sigma^2_{gx}$
Error	v (r-1)	E_{xx}	σ^2_{ex}	E_{xy}	σ^2_{exy}	E_{xy}	σ^2_{xy}
Total	Vr-1		T_{xx}			T_{yy}	

Where,

σ_{gx} - Genotypic standard deviation

σ_{px} - Phenotypic standard deviation

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

3.3.3 Heritability

$$H^2 = \frac{\sigma^2_{gx}}{\sigma^2_{px}} \text{ X } 100$$

Where, H^2 is the heritability expressed in percentage (Jain, 1982). Heritability estimates were categorized as suggested by Johnson *et al.* (1955).

0 – 30 per cent ⟶ Low

31 – 60 per cent ⟶ Moderate

>60 per cent ⟶ High

3.3.4 Genetic Advance as percentage mean

$$GA = \frac{k H^2 \sigma_p}{\bar{x}} \text{ x } 100$$

Where, k is the standard selection differential.

K = 2.06 at 5% selection intensity (Miller *et al.*, 1958)

The range of genetic advance as per cent of mean was classified according to Johnson *et al.* (1955).

0- 10 per cent ⟶ Low

11- 20 per cent ⟶ Moderate

> 20 per cent ⟶ High

3.3.5 Correlation

Genotypic correlation coefficient (r_{gxy}) $= \frac{\sigma g_{xy}}{\sigma g_x \text{ x } \sigma g_y}$

Phenotypic correlation coefficient (r_{pxy}) $= \frac{\sigma p_{xy}}{\sigma p_x \text{ x } \sigma p_y}$

Environmental correlation coefficient (r_{exy}) $= \frac{\sigma e_{xy}}{\sigma e_x \text{ x } \sigma e_y}$

3.3.6 Path analysis

The direct and indirect effects of yield contributing factors were estimated through path analysis technique (Wright, 1954; Dewey and Lu, 1959)

3.3.7 Selection Index

The selection index developed by Smith (1937) using discriminate function of Fisher (1936) was used to discriminate the genotypes based on all the characters.

The selection index is described by the function, $I = b_1 x_1 + b_2 x_2 + \ldots\ldots\ldots + b_k x_k$ and the merit of a plant is described by the function, $H = a_1 G_1 + a_2 G_2 + \ldots\ldots\ldots + b_k G_k$ where $x_1, x_2 \ldots\ldots\ldots\ldots x_k$ are the phenotypic values and $G_1, G_2 \ldots\ldots\ldots\ldots G_k$ are the genotypic values of the plants with respect to characters, $x_1, x_2 \ldots\ldots\ldots\ldots x_k$ and H is the genetic worth of the plant. It is assumed that the economic weight assigned to each character is equal to unity i. e., $a_1, a_2 \ldots\ldots\ldots\ldots a_{k=1}$

The regression coefficients (b) are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form, $b = P^{-1}Ga$ where, P is the phenotypic variance-covariance matrix and G is the genotypic variance-covariance matrix x.

RESULTS

4. Results

The experimental data collected on growth characters, yield and yield attributes, quality characters and pest and disease incidence were statistically analyzed and the results are presented under the following heads:

4.1 Experiment 1: Evaluation of vegetable cowpea accessions for genetic variability, yield, quality and tolerance to pests and diseases. Field view of this experiment was given in Plate 2

4.2 Experiment 2: Screening of vegetable cowpea accessions for collar rot and web blight resistance under artificial conditions and basis of resistance was also studied.

4.1 Experiment I

Separate experiments were laid out with 44 accessions of yard long bean and 22 accessions of bush cowpea. All the accessions were subjected to detailed studies on variability, heritability, genetic advance, correlation, path analysis, and pest and disease incidence.

4.1.1 Analysis of variance

The analysis of variance revealed significant variation among the 44 yard long bean accessions (Table 5) and 22 bush cowpea accessions (Table 6) for 20 characters studied.

4.1.2 Mean performance of accessions

The mean values of the accessions for growth, yield, and quality characters were given below.

4.1.2.1 Growth characters

Yard long bean

The mean values for growth characters were furnished in table 7.

VS 9 had the longest vine (569.22) and VS 22 had the shortest vine (125.89 cm). Primary branches per plant varied from 3.2 cm (VS 46) to 6.22 cm (VS 38). Wide variation among the accessions was observed for petiole length. It ranged from 5.71 cm in VS 11 to 11.05 cm in VS 22.

Field view of yard long bean

Field view of yard long bean

Plate 2. Field view of Experiment I

Table 5. Analysis of variance for 20 characters in yard long bean (Mean squares are given)

Source	D.F	1	2	3	4	5	6
Replication	2	776	7.814	17.327	2.36	0.00903	3.521
Treatment	43	19739.12**	1.744**	5.919**	3.185**	2.469**	1.513**
Error	86	384.837	0.338	0.649	0.591	0.326	0.206

Source	D.F	7	8	9	10	11	12	13
Replication	2	1.423	0.844	1517.16	0.313	3.922	0.0184	0.465
Treatment	43	1.257**	10.484**	1477.433**	22.444**	427.734**	0.561**	216.903**
Error	86	0.119	0.314	728.051	1.189	3.702	0.01345	1.209

Source	D.F	14	15	16	17	18	19	20
Replication	2	0.826	0.00684	23.266	5756	0.0217	2.917	4.918
Treatment	43	14.288**	15.053**	486.639**	62078.14**	9.124**	1.042**	104.748**
Error	86	0.74	0.435	19.847	3725.12	0.0147	0.0133	1.41

Table 6. Analysis of variance for 20 characters in bush cowpea (Mean squares are given)

Source	D.F	1	2	3	4	5	6
Replication	2	0.313	0.108	0.789	0.157	0.07129	0.367
Treatment	21	4607.572**	2.028**	10.121**	15.091**	5.169**	5.159**
Error	42	40.248	0.106	1.745	0.298	0.0983	0.0988

Source	D.F	7	8	9	10	11	12	13
Replication	2	0.0411	8.379	3.679	4.419	1.574	0.297	0.0394
Treatment	21	1.9855**	13.126**	10.958**	12.873**	65.825**	0.284**	19.839**
Error	42	0.1923	0.585	0.285	1.659	0.359	0.00827	0.0297

Source	D.F	14	15	16	17	18	19	20
Replication	2	3.045	0.0254	2.773	41.25	0.0217	0.075	0.570
Treatment	21	10.612**	10.443**	389.441**	5513.739**	4.157**	1.202**	51.87**
Error	42	0.807	0.0594	9.804	198.577	2.397	0.0115	2.41

Table 7. Mean performance of 44 yard long bean accessions for vegetative and flowering characters

Accessions	Vine length (cm)	Primary branches per plant	Petiole length (cm)	Length of leaflets (cm)		Breadth of leaflets (cm)		Days to first flowering	Days to first harvest	Peduncle length
				Terminal	Lateral	Terminal	Lateral			
VS 1	400.72	5.11	6.77	14.24	7.83	9.42	6.17	35.82	44.29	13.87
VS 2	440.11	4.89	7.19	11.34	8.62	6.72	6.16	37.63	45.58	14.07
VS 3	428.84	3.89	8.71	13.06	7.49	7.15	5.60	39.25	48.42	12.88
VS 4	568.83	4.33	9.97	12.89	7.52	9.34	5.67	37.89	46.52	19.87
VS 5	446.61	4.67	8.05	11.47	9.75	7.88	5.83	37.53	46.35	14.43
VS 6	548.06	4.45	6.39	11.92	9.37	7.59	5.50	44.36	53.32	15.49
VS 7	434.88	4.11	6.25	10.31	8.02	6.73	5.87	37.50	46.41	13.61
VS 8	446.50	4.56	8.09	13.15	9.28	6.21	5.38	37.65	46.69	21.22
VS 9	569.22	4.55	8.48	13.72	9.21	10.10	5.73	38.38	48.37	13.76
VS 10	454.33	5.11	5.82	10.77	9.32	6.91	7.18	38.91	47.09	12.55
VS 11	545.33	4.78	5.71	11.84	9.24	7.24	6.01	39.84	48.15	15.93
VS 12	455.72	4.78	10.48	11.57	9.56	8.00	6.41	40.61	49.2	21.74
VS 13	539.78	4.00	6.31	11.33	8.30	6.84	5.37	40.38	50.22	17.05
VS 14	448.78	5.11	9.30	11.46	8.88	6.71	5.18	38.06	46.72	13.49
VS 15	444.67	4.56	9.68	11.77	9.40	7.36	4.99	38.35	48.05	12.96
VS 16	552.66	4.89	9.19	12.61	8.88	7.68	6.21	38.14	47.36	12.34
VS 18	427.50	4.33	9.58	12.25	8.50	7.80	6.19	35.62	45.78	12.87
VS 19	411.78	5.45	8.86	12.26	8.29	8.36	5.67	38.68	48.00	12.96
VS 20	475.80	5.67	8.77	12.17	7.37	6.49	4.93	33.32	42.65	13.90
VS 21	443.50	5.89	10.00	11.00	7.01	7.49	4.67	38.65	48.25	14.82
VS 22	125.89	5.45	11.05	11.77	8.07	7.53	6.23	36.30	45.30	20.94
VS 23	419.56	4.56	10.68	13.23	7.72	7.89	5.35	38.69	47.30	14.79

Table 7. Continued...

Accessions	Vine length (cm)	Primary branches per plant	Petiole length (cm)	Length of leaflets (cm)		Breadth of leaflets (cm)		Days to first flowering	Days to first harvest	Peduncle length
				Terminal	Lateral	Terminal	Lateral			
VS 24	423.99	5.45	9.08	12.52	7.81	7.60	4.88	34.24	43.50	12.36
VS 27	381.39	5.11	10.66	11.80	8.80	7.44	6.34	38.14	46.55	13.36
VS 28	439.16	5.67	10.32	11.68	8.35	7.39	5.43	37.02	45.46	11.55
VS 29	417.33	6.11	10.08	11.16	8.72	7.29	5.83	37.65	46.61	12.65
VS 30	373.28	6.11	7.51	10.93	8.19	6.51	6.36	37.38	47.30	12.69
VS 31	428.94	4.89	9.01	11.25	7.09	7.59	5.41	37.62	46.65	12.62
VS 32	539.17	4.33	7.28	11.45	7.38	7.38	5.27	37.19	45.68	12.50
VS 33	483.00	4.11	7.70	12.92	9.78	9.26	7.92	38.39	47.47	18.90
VS 34	506.06	4.78	8.90	13.59	8.32	8.60	5.63	38.24	47.29	13.51
VS 35	522.00	5.33	9.89	13.37	8.82	8.99	6.24	39.26	49.35	20.46
VS 36	507.61	4.78	9.52	12.78	8.66	7.43	6.24	38.05	47.61	15.19
VS 37	474.94	4.00	8.29	13.08	8.24	7.30	6.32	38.31	47.45	15.20
VS 38	535.89	6.22	7.70	12.89	7.74	7.57	6.01	38.28	47.24	15.02
VS 39	504.11	6.00	8.89	13.90	8.69	8.55	6.61	38.06	48.12	17.27
VS 40	448.39	5.22	9.87	12.18	8.25	7.33	6.56	38.19	47.25	14.42
VS 41	451.61	3.22	8.91	12.99	7.64	8.54	5.83	37.62	46.69	14.53
VS 42	413.56	5.67	7.95	11.06	8.37	7.26	6.30	39.08	49.15	12.60
VS 43	447.11	4.67	10.46	14.56	8.49	9.44	7.23	36.65	46.09	11.83
VS 44	419.44	4.56	9.01	12.36	9.15	6.55	6.81	38.10	48.28	10.48
VS 45	504.89	3.22	9.43	12.57	8.34	7.81	6.10	37.56	47.06	15.23
VS 46	419.56	3.20	9.41	11.53	8.51	6.44	5.96	32.02	41.39	13.23
VS 47	405.89	3.89	10.44	14.37	8.89	7.90	6.20	37.62	47.35	15.91
CD (5%)	31.875	0.945	1.309	1.249	0.928	0.737	0.561	0.910	1.558	1.772
Mean	456.28	4.81	8.76	12.30	8.45	7.67	5.95	37.87	47.36	14.71

Significant differences were observed for terminal leaflet length. VS 43 had the longest (14.56 cm) and VS7 had the shortest terminal leaflet (10.31 cm). Breadth of terminal leaflets varied from 6.21 cm in VS 8 to 10.10 cm in VS 9. The accessions varied considerably for lateral leaflet length also. VS 21 had shortest lateral leaflet length (7.01 cm) and VS 33 had longest lateral leaflet length (9.78 cm). Breadth of lateral leaflets from 4.67 cm in VS 21 to 7.92 in VS 33.

Days to first flowering exhibited a range of 32.02 days in VS 46 to 44.36 days in VS 6. Peduncle length varied from 10.48 cm (VS 44) to 21.74 cm (VS 12).Days to first harvest was least in VS 46 (41.39 days) and highest in VS 6 (53.32 days).

Bush cowpea

The mean values for growth characters were furnished in table 8.

Vine length was highest in VU 22 (182.97) and lowest in VU 24 (58.9 cm). Primary branches per plant found to vary from 4.22 (VU 15) to 7.44 (VU 11). Wide variation among the accessions was observed for petiole length. It ranged from 7.35 cm in VU 16 to 13.87 cm in VU 3.

Significant differences were observed in all accessions for terminal leaflet length. VU 19 had the longest (17.27 cm) and VU 9 had the shortest terminal leaflet length (9.62 cm).Breadth of terminal leaflet varied from 10.87 cm in VU 2 to 6.78 in VU 9. The accessions varied considerably for lateral leaflet length from 8.51cm in VU 5 to 13.21 in VU 22. Breadth of lateral leaflets varied 5.76 in VU 5 to 8.85 cm in VU 22 with a mean of 7.54 cm.

Days to first flowering was noticed less (31.40 days) in three accessions (VU 5, VU 7, and VU 8) and high in VU 14 (38.29 days). Among 22 accessions VU 5, VU 7 and VU 8 were the earliest and VU 14 was the latest accession. Peduncle length was recorded longest in VU 9 (26.07 cm) and the shortest in VU 11 (17.57 cm). Days to first harvest ranged from 40.69 in VU 24 to 47.71 days in VU 14.

4.1.2.2 Yield and yield attributes

Yard long bean

Mean values for yield and yield attributing characters were furnished in table 9.

Table 8. Mean performance of 22 bush cowpea accessions for vegetative and flowering characters

Accessions	Vine length (cm)	Primary branches per plant	Petiole length (cm)	Length of leaflets (cm)		Breadth of leaflets (cm)		Days to first flowering	Days to first harvest	Peduncle length
				Terminal	Lateral	Terminal	Lateral			
VU 1	170.53	7.33	8.36	16.12	12.48	10.73	8.45	37.12	46.25	22.70
VU 2	91.97	6.78	9.03	14.25	10.52	10.87	7.57	33.38	42.35	22.17
VU 3	80.63	6.33	13.87	14.88	10.77	9.67	7.21	33.30	43.42	20.60
VU 4	177.77	6.56	13.71	13.60	10.61	10.24	7.59	36.24	45.24	25.23
VU 5	101.50	5.33	12.39	11.62	8.51	9.15	5.76	31.40	40.62	20.67
VU 6	83.47	4.78	12.50	15.91	12.10	10.35	8.63	31.30	41.25	21.97
VU 7	166.83	5.78	12.93	11.29	11.05	7.56	7.70	31.40	41.50	20.87
VU 8	119.27	5.22	10.32	10.49	9.10	7.44	6.52	31.40	41.08	25.73
VU 9	129.37	6.22	12.76	9.62	8.94	6.78	6.56	35.08	44.58	26.07
VU 10	106.83	5.56	9.97	10.74	9.94	8.10	8.01	33.48	42.65	19.67
VU 11	97.30	7.44	9.93	10.85	10.11	7.24	7.13	33.12	42.65	17.57
VU 13	135.43	5.56	8.70	11.09	9.93	7.37	6.61	36.25	45.60	20.57
VU 14	161.27	5.11	12.38	12.98	10.01	8.90	7.46	38.29	47.71	23.13
VU 15	178.20	4.22	11.93	12.99	10.69	8.91	7.38	33.18	42.68	20.27
VU 16	168.23	5.44	7.35	11.19	10.30	7.73	8.36	33.62	41.52	20.23
VU 17	134.53	5.67	12.32	15.35	11.94	8.85	8.11	34.05	42.65	22.07
VU 18	80.53	5.44	10.63	16.24	12.41	10.71	8.30	37.36	44.36	23.43
VU 19	97.73	5.22	12.29	17.27	9.49	10.42	7.49	35.02	43.69	21.70
VU 20	75.53	6.39	11.91	13.79	11.74	8.29	7.78	33.76	42.60	22.67
VU 21	114.57	5.22	9.80	12.28	12.03	8.37	8.13	32.14	41.62	21.57
VU 22	182.97	6.78	10.70	15.78	13.21	10.53	8.85	34.72	43.28	23.97
VU 24	58.90	5.33	9.12	14.34	8.91	8.79	6.27	31.65	40.69	20.43
CD (5%)	10.468	0.188	2.179	0.900	0.518	0.517	0.724	1.26	0.881	2.125
Mean	123.33	5.81	11.04	13.30	10.67	8.95	7.54	33.97	43.09	21.97

Table 9. Mean performance of 44 yard long bean accessions for yield and quality attributes

Accessions	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pods per plant	Yield per plant (g)	Seeds per pod	100 seed weight (g)	Pod protein (%)	Keeping quality (days)
VS 1	42.80	3.27	22.33	67.05	1038.93	20.15	10.28	6.27	3.53
VS 2	44.30	3.17	19.92	73.35	880.58	16.05	14.22	5.62	3.07
VS 3	46.53	3.10	18.44	61.12	733.70	18.10	14.10	5.65	3.47
VS 4	67.17	3.27	38.73	35.39	915.83	19.30	12.03	7.09	3.43
VS 5	53.27	2.70	20.54	53.35	613.61	19.38	17.69	4.32	5.17
VS 6	55.47	2.67	21.41	52.28	733.15	21.20	16.00	4.90	3.47
VS 7	59.30	2.97	20.76	51.65	698.01	21.18	16.72	6.50	4.00
VS 8	42.83	3.00	18.14	51.62	724.07	18.65	16.07	5.54	4.53
VS 9	66.63	3.30	32.53	32.58	829.08	17.62	20.98	4.62	3.23
VS 10	37.37	3.10	16.73	54.60	683.60	18.36	17.26	6.51	5.17
VS 11	50.27	3.03	21.10	51.69	682.04	18.02	16.65	8.08	4.03
VS 12	61.20	3.37	24.04	45.32	612.26	15.70	16.26	7.71	3.07
VS 13	53.67	2.53	17.99	46.08	538.65	19.10	15.85	7.93	3.57
VS 14	50.40	2.70	19.52	62.02	868.62	20.35	17.90	7.83	4.53
VS 15	46.73	2.77	17.19	64.42	740.41	20.06	16.65	7.54	4.47
VS 16	56.63	2.87	22.68	62.62	844.12	22.72	17.84	8.50	4.20
VS 18	40.53	2.87	17.49	58.60	642.74	17.32	17.33	8.52	4.37
VS 19	39.23	2.77	23.07	70.25	914.69	19.60	14.08	7.61	3.13
VS 20	27.13	3.53	15.08	66.62	707.45	16.65	13.14	4.84	4.58
VS 21	51.13	3.03	18.02	56.65	722.88	22.72	14.60	6.49	4.00
VS 22	29.93	2.90	14.84	65.54	663.54	16.50	14.02	5.84	4.93
VS 23	42.37	3.23	21.72	68.69	773.87	14.58	11.70	5.80	3.53

Table 9. Continued…

Accessions	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pods per plant	Yield per plant (g)	Seeds per pod	100 seed weight (g)	Pod protein (%)	Keeping quality (days)
VS 24	44.03	3.50	20.67	55.12	699.60	17.15	15.15	5.74	3.57
VS 27	41.80	2.77	18.74	57.30	740.75	19.10	16.59	8.14	3.13
VS 28	44.40	2.90	22.53	54.05	839.49	16.30	19.27	4.59	3.43
VS 29	46.13	2.77	17.10	87.09	1127.52	18.65	13.42	9.22	4.07
VS 30	32.13	2.77	14.50	81.15	1044.92	20.02	13.98	3.43	4.43
VS 31	44.50	3.70	21.64	78.35	1010.55	16.60	12.13	8.53	4.38
VS 32	41.97	2.93	20.57	63.12	773.64	18.08	12.98	3.17	4.13
VS 33	35.03	3.73	20.93	52.65	578.22	16.75	17.09	4.21	4.00
VS 34	51.00	3.53	28.68	67.35	1018.78	21.68	15.02	7.82	4.40
VS 35	47.60	2.47	27.47	54.56	866.65	20.72	14.48	4.36	4.40
VS 36	43.00	2.90	21.51	55.45	736.19	20.62	18.04	4.16	5.00
VS 37	50.70	2.67	18.24	56.00	642.89	21.05	14.26	7.66	4.50
VS 38	33.23	3.23	22.53	53.16	645.54	14.30	19.53	4.74	4.10
VS 39	55.57	3.03	26.20	53.05	728.75	20.42	14.21	5.86	4.13
VS 40	49.50	3.17	21.82	51.30	770.48	18.28	17.38	3.82	3.62
VS 41	54.93	2.93	17.33	41.20	500.51	23.32	18.38	3.66	3.97
VS 42	54.13	3.77	26.67	49.48	810.10	19.65	14.95	8.52	4.64
VS 43	44.23	3.20	19.69	37.24	560.40	19.38	15.77	3.85	4.57
VS 44	29.63	2.87	16.33	57.35	809.55	17.25	15.97	4.63	5.12
VS 45	91.67	4.63	67.07	19.30	741.28	21.65	18.32	8.51	4.62
VS 46	45.17	3.43	29.37	42.15	883.26	16.70	16.25	4.34	4.17
VS 47	72.17	4.23	32.63	49.42	967.89	22.10	16.65	4.53	4.30
CD (5%)	3.13	0.188	1.787	7.238	99.169	1.398	0.116	0.197	0.187

For pod length, highest value of 91.67 cm was recorded by VS 45 and lowest value of 27.13 cm by VS 20. Pod girth varied from 2.47 cm (VS 35) to 4.63 cm (VS 45).

Highest value for pod weight was recorded by VS 45 (67.06 g) followed by VS 4 (38.73 g) and lowest was for VS 30 (14.5g) followed by VS 22 (14.84). For pods per plant, highest value was noted in VS29 (87.09) followed by VS 30 (81.15) and lowest value in VS 45 (19.30) followed by VS 9 (32.58).

Highest average yield was obtained for VS 29 (1127.5 g) followed by VS 30 (1044.92 g) and VS 1(1038.93 g) and lowest for VS 41 (500.51 g) followed by VS 13 (538.65 g) and VS 43 (560.40 g).

Seeds per pod were highest in VS 41 (23.32) and lowest in VS 38 (14.30).Wide variation in 100-seed weight was observed among 44 accessions. VS 9 was showing the highest value of 20.98 g and VS 1 with the lowest of 10.28 g.

Bush cowpea

Mean values of yield and yield attributing characters were furnished in the table 10.

For pod length, highest value of 32.53 cm was recorded by VU 20 and lowest value of 12.40 cm by VU 24. Pod girth varied from 1.83 cm (VU 24) to 2.93cm (VU 1).

Pod weight varied from 4.74 in VU 24 to 12.44 in VU 20 with a mean of 7.44. For pods per plant, highest value was found in VU 8 (70.30) followed by VU 7 (58.10) and lowest in VS 22 (23.35) followed by VU 19 (26.12).

Highest yield was obtained for VU 6 (310.41 g) followed by VU 2 (282.26 g) and VU 18 (262.04 g) lowest for VU 15 (150.86 g) followed by VU 21 (154.30 g) and VU 3 (156.35 g).

Seeds per pod was highest in VU 19 (19.28) and lowest in VU 24 (11.35). Wide variation in 100-seed weight was observed among 22 accessions and ranged from 7.58 in VU 8 to 16.04 in VU 19.

Table 10. Mean performance of 22 bush cowpea accessions for yield and quality attributes

Accessions	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pods per plant	Yield per plant (g)	Seeds per pod	100 seed weight (g)	Pod protein (%)	Keeping quality (days)
VU 1	28.20	2.93	12.14	30.28	252.15	17.12	14.42	7.56	3.42
VU 2	17.87	2.37	6.60	42.38	282.26	17.65	10.29	6.55	3.43
VU 3	19.97	2.03	6.41	32.25	156.35	13.35	11.18	6.61	3.17
VU 4	17.30	2.33	5.72	36.62	181.04	17.62	10.52	6.82	3.47
VU 5	18.60	2.37	8.10	51.05	233.37	17.32	12.28	5.99	4.15
VU 6	21.83	2.83	9.44	38.56	310.41	14.28	12.85	7.23	4.35
VU 7	17.60	2.43	6.68	58.10	261.70	16.69	9.74	6.51	2.75
VU 8	17.00	1.87	5.13	70.30	230.63	14.05	7.58	6.49	3.12
VU 9	27.83	2.57	10.59	48.68	196.77	18.39	10.86	8.17	3.10
VU 10	16.53	2.33	5.32	42.32	214.87	13.62	11.45	7.26	3.13
VU 11	16.57	2.53	5.87	32.69	160.11	15.60	10.37	6.54	2.57
VU 13	16.73	2.13	4.78	35.42	210.19	15.65	10.11	6.50	2.58
VU 14	20.37	2.30	5.44	38.15	253.96	17.30	9.86	5.49	3.50
VU 15	16.60	2.20	5.28	33.00	150.86	17.09	10.31	5.88	2.62
VU 16	18.50	2.73	6.75	47.20	225.89	19.28	11.12	7.05	2.57
VU 17	19.27	2.07	5.33	55.45	241.14	16.29	10.32	3.69	3.00
VU 18	24.00	2.60	8.86	44.35	262.04	17.65	12.13	8.60	3.07
VU 19	26.47	2.87	10.90	26.12	237.70	15.70	16.04	8.46	4.15
VU 20	32.53	2.17	12.44	26.38	238.74	14.65	14.35	6.90	4.17
VU 21	16.87	2.13	7.28	46.54	154.30	16.10	12.56	5.59	3.10
VU 22	21.90	2.53	8.54	23.35	213.40	16.25	10.29	4.41	3.13
VU 24	12.40	1.83	4.74	39.00	197.89	11.35	10.64	5.77	4.83
CD (5%)	0.988	0.149	0.284	5.167	23.253	1.483	0.402	0.255	0.177
Mean	20.22	2.37	7.40	40.83	221.17	16.04	11.33	6.55	3.34

4.1.2.3 Quality characters

The quality characters like, pod protein and keeping quality were also studied and showed in table 9 for yard long bean and table 10 for bush cowpea.

Yard long bean

The protein content was highest in VS 29 (9.22%) and least in VS 32 (3.17). The accession VS 5 had highest keeping quality (5.17) and VS 12 had least (3.07).

Bush cowpea

'The protein content was highest in VU 18 (8.60%) and least in VS 17 (3.69%). The accession VU 24 had highest keeping quality (4.83 days) and VU 11and VU 16 had least (2.57 days).

4.1.2.4 Morphological characters

Yard long bean

Morphological characters like pigmentation on leaf and stem, flower colour, fruit colour of all accessions were given in the table 11.

Out of 44 yard long bean accessions, very slight variation of leaf colour was observed in 2 accessions viz., VS 33 having dark green colour and VS 42 having light green colour. (Plate 3).

Regarding stem pigmentation, 31 accessions had green colour and 13 had green colour with slight or moderate red.

In case of flower colour, 8 accessions *viz.*, VS 6, VS 7, VS 13, VS 22, VS 33, VS 35, VS 39 and VS 45 had mauve pink colour. VS 30, VS 31, VS 42 had cream colour and the rest had violet pigmentation on flower (Plate 4).

Fruit colour exhibited wide variation *viz.*, light green (19 accessions), dark green (7 accessions), light green with red tip (14 accessions) and red (4 accessions) were noted. (Plate 5)

Bush cowpea

Morphological characters like pigmentation on leaf and stem, flower colour, fruit colour of all accessions were given in the table 12.

Table 11. Morphological characters of 44 accessions of yard long bean

Accession	Leaf Pigmentation	Stem pigmentation	Flower colour	Fruit colour	Seed colour
VS 1	Green	Green	Violet	Light green	Brown with white tip
VS 2	Green	Green	Violet	Light green	Brown and white
VS 3	Green	Green	Violet	Light green	Brown
VS 4	Green	Green	Violet	Dark green	Light brown
VS 5	Green	Green	Violet	Light green with red tip	Black
VS 6	Green	Green with light red	Mauve pink	Red	Brown
VS 7	Green	Green with moderate red	Mauve pink	Red	Brown
VS 8	Green	Green	Violet	Light green with red tip	Black
VS 9	Green	Green	Violet	Dark green	Light brown
VS 10	Green	Green	Violet	Light green with red tip	Black
VS 11	Green	Green with light red	Violet	Light green with red tip	Black
VS 12	Green	Green	Violet	Light green	Brown
VS 13	Green	Green with moderate red	Mauve pink	Red	Brown
VS 14	Green	Green	Violet	Light green	Light brown
VS 15	Green	Green	Violet	Light green with red tip	Black
VS 16	Green	Green	Violet	Light green	Light brown
VS 18	Green	Green with light red	Violet	Light green with red tip	Black
VS 19	Green	Green with light red	Violet	Light green with red tip	Black
VS 20	Green	Green	Violet	Dark green	Brown
VS 21	Green	Green with light red	Violet	Light green	Brown
VS 22	Green	Green	Mauve pink	Light green	Brown
VS 23	Green	Green with moderate red	Violet	Light green	Brown

Table 11. Continued...

Accession	Leaf pigmentation	Stem pigmentation	Flower colour	Fruit colour	Seed colour
VS 24	Green	Green	Violet	Light green with red tip	Black
VS 27	Green	Green	Violet	Light green with red tip	Black
VS 28	Green	Green	Violet	Light green	Brown
VS 29	Green	Green	Violet	Dark green	Brown
VS 30	Green	Green	Cream colour	Dark green	Creamy white
VS 31	Green	Green	Cream colour	Dark green	Brown and white
VS 32	Green	Green	Violet	Light green	Brown and white
VS 33	Dark green	Green with intermediate red	Mauve pink	Dark red	Brown
VS 34	Green	Green	Violet	Light green	Brown
VS 35	Green	Green with light red	Mauve pink	Light green with red tip	Black
VS 36	Green	Green	Violet	Light green with red tip	Black
VS 37	Green	Green	Violet	Light green	Brown
VS 38	Green	Green	Violet	Light green with red tip	Black
VS 39	Green	Green with light red	Mauve pink	Light green with red tip	Black
VS 40	Green	Green with light red	Violet	Light green	Brown
VS 41	Green	Green with light red	Violet	Light green	Brown
VS 42	Light green	Green	Cream colour	Light green	Brown and white
VS 43	Green	Green	Violet	Light green with red tip	Black
VS 44	Green	Green	Violet	Light green	Light brown
VS 45	Green	Green	Mauve pink	Light green	Brown
VS 46	Green	Green	Violet	Light green	Brown
VS 47	Green	Green with light red	Violet	Light green	Light brown

Plate 3. Variation in leaf shape and colour in different accession of yard long bean

Plate 4. Variation in flower colour different accession of yard long bean

Plate 5. Variability in pod characters of yard long bean- Accessions VS 1- VS 15

Plate 5. Variability in pod characters of yard long bean- Accessions VS 16- VS 35

Table 12. Morphological characters of 22 accessions of bush cowpea

Accession	Leaf pigmentation	Stem pigmentation	Flower colour	Fruit colour	Seed colour
VU 1	Green	Green	Violet	Light green	Creamy white
VU 2	Green	Green	Violet	Light green	Light brown
VU 3	Green	Green	White	Light green	Brown and white
VU 4	Green	Green	Violet	Dark greens	Creamy white
VU 5	Green	Green	Violet	Dark green	Brown and white
VU 6	Light green	Green	Violet	Light green	Brown with strips
VU 7	Green	Green	White	Dark green	Brown
VU 8	Green	Green	Violet	Dark green	Light brown and white
VU 9	Green	Green	Violet	Dark green	Black
VU 10	Green	Green	Violet	Dark green	Dark brown
VU 11	Green	Green	Violet	Dark green	Dark brown
VU 13	Green	Green	Violet	Dark green	Creamy white
VU 14	Green	Green	Violet	Light green	Brown
VU 15	Green	Green	Violet	Dark green	Brown
VU 16	Green	Green	Violet	Light green	Black
VU 17	Green	Green	Violet	Light green	Creamy white
VU 18	Green	Green with moderate red	Mauve pink	Red	Creamy white
VU 19	Green	Green	Violet	Dark green	Creamy white
VU 20	Green	Green	White	Light green	Light brown and white
VU 21	Green	Green	Violet	Dark green	Brown and white
VU 22	Green	Green with light red	Violet	Light green	Black
VU 24	Green	Green	Violet	Dark green	Creamy white

Among all accessions of bush cowpea, only VU 6 showed slight variation in leaf colour and remaining accessions had normal green colour (Plate 6). Regarding pigmentation on stem, only VU 18 and VU 22 had green with slight or moderate red, rest of the accessions were green. In the case of flower colour, only VU 3, VU 7 and VU 20 had creamy white flowers whereas the remaining were violet (Plate 7). There was wide variation for fruit colour such as light green (9 accessions), dark green (12 accessions) and red (1 accession) (Plate 8).

4.1.3 Genetic variability, heritability and genetic advance

The population means, range, genotypic coefficients of variation (GCV), phenotypic coefficients of variation (PCV), heritability and genetic advance for 20characters were studied and are presented in table 13 (Fig. 1 and 2) and table 14 (Fig. 3 and 4) for yard long bean and bush cowpea respectively.

4.1.3.1 Growth characters

Yard long bean

Plant height ranged from 125.89 cm to 569.22 cm with a mean of 456.28 cm The GCV was 17.83 and PCV was 18.35. Heritability was as high as 94.37 per cent while genetic advance as high as 35.23.

Primary branches showed a range of 3.20-6.22 and the mean was 4.81 GCV was found to be 14.22 and PCV was 18.67. Heritability was moderate as 58.09 per cent while genetic advance was 22.24.

Petiole length ranged from 5.71-11.05 cm and showed a mean value of 8.76 cm. The GCV and PCV were 15.12 and 17.69 respectively. Heritability was 73.02per cent and genetic advance was 26.60.

Length of terminal leaflets ranged from 10.31-14.53 cm and showed a mean value of 12.30 cm. The GCV and PCV were 7.56 and 9.81respectively. Heritability was moderate (59.37 per cent) and genetic advance was moderate (11.95).

Breadth of terminal leaflets ranged from 6.21-10.09 cm with an overall mean of 7.67 cm. GCV was 11.02 and PCV was 13.29. Heritability was found to be 68.65 per cent. Genetic advance was 18.77.

Plate 6. Variation in leaf shape and colour in bush cowpea

Plate 7. Variation in flower colour in bush cowpea

Plate 8. Variability in pod characters of bush cowpea- Accessions VU 1- VU 11

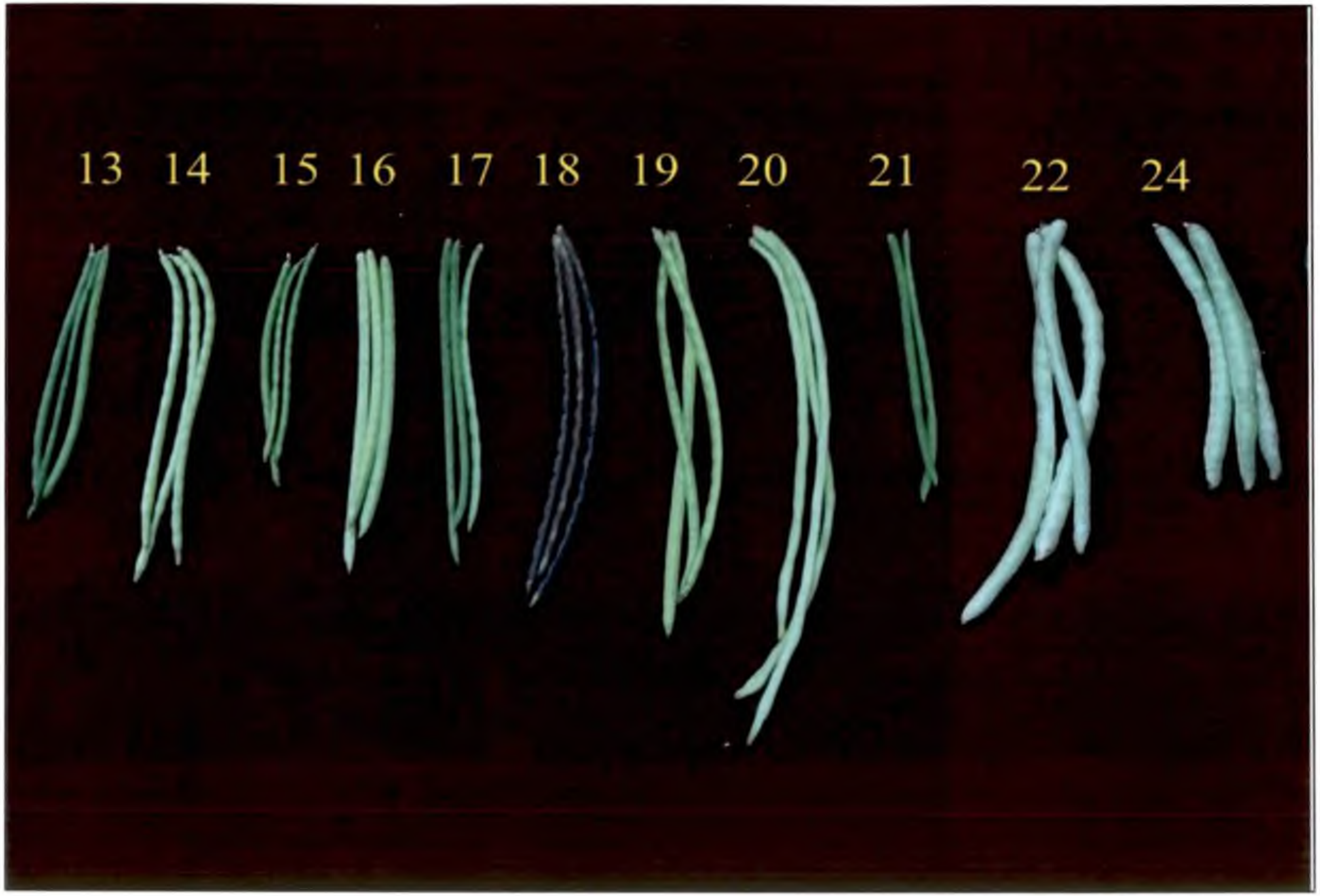
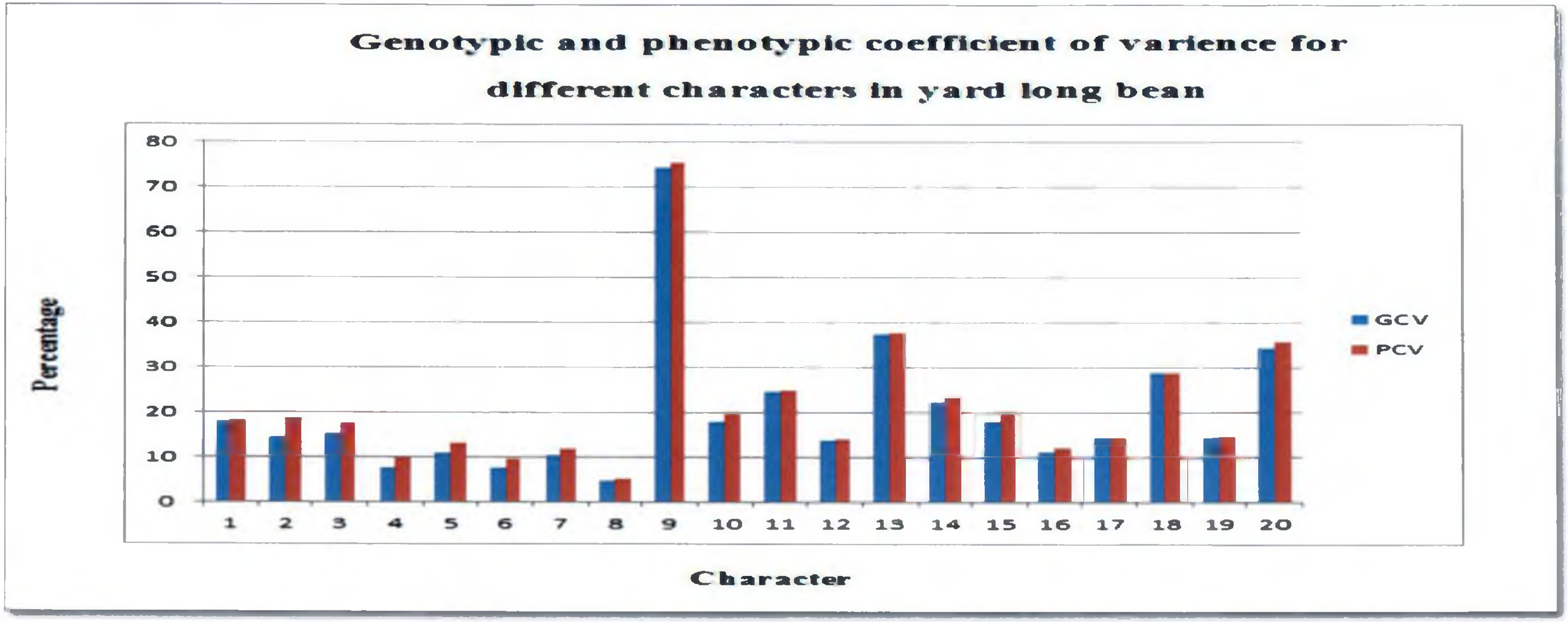


Plate 8. Variability in pod characters of bush cowpea- Accessions VU 13- VU 24

Table 13. Estimates of genetic parameters for various characters in yard long bean

Characters	Range	Mean	GCV	PCV	Heritability (%)	Genetic Advance (GA) at 5%	Genetic advance as percentage of mean
Vine length (cm)	125.89-569.22	456.28	17.83	18.35	94.37	160.74	35.23
Primary branches per plant	3.20-6.22	4.81	14.22	18.67	58.09	1.07	22.24
Petiole length (cm)	5.71-11.05	8.76	15.12	17.69	73.02	2.33	26.60
Length of terminal leaflets (cm)	10.31-14.53	12.30	7.56	9.81	59.37	1.47	11.95
Breadth of terminal leaflets (cm)	6.21-10.09	7.67	11.02	13.29	68.65	1.44	18.77
Length of lateral leaflets (cm)	7.01-9.78	8.45	7.81	9.48	67.91	1.12	13.25
Breadth of lateral leaflets (cm)	4.67-7.92	5.95	10.35	11.86	76.11	1.11	18.66
Days to first flowering	32.02-44.36	37.87	4.84	5.09	91.52	3.63	9.58
Days to first harvest	41.32-53.39	47.36	74.37	75.60	93.24	3.43	7.24
Peduncle length	10.48-21.74	14.71	18.09	19.55	85.62	5.07	34.46
Pod length (cm)	27.13-91.67	48.12	24.70	25.03	97.44	24.18	50.25
Pod girth (cm)	2.47-4.63	3.12	13.69	14.19	93.14	0.84	26.92
Pod weight (g)	14.5-67.07	22.60	37.52	37.83	98.34	17.32	76.64
Pods per plant	19.30-87.09	56.07	22.26	23.64	88.68	24.19	43.14
Yield per plant (g)	500.51-1127.52	774.06	18.03	19.68	83.92	263.20	34.00
Seeds per pod	14.30-23.32	18.93	11.24	12.13	85.91	4.06	21.45
100 seed weight (g)	10.28-20.98	15.71	14.26	14.26	99.89	4.61	29.34
Pod protein (%)	3.17-9.22	6.07	28.69	28.76	99.51	3.58	58.97
Keeping quality (days)	3.07-5.17	4.09	14.30	14.57	96.26	1.18	28.85
Pod borer infestation (%)	15.68-44.57	27.75	34.45	35.85	96.08	11.53	41.54

Fig 1



X1. Vine length (cm)

X2. Primary branches per plant

X3. Petiole length (cm)

X4. Length of terminal leaflet (cm)

X5. Breadth of terminal leaflet (cm)

X6. Length of lateral leaflet (cm)

X7. Breadth of terminal leaflet (cm)

X8. Days to first flowering

X9. Days to first harvest

X10. Peduncle length (cm)

X11. Pod length (cm)

X12. Pod girth (cm)

X13. Pod weight (g)

X14. Seeds per pod (g)

X15. 100 seed weight (g)

X16. Pods per plant

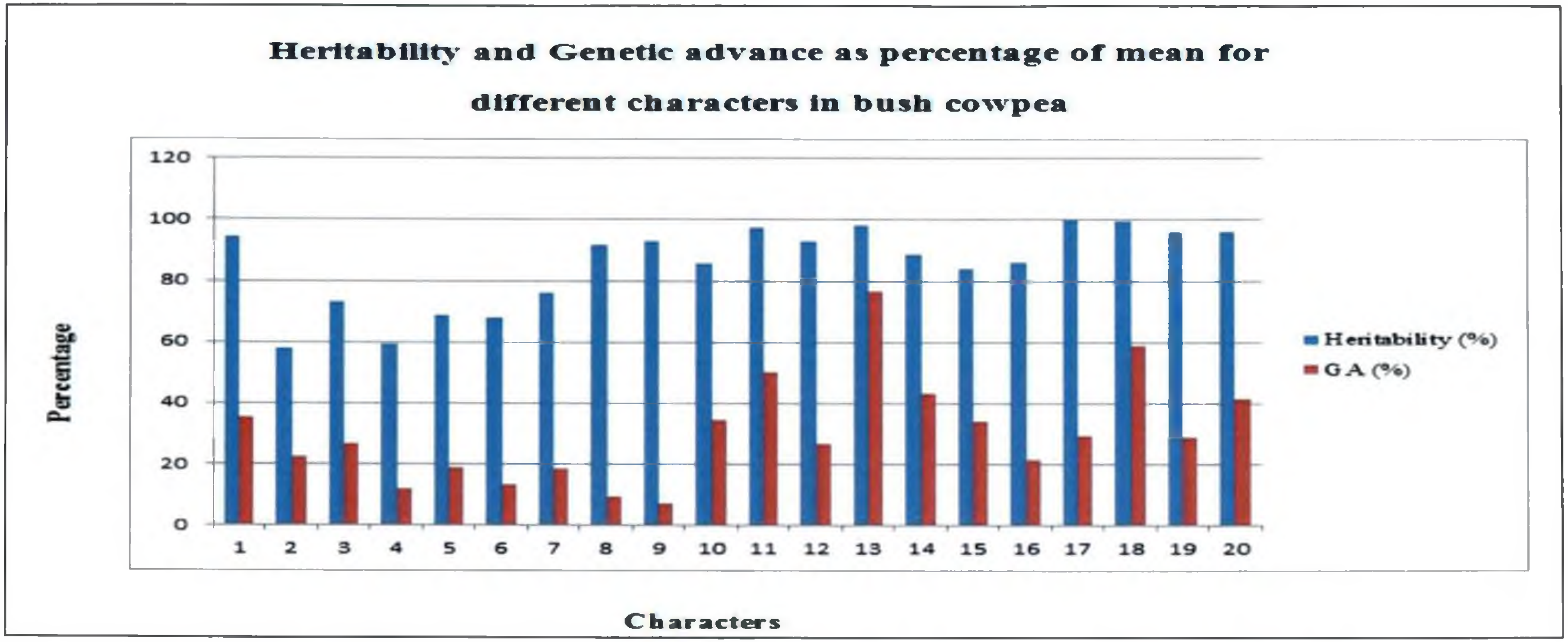
X17. Yield per plant (g)

X18. Pod protein (%)

X19. Keeping quality (days)

X 20. Pod borer incidence (%)

Fig 2

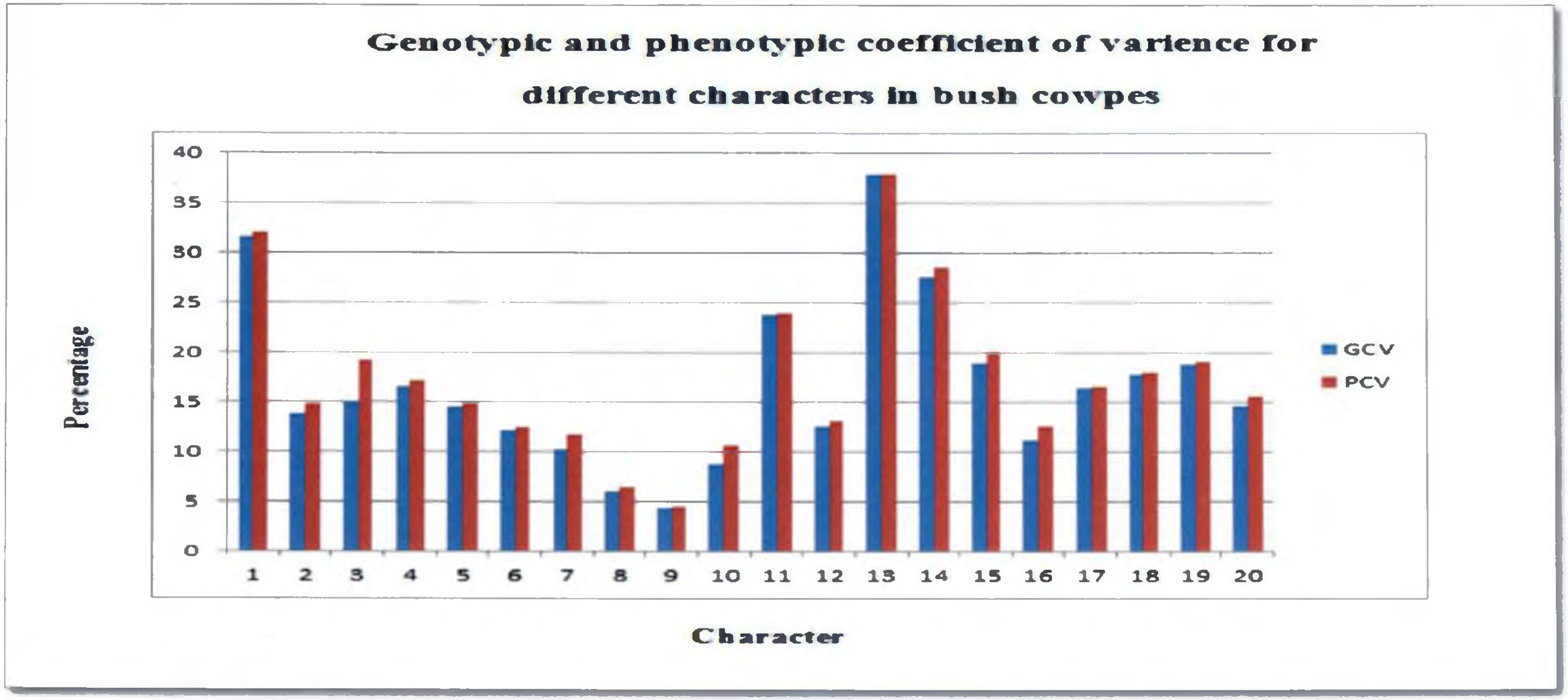


X1. Vine length (cm)
X2. Primary branches per plant
X3. Petiole length (cm)
X4. Length of terminal leaflet (cm)
X5. Breadth of terminal leaflet (cm)
X6. Length of lateral leaflet (cm)
X7. Breadth of terminal leaflet (cm)
X8. Days to first flowering
X9. Days to first harvest
X10. Peduncle length (cm)
X11. Pod length (cm)
X12. Pod girth (cm)
X13. Pod weight (g)
X14. Seeds per pod (g)
X15. 100 seed weight (g)
X16. Pods per plant
X17. Yield per plant (g)
X18. Pod protein (%)
X19. Keeping quality (days)
X 20. Pod borer incidence (%)

Table 14. Estimates of genetic parameters for various characters in bush cowpea

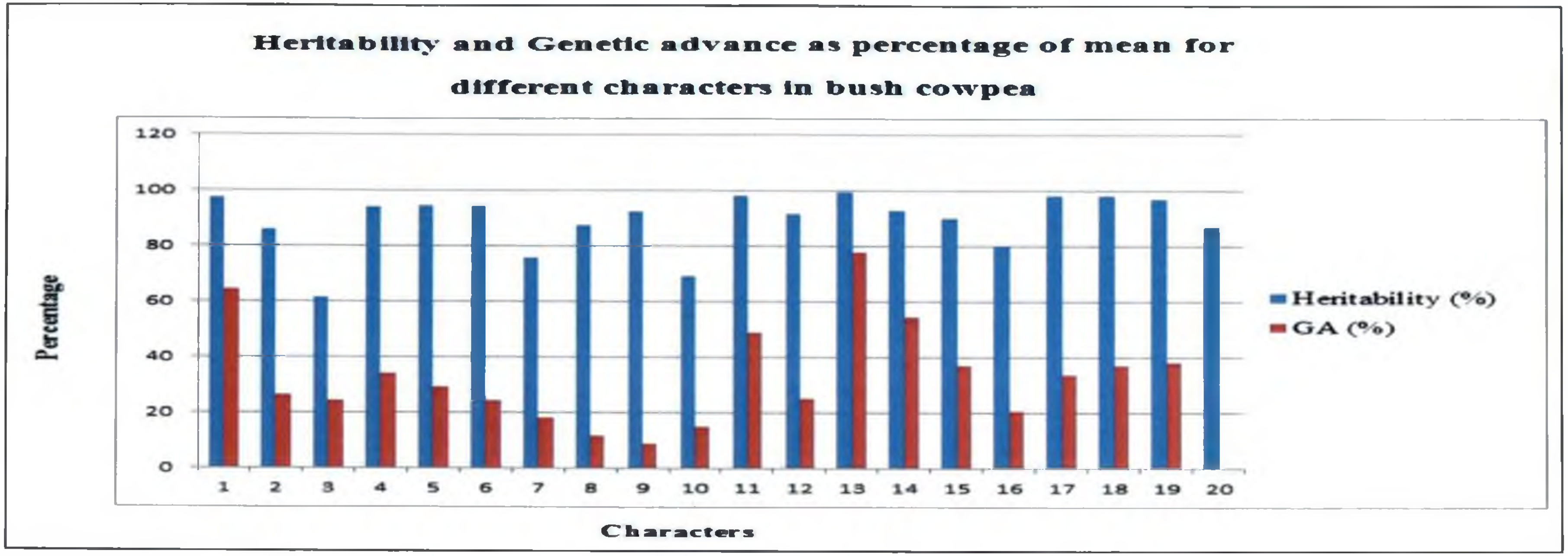
Characters	Range	Mean	GCV	PCV	Heritability (%)	Genetic Advance (GA) at 5%	Genetic advance as percentage of mean
Vine length (cm)	58.90-182.97	123.33	31.64	32.05	97.42	79.33	64.32
Primary branches per plant	5.33-7.33	5.81	13.79	14.88	85.83	1.53	26.34
Petiole length (cm)	7.35-13.87	11.04	15.13	19.29	61.53	2.70	24.46
Length of terminal leaflets (cm)	9.62-17.26	13.03	16.69	17.18	94.29	4.44	34.08
Breadth of terminal leaflets (cm)	6.78-10.87	8.95	14.52	14.93	94.50	2.60	29.05
Length of lateral leaflets (cm)	8.51-13.21	10.67	12.17	12.52	94.47	2.60	24.37
Breadth of lateral leaflets (cm)	5.76-8.84	7.54	10.25	11.79	75.66	1.38	18.30
Days to first flowering	31.29-38.40	33.97	6.02	6.42	87.72	3.94	11.60
Days to first harvest	40.69-47.71	43.09	4.38	4.55	92.58	3.74	8.68
Peduncle length	17.57-26.07	21.97	8.8	10.58	69.25	3.31	15.07
Pod length (cm)	12.40-32.53	20.22	23.85	24.04	98.38	9.54	48.70
Pod girth (cm)	1.83-2.93	2.37	12.62	13.18	91.76	0.60	25.00
Pod weight (g)	4.74-12.44	7.40	37.85	37.94	99.55	5.28	77.76
Pods per plant	23.35-70.30	40.83	27.59	28.64	92.80	22.32	54.67
Yield per plant (g)	150.86-301.41	221.17	19.03	20.07	89.92	82.22	37.18
Seeds per pod	11.35-19.28	16.04	11.27	12.58	80.19	3.33	20.76
100 seed weight (g)	7.58-16.04	11.33	16.42	16.56	98.31	3.80	33.54
Pod protein (%)	3.69-8.60	6.45	17.92	18.08	98.29	2.39	37.05
Keeping quality (days)	2.57-4.83	3.34	18.89	19.16	97.18	1.28	38.32
Pod borer (%)	17.44-36.99	27.75	14.63	15.67	87.24	7.81	28.16

Fig 3



X1. Vine length (cm)
X2. Primary branches per plant
X3. Petiole length (cm)
X4. Length of terminal leaflet (cm)
X5. Breadth of terminal leaflet (cm)
X6. Length of lateral leaflet (cm)
X7. Breadth of terminal leaflet (cm)
X8. Days to first flowering
X9. Days to first harvest
X10. Peduncle length (cm)
X11. Pod length (cm)
X12. Pod girth (cm)
X13. Pod weight (g)
X14. Seeds per pod (g)
X15. 100 seed weight (g)
X16. Pods per plant
X17. Yield per plant (g)
X18. Pod protein (%)
X19. Keeping quality (days)
X 20. Pod borer incidence (%)

Fig 4



X1. Vine length (cm)
X2. Primary branches per plant
X3. Petiole length (cm)
X4. Length of terminal leaflet (cm)
X5. Breadth of terminal leaflet (cm)
X6. Length of lateral leaflet (cm)
X7. Breadth of terminal leaflet (cm)
X8. Days to first flowering
X9. Days to first harvest
X10. Peduncle length (cm)
X11. Pod length (cm)
X12. Pod girth (cm)
X13. Pod weight (g)
X14. Seeds per pod (g)
X15. 100 seed weight (g)
X16. Pods per plant
X17. Yield per plant (g)
X18. Pod protein (%)
X19. Keeping quality (days)
X 20. Pod borer incidence (%)

Mean of days to first flowering was 37.87 days and the range was 32.02-44.36 days. GCV and PCV values were 4.84 and 5.09 respectively. Heritability was 91.52 per cent but genetic advance was low i.e. 9.58.

Peduncle length ranged from 10.48 to 21.74 cm with a mean of 14.71 cm. The GCV was 18.09 and PCV was 19.55, heritability was 85.62 and genetic advance was 34.46.

Bush cowpea

The range of vine length was 58.90 cm to 182.97 cm with a mean of 123.33 cm. The GCV was 31.64 and PCV was 32.05. Heritability was as high as 97.42 while genetic advance was very high i.e. 64.32.

Primary branches ranged from 5.33-7.33 and the mean was 5.81. GCV was found to be 13.79 and PCV was 14.88. Heritability was 85.83 per cent and genetic advance was 26.32.

Petiole length showed a range of 7.35-13.87 cm and showed a mean value of 11.04 cm. The GCV and PCV were 15.13 and 19.29 respectively. Heritability was 61.53 per cent and genetic advance was 24.46.

Length of terminal leaflets ranged 9.62-17.26 cm and showed a mean value of 13.03 cm. The GCV and PCV were 16.69 and 17.81 respectively. Heritability was high as 94.29 per cent and genetic advance was 34.08

The range of breadth of terminal leaflets varied from 6.78-10.87 cm with an overall mean of 8.95 cm. GCV was 14.52 and PCV was 14.93. Heritability was found to be 94.50 per cent. Genetic advance was 29.05.

Days to first flowering showed the range of 31.29-38.40 and mean was 33.97. GCV and PCV values were 6.02 and 6.42 respectively. Heritability was 87.72 per cent and genetic advance was 11.60.

Peduncle length ranged from 17.57-26.07 cm with a mean of 21.97 cm. The GCV was 8.80 and PCV was 10.58, heritability was 69.25 and genetic advance was 15.07.

4.1.3.2 Yield characters

Yard long bean

Pod length ranged from 27.13-91.67 cm with an overall mean of 48.12 cm. GCV was 24.70 and PCV was 25.03. Heritability was 97.44 per cent. Genetic advance was high as 50.25.

Pod girth ranged from 2.47-4.63 cm with an overall mean of 3.12 cm. GCV and PCV was 13.69 and 14.19 respectively. Heritability was 93.14 per cent. Genetic advance was 26.92

Pod weight ranged from 14.5-67.07 g with a mean of 22.60 g. The GCV was 37.52 and PCV was 37.83. Heritability was 98.34 and genetic advance was very high (76.64).

Range of pods per plant was 19.30-87.09 with a mean of 56.07. The GCV was 22.26 and PCV was 23.64. Heritability was 88.68 and genetic advance was high 43.14.

Yield per plant showed a range of 500.51-1127.52 g and the mean was 774.06 g. GCV was found to be 18.03 and PCV was 19.68. Heritability was 83.92 and genetic advance was high (34.00).

Seeds per pod ranged from 14.33 to with a mean of 14.30-23.32. The GCV was 11.24 and PCV was 12.13. Heritability was 85.91and genetic advance was 21.45.

100 seed weight showed a range of 10.28-20.98g and the mean was 15.71 g. GCV was found to be 14.26 and PCV was 14.26. Heritability was 99.89 and genetic advance was 29.34.

Bush cowpea

Pod length ranged from 12.40-32.53 cm with an overall mean of 20.22 cm. GCV was 23.85 and PCV was 24.04. Heritability was noticed very high as 98.38 per cent. Genetic advance was very high 48.70.

Pod girth showed a range of 1.83-2.93 cm with an overall mean of 2.37 cm. GCV was 12.62 and PCV was 13.18. Heritability was 91.76 per cent. Genetic advance was high25.00.

Pod weight ranged from 4.74-12.44 g with a mean of 7.40 g. The GCV was 37.85 and PCV was 37.94. Heritability was 99.55 and genetic advance was very high77.76.

Pods per plant ranged from 23.35-70.30 with a mean of 40.83. The GCV was 27.59 and PCV was 28.64. Heritability was 92.8 and high genetic advance was noticed i.e.54.67.

Yield per plant showed a range of 150.86-301.41 g and the mean was 221.17 g. GCV was found to be 19.03 and PCV was 20.07. Heritability was 89.928 and genetic advance was 37.18.

Pods per plant ranged from 11.35-19.28 with a mean of 16.04. The GCV was 11.27 and PCV was 12.58. Heritability was 80.19 and genetic advance was 20.76.

100 seed weight showed a range of 7.58-16.04 g and the mean was 11.33 g. GCV was found to be 16.42 and PCV was 16.56. Heritability was 98.31 and genetic advance was 33.54.

4.1.3.3 Quality characters

Yard long bean

Protein content varied from 3.17-9.22 % and the mean was 6.07. GCV was 28.69 and PCV was 28.76. Heritability was 99.51 and genetic advance was very high i.e.58.97. Keeping quality showed a range of 3.07-5.17 days and the mean was 4.09. GCV was found to be 14.30 and PCV was 14.57. Heritability was 96.26 and genetic advance was 28.85.

Bush cowpea

Protein content varied from 3.69-8.60 % and the mean was 6.45. GCV was 17.92 and PCV was 18.08. Heritability was 98.29 and genetic advance was 37.05. Keeping quality showed a range of 2.57-4.83 days and the mean was 3.34. GCV was found to be 18.89 and PCV was 19.16. Heritability was 97.18 and genetic advance was high (38.32).

4.1.3.4 Other pest and diseases

4.1.3.4. 1 Cowpea pod borer

Yard long bean

Pod borer incidence ranged from 15.68-44.57 with a mean of 27.72. The GCV was 34.45 and PCV was 35.85. Heritability was 96.08 and genetic advance was high 41.54.

Bush cowpea

Percentage of pod borer incidence ranged from 17.44-36.99 % and the mean was 27.75%. GCV was found to be 14.63 and PCV was 15.67. Heritability was 87.24 and genetic advance was high (28.16).

4.1.4 Correlation studies

The phenotypic, genotypic and environmental correlation among 19 characters both in yard long bean and bush cowpea were worked out and are presented in tables 15, 16 and 17 in yard long bean and tables 18, 19 and 20 in bush cowpea respectively.

4.1.4.1 Phenotypic Correlation Coefficients

Yard long bean

Yield per plant showed significant positive correlation with number of primary branches (0.249), and number of pods per plant (0.545). Peduncle length was found to be negatively correlated with yield per plant (-0.228). Pod length was highly correlated with vine length (0.470), days to first flowering (0.252) and peduncle length (0.178). Pod length was negatively correlated with number of primary branches per plant (-0.383). Pod weight had strong correlation with pod length (0.772) and pod girth (0.644). Pods per plant exhibited high negative correlation with peduncle length (-0.242), pod length (-0.598), pod girth (-0.336) and pod weight (-0.499).

Bush cowpea

Yield per plant showed significant positive correlation with pod length (0.371), pod weight (0.368) and breadth of terminal leaflets (0.329). Days to first harvest was strongly associated with days to first flowering (0.931). Pod weight had strong correlation with pod length (.0748) and pod girth (0.412). Pods per plant is negative correlated with pod length (-0.497), pod girth (-0.383) and pod weight (-0.517).

Table 15. Phenotypic correlation coefficients for biometric and quality characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1.000																		
X2	-0.199	1.000																	
X3	-0.273	0.045	1.000																
X4	0.137	-0.137	0.192	1.000															
X5	0.269	-0.038	0.165	0.547	1.000														
X6	0.188	-0.079	-0.100	0.045	0.019	1.000													
X7	0.025	-0.019	-0.057	0.181	0.194	0.505	1.000												
X8	0.436	-0.003	0.182	-0.042	0.098	0.307	0.063	1.000											
X9	0.079	-0.003	0.150	0.029	-0.057	0.063	0.051	0.052	1.000										
X10	0.020	-0.064	0.088	0.157	0.194	0.166	0.093	0.222	0.056	1.000									
X11	0.470	-0.383	0.074	0.127	0.263	0.090	-0.083	0.252	-0.011	0.178	1.000								
X12	-0.054	-0.214	0.107	0.187	0.155	-0.129	0.103	-0.245	-0.036	0.031	0.410	1.000							
X13	0.340	-0.300	0.144	0.228	0.299	0.008	0.041	-0.003	-0.004	0.160	0.771	0.644	1.000						
X14	0.224	-0.148	-0.007	0.091	0.112	0.007	-0.041	0.183	0.089	-0.043	0.483	-0.072	0.211	1.000					
X15	0.309	-0.159	-0.012	0.026	-0.014	0.432	0.159	0.148	0.100	-0.080	0.255	0.011	0.163	0.074	1.000				
X16	-0.375	0.446	-0.026	-0.249	-0.293	-0.149	-0.171	-0.059	-0.014	-0.242	-0.598	-0.336	-0.583	-0.163	-0.498	1.000			
X17	-0.049	0.249	0.108	-0.023	-0.010	-0.117	-0.149	-0.145	-0.031	-0.228	0.019	0.119	0.158	0.076	-0.379	0.545	1.000		
X18	0.049	0.049	0.026	-0.210	-0.082	0.021	-0.146	0.150	-0.089	-0.021	0.269	0.053	0.164	0.119	-0.139	0.142	0.169	1.000	
X19	-0.223	0.007	-0.019	-0.039	-0.234	0.133	0.192	-0.205	0.128	-0.079	0.179	0.022	-0.059	0.190	0.108	0.029	-0.088	-0.080	1.000

X1. Vine length (cm)

X2. Primary branches per plant

X3. Petiole length (cm)

X4. Length of terminal leaflet (cm)

X5. Breadth of terminal leaflet (cm)

X6. Length of lateral leaflet (cm)

X7. Breadth of terminal leaflet (cm)

X8. Days to first flowering

X9. Days to first harvest

X10. Peduncle length (cm)

X11. Pod length (cm)

X12. Pod girth (cm)

X13. Pod weight (g)

X14. Seeds per pod (g)

X15. 100 seed weight (g)

X16. Pods per plant

X17. Yield per plant (g)

X18. Pod protein (%)

X19. Keeping quality (days)

Table 16. Genotypic correlation coefficients for biometric and quality characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1.000																		
X2	-0.290	1.000																	
X3	-0.344	0.104	1.000																
X4	0.221	-0.221	0.323	1.000															
X5	0.345	-0.089	0.233	0.727	1.000														
X6	0.247	-0.132	-0.144	-0.001	0.058	1.000													
X7	0.043	-0.111	-0.072	0.244	0.307	0.422	1.000												
X8	0.471	0.023	-0.221	-0.069	0.096	0.363	0.064	1.000											
X9	0.941	-0.035	-0.279	0.522	0.070	0.322	0.424	0.637	1.000										
X10	0.027	-0.093	0.119	0.217	0.222	0.231	0.136	0.256	0.122	1.000									
X11	0.491	-0.506	0.080	0.195	0.321	0.122	-0.097	0.270	-0.305	0.192	1.000								
X12	-0.060	-0.270	0.134	0.289	0.189	-0.152	0.134	-0.265	-0.701	0.013	0.418	1.000							
X13	0.360	-0.400	0.163	0.299	0.359	0.003	0.042	-0.001	-0.126	0.164	0.779	0.662	1.000						
X14	0.248	-0.230	-0.042	0.191	0.181	0.019	-0.065	0.237	0.867	-0.038	0.495	-0.088	0.216	1.000					
X15	0.317	-0.207	-0.015	-0.031	-0.012	0.529	0.186	0.156	1.034	-0.086	0.258	0.012	0.165	0.078	1.000				
X16	-0.406	0.588	-0.034	-0.314	-0.340	-0.209	-0.200	-0.052	-0.091	-0.295	-0.636	-0.359	-0.624	-0.174	-0.529	1.000			
X17	-0.046	0.325	0.122	0.005	0.010	-0.170	-0.173	-0.146	-0.296	-0.286	0.030	0.141	0.173	0.102	-0.414	0.482	1.000		
X18	0.049	0.061	0.035	-0.286	-0.097	0.019	-0.171	0.161	-0.921	-0.025	0.274	0.056	0.166	0.130	-0.140	0.150	0.184	1.000	
X19	-0.218	0.007	-0.023	-0.079	-0.281	0.165	0.220	-0.210	1.332	-0.082	-0.182	0.036	-0.058	0.211	0.110	0.023	-0.108	0.082	1.000

X1. Vine length (cm)

X2. Primary branches per plant

X3. Petiole length (cm)

X4. Length of terminal leaflet (cm)

X5. Breadth of terminal leaflet (cm)

X6. Length of lateral leaflet (cm)

X7. Breadth of terminal leaflet (cm)

X8. Days to first flowering

X9. Days to first harvest

X10. Peduncle length (cm)

X11. Pod length (cm)

X12. Pod girth (cm)

X13. Pod weight (g)

X14. Seeds per pod (g)

X15. 100 seed weight (g)

X16. Pods per plant

X17. Yield per plant (g)

X18. Pod protein (%)

X19. Keeping quality (days)

Table 17. Environmental correlation coefficients for biometric and quality characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1.000																		
X2	0.102	1.000																	
X3	0.102	-0.069	1.000																
X4	-0.187	-0.017	-0.063	1.000															
X5	-0.060	0.053	0.000	0.231	1.000														
X6	-0.077	0.009	0.005	0.126	-0.062	1.000													
X7	-0.985	0.171	-0.011	0.055	-0.102	0.727	1.000												
X8	-0.024	-0.105	-0.005	0.046	0.131	0.121	0.061	1.000											
X9	-0.045	0.000	0.337	-0.017	-0.113	0.065	0.030	-0.028	1.000										
X10	-0.040	0.008	-0.030	0.010	0.113	-0.046	-0.088	-0.044	0.119	1.000									
X11	-0.004	-0.020	0.071	-0.215	0.001	-0.102	0.007	-0.078	0.117	0.044	1.000								
X12	0.042	-0.092	-0.028	-0.172	0.024	-0.057	-0.075	-0.001	0.118	0.192	0.274	1.000							
X13	-0.214	0.026	0.085	-0.005	0.044	0.065	0.061	-0.099	0.068	0.198	0.386	0.300	1.000						
X14	0.006	0.061	0.133	-0.189	-0.130	-0.038	0.068	-0.261	0.026	-0.066	0.489	0.068	0.243	1.000					
X15	0.197	-0.056	0.045	-0.142	-0.218	-0.212	-0.222	-0.125	-0.050	-0.004	0.014	-0.125	-0.121	0.116	1.000				
X16	-0.043	0.107	0.007	-0.098	-0.144	0.070	-0.040	-0.130	-0.017	0.125	-0.118	-0.104	0.011	-0.083	-0.010	1.000			
X17	-0.095	0.084	0.061	-0.104	-0.083	0.051	-0.055	-0.146	-0.012	0.100	-0.129	-0.047	0.013	-0.069	0.004	0.957	1.000		
X18	0.057	0.071	-0.113	0.210	-0.040	0.140	0.102	-0.192	0.010	0.082	-0.115	-0.074	-0.082	-0.052	0.092	0.036	0.036	1.000	
X19	-0.333	0.016	0.004	0.162	-0.049	-0.010	0.036	-0.132	-0.005	-0.057	-0.078	-0.238	-0.074	-0.024	0.039	0.109	0.123	0.059	1.000

X1. Vine length (cm)

X2. Primary branches per plant

X3. Petiole length (cm)

X4. Length of terminal leaflet (cm)

X5. Breadth of terminal leaflet (cm)

X6. Length of lateral leaflet (cm)

X7. Breadth of terminal leaflet (cm)

X8. Days to first flowering

X9. Days to first harvest

X10. Peduncle length (cm)

X11. Pod length (cm)

X12. Pod girth (cm)

X13. Pod weight (g)

X14. Seeds per pod (g)

X15. 100 seed weight (g)

X16. Pods per plant

X17. Yield per plant (g)

X18. Pod protein (%)

X19. Keeping quality (days)

Table 18. Phenotypic correlation coefficients for biometric and quality characters in bush cowpea

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1.000																		
X2	0.057	1.000																	
X3	0.014	-0.144	1.000																
X4	-0.159	0.041	0.131	1.000															
X5	-0.052	0.114	0.102	0.861	1.000														
X6	0.213	0.213	-0.036	0.540	0.463	1.000													
X7	0.249	0.128	-0.243	0.439	0.399	0.814	1.000												
X8	0.315	0.213	0.008	0.290	0.286	0.236	0.220	1.000											
X9	0.393	0.245	0.056	0.158	0.179	0.149	0.128	0.931	1.000										
X10	0.203	0.059	0.218	0.110	0.157	0.097	0.059	0.281	0.275	1.000									
X11	-0.063	0.249	0.104	0.571	0.413	0.518	0.446	0.386	0.334	0.192	1.000								
X12	0.096	0.249	0.062	0.363	0.403	0.276	0.396	0.243	0.247	-0.074	0.488	1.000							
X13	-0.223	0.181	-0.023	0.588	0.450	0.260	0.238	0.018	-0.033	-0.031	0.748	0.412	1.000						
X14	0.550	0.119	-0.007	-0.118	0.051	0.095	0.156	0.379	0.326	0.206	0.116	0.313	-0.187	1.000					
X15	-0.288	0.058	0.035	0.523	0.411	0.236	0.264	0.149	0.089	-0.095	0.725	0.531	0.759	-0.006	1.000				
X16	0.011	-0.292	-0.024	0.479	-0.425	-0.295	-0.239	-0.394	-0.387	0.187	-0.497	-0.383	0.517	0.053	-0.518	1.000			
X17	-0.112	-0.066	-0.070	0.320	0.329	0.198	0.283	0.056	-0.015	0.195	0.371	0.226	0.368	0.084	0.178	0.237	1.000		
X18	-0.272	0.055	-0.032	0.009	0.069	-0.182	-0.019	0.180	0.172	0.109	0.329	0.520	0.235	0.109	0.461	0.102	0.187	1.000	
X19	-0.532	-0.123	0.177	0.429	0.390	-0.157	-0.171	-0.177	-0.209	0.107	0.244	-0.031	0.633	-0.414	0.473	-0.208	0.325	0.100	1.000

X1. Vine length (cm)
X2. Primary branches per plant
X3. Petiole length (cm)
X4. Length of terminal leaflet (cm)
X5. Breadth of terminal leaflet (cm)
X6. Length of lateral leaflet (cm)
X7. Breadth of terminal leaflet (cm)
X8. Days to first flowering
X9. Days to first harvest
X10. Peduncle length (cm)
X11. Pod length (cm)
X12. Pod girth (cm)
X13. Pod weight (g)
X14. Seeds per pod (g)
X15. 100 seed weight (g)
X16. Pods per plant
X17. Yield per plant (g)
X18. Pod protein (%)
X19. Keeping quality (days)

Table 19. Genotypic correlation coefficients for biometric and quality characters in bush cowpea

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1.000																		
X2	0.057	1.000																	
X3	-0.015	-0.142	1.000																
X4	-0.162	0.072	0.148	1.000															
X5	-0.052	0.133	0.121	0.880	1.000														
X6	0.219	0.253	-0.027	0.579	0.487	1.000													
X7	0.315	0.152	-0.047	0.527	0.465	0.899	1.000												
X8	0.337	0.257	0.014	0.305	0.305	0.240	0.266	1.000											
X9	0.407	0.300	0.090	0.157	0.186	0.141	0.145	0.960	1.000										
X10	0.252	0.070	0.333	0.114	0.210	0.121	0.056	0.354	0.352	1.000									
X11	-0.059	0.274	0.124	0.586	0.430	0.542	0.529	0.417	0.349	0.217	1.000								
X12	0.099	0.314	0.096	0.384	0.431	0.299	0.487	0.260	0.260	-0.052	0.504	1.000							
X13	-0.226	0.194	-0.028	0.608	0.465	0.267	0.274	0.020	-0.033	-0.047	0.755	0.430	1.000						
X14	0.612	0.120	-0.042	-0.126	0.081	0.148	0.253	0.408	0.375	0.282	0.125	0.369	-0.211	1.000					
X15	-0.295	0.062	0.031	0.540	0.424	0.244	0.304	0.151	0.098	-0.129	0.738	0.551	0.765	-0.007	1.000				
X16	0.010	-0.327	0.016	-0.517	-0.445	-0.326	-0.317	-0.414	-0.423	0.236	-0.523	-0.409	0.539	0.121	-0.541	1.000			
X17	-0.119	-0.079	-0.037	0.343	0.368	0.200	0.303	0.091	-0.019	0.256	0.393	0.260	0.387	0.173	0.190	0.168	1.000		
X18	-0.279	0.053	-0.043	0.013	0.077	-0.185	-0.016	0.184	0.177	0.122	0.332	0.551	0.237	0.124	0.496	0.215	0.194	1.000	
X19	-0.546	-0.143	0.213	0.458	0.410	-0.163	-0.194	-0.181	-0.210	0.141	0.251	-0.036	0.646	-0.473	0.484	-0.212	0.355	0.101	1.000

X1. Vine length (cm)

X2. Primary branches per plant

X3. Petiole length (cm)

X4. Length of terminal leaflet (cm)

X5. Breadth of terminal leaflet (cm)

X6. Length of lateral leaflet (cm)

X7. Breadth of terminal leaflet (cm)

X8. Days to first flowering

X9. Days to first harvest

X10. Peduncle length (cm)

X11. Pod length (cm)

X12. Pod girth (cm)

X13. Pod weight (g)

X14. Seeds per pod (g)

X15. 100 seed weight (g)

X16. Pods per plant

X17. Yield per plant (g)

X18. Pod protein (%)

X19. Keeping quality (days)

Table 20. Environmental correlation coefficients for biometric and quality characters in bush cowpea

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	1.000																		
X2	0.089	1.000																	
X3	0.254	-0.175	1.000																
X4	-0.115	-0.257	0.125	1.000															
X5	-0.051	-0.061	0.066	0.542	1.000														
X6	0.074	-0.167	-0.107	-0.113	0.042	1.000													
X7	-0.270	0.029	-0.690	-0.047	0.055	0.464	1.000												
X8	0.058	-0.075	-0.012	0.144	0.099	0.213	0.018	1.000											
X9	0.130	-0.219	-0.070	0.180	0.093	0.257	0.045	0.697	1.000										
X10	-0.044	0.024	0.001	0.136	-0.104	-0.006	0.069	0.028	-0.048	1.000									
X11	-0.261	-0.048	0.091	0.207	-0.053	-0.014	-0.162	-0.036	0.015	0.181	1.000								
X12	0.063	-0.272	-0.056	0.086	0.030	-0.036	-0.072	0.092	0.094	-0.208	0.238	1.000							
X13	-0.044	0.077	-0.026	-0.076	-0.072	0.068	0.030	-0.032	-0.123	0.216	0.023	0.033	1.000						
X14	0.137	0.117	0.083	-0.085	-0.190	-0.318	-0.189	0.233	0.025	-0.014	0.095	-0.029	0.052	1.000					
X15	0.013	0.019	0.140	0.120	0.058	0.038	0.031	0.188	-0.121	0.165	-0.045	0.193	0.256	0.001	1.000				
X16	0.036	-0.001	-0.215	0.072	-0.138	0.161	0.196	-0.211	0.072	-0.016	0.074	-0.077	0.059	-0.437	-0.044	1.000			
X17	-0.015	0.032	-0.214	0.045	-0.145	0.183	0.210	-0.222	0.030	-0.039	0.036	-0.106	0.077	-0.446	-0.035	0.983	1.000		
X18	0.039	0.143	0.023	-0.109	-0.152	-0.099	-0.070	0.200	0.091	0.117	0.151	-0.083	0.034	-0.018	0.180	0.098	0.110	1.000	
X19	-0.020	0.113	0.116	-0.238	-0.073	-0.028	-0.059	-0.157	-0.211	-0.091	-0.060	0.076	-0.229	0.054	-0.013	-0.161	-0.133	0.077	1.000

X1. Vine length (cm)

X2. Primary branches per plant

X3. Petiole length (cm)

X4. Length of terminal leaflet (cm)

X5. Breadth of terminal leaflet (cm)

X6. Length of lateral leaflet (cm)

X7. Breadth of terminal leaflet (cm)

X8. Days to first flowering

X9. Days to first harvest

X10. Peduncle length (cm)

X11. Pod length (cm)

X12. Pod girth (cm)

X13. Pod weight (g)

X14. Seeds per pod (g)

X15. 100 seed weight (g)

X16. Pods per plant

X17. Yield per plant (g)

X18. Pod protein (%)

X19. Keeping quality (days)

4.1.4.2 Genotypic Correlation Coefficients

Yard long bean

In general, genotypic correlation coefficients were higher than phenotypic correlation for all the characters under study.

High positive correlation was obtained between yield and number of primary branches (0.325) and pods per plant (0.482). It exhibited negative correlation with days to first harvest (-0.296) and peduncle length (-0.287). Days to first harvest was highly correlated with days to first flowering (0.637).

Bush cowpea

Yield per plant had high positive correlation with pod length (0.393), pod girth (0.260) and pod weight (0.387). Pods per plant is negative correlated with pod length (-0.523), pod girth (-0.409) and pod weight (-0.539).

4.1.4.3 Environmental correlation coefficients

Most of the environmental correlation coefficients were very low indicating that the effect of environment on expression of the association between the character was not so strong as to alter it markedly.

4.1.5 Path coefficient analysis

Genotypic correlation between yield and its component characters were portioned into different components to find out the direct and indirect contribution of each character on yield. Vine length, days to flowering, pod length, pod girth, pod weight and pods per plant were selected for path coefficient analysis both in yard long bean and bush cowpea.

Yard long bean

Direct effects and correlation of the yield components are presented in table 21 and Fig. 5

All characters except days to first flowering and pod girth recorded positive direct effect. Highest positive direct effect was observed for number of pods per plant (1.0462) followed by pod weight (0.6496).

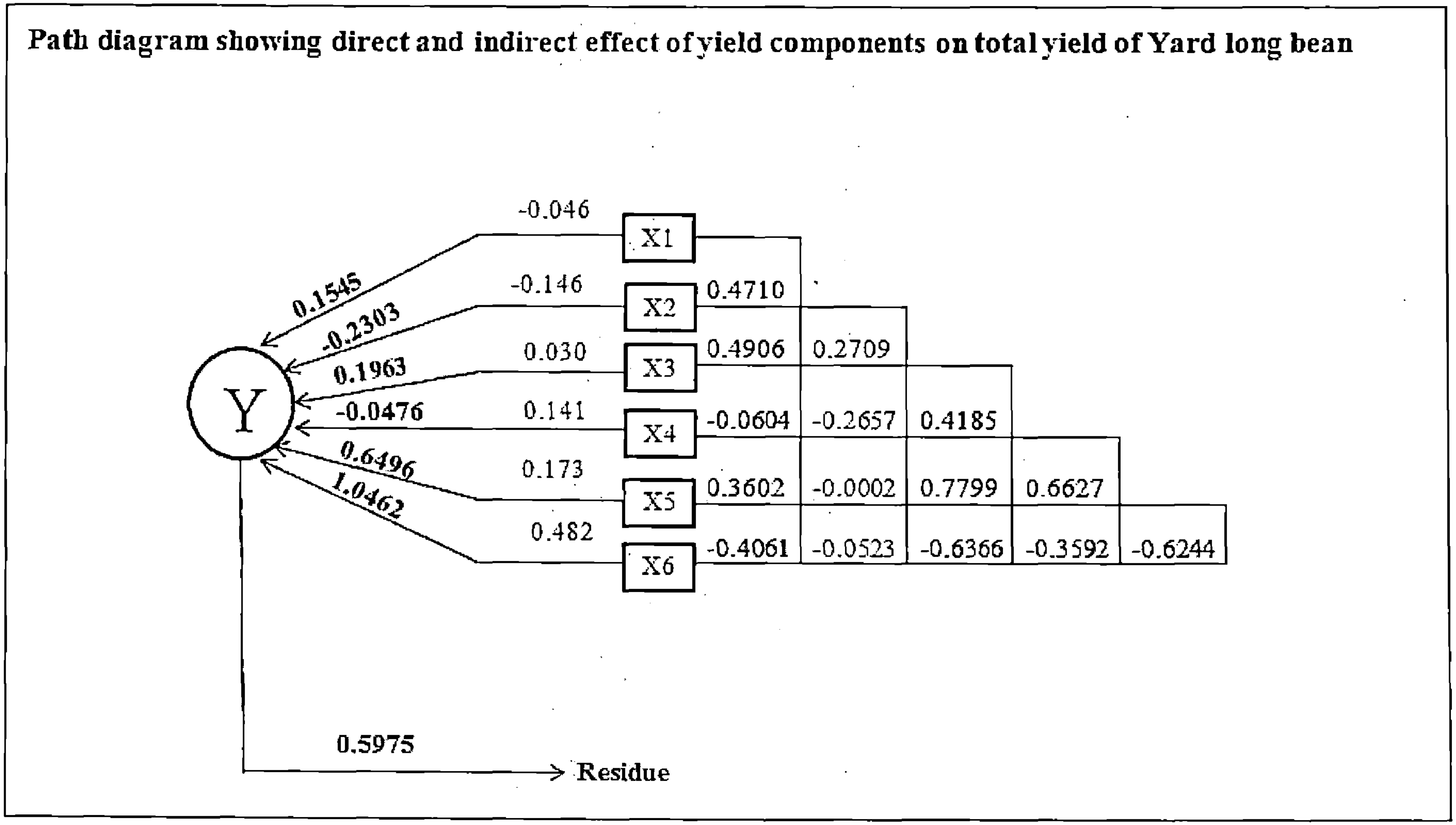
Table 21. Direct and indirect effect of yield components of yard long bean

Characters	Vine length	Days to first flowering	Pod length	Pod girth	Pod weight	Pods per plant	Genotypic correlation with yield
Vine length	**0.1545**	-0.1085	0.9630	0.0029	0.2340	-0.4248	-0.046
Days to first flowering	0.0727	**-0.2303**	0.0532	0.0127	-0.0001	-0.0547	-0.146
Pod length	0.0758	-0.0624	**0.1963**	-0.0199	0.5066	-0.6660	0.030
Pod girth	-0.0093	0.0612	0.0822	**-0.0476**	0.4305	-0.3758	0.141
Pod weight	0.0056	0.0000	0.1531	-0.0316	**0.6496**	-0.6532	0.173
Pods per plant	-0.0627	0.0120	-0.1250	0.0171	-0.4056	**1.0462**	0.482

Residue (R) = 0.5975

(Underlined figures are Direct effect)

Fig 5


Path diagram showing direct and indirect effect of yield components on total yield of Yard long bean
Y
X1
X2
X3
X4
X5
X6
-0.046
-0.146
0.030
0.141
0.173
0.482
0.1545
-0.2303
0.1963
-0.0476
0.6496
1.0462
0.4710
0.4906
0.2709
-0.0604
-0.2657
0.4185
0.3602
-0.0002
0.7799
0.6627
-0.4061
-0.0523
-0.6366
-0.3592
-0.6244
0.5975
Residue

Vine length had direct effect of 0.1545. Major portion of indirect effects was through pod weight (0.2340). Indirect effect of vine length on yield through days to first flowering (-0.1085), pod length (0.0963), pod girth (0.0029), and pods per plant (-0.4248).

Days to first flowering had a genotypic correlation of -0.1466 with yield. In this, the direct effect was -0.2303. Indirect effect on yield through pod length (0.0532), vine length (0.0727), pod girth (0.0127), pod weight (-0.0001), and number of pods per plant (-0.0547).

Genotypic correlation of pod length with yield was only0.0304. Its direct effect is 0.1963. But its indirect effect on yield through vine length, days to first flowering, pod girth, pod weight, and pods per plant were 0.0758, -0.0624, -0.0199, 0.5066 and -0.6660 respectively.

The direct effect of pod girth on yield was negative (-0.0476) but genotypic correlation with yield was 0.1411. The pod girth had indirect effect on yield mainly through vine length (-0.0093), days to first flowering (0.0612) pod length (0.0822), pod weight (0.4305), and number of pods per plant (-0.3758).

The total genetic correlation of pod weight on yield was 0.1736. The direct effect was very high (0.6496). The rest of its effect on yield was contributed by indirect effect through vine length, pod length, pod girth, and pods per plant were 0.0556, 0.1531, -0.0316, -0.6532.

The direct effect of pods per plant on yield was very high (1.0462) and genotypic correlation with yield was also high (0.4820).The major contribution of its total correlation was through vine length (-0.0627), days to first flowering (0.0120), pod length (-0.1250), pod girth (0.0171) and pod weight (-0.4056).

The residue obtained (R=0.5975) indicated that 41% of the variation was explained by the path coefficient analysis.

Bush cowpea

Direct effects and correlation of these yield components are presented in table 22 and Fig. 6

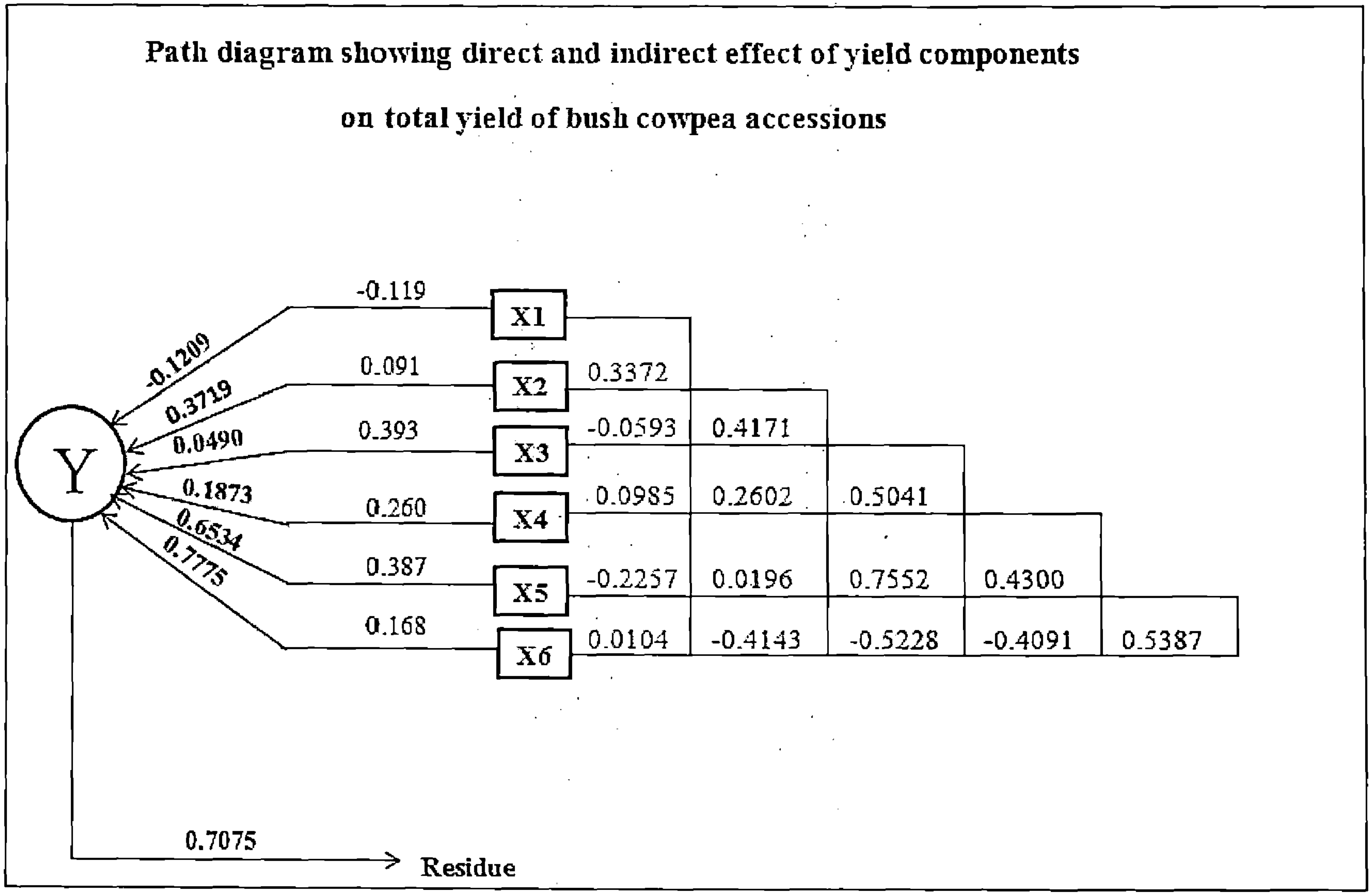
Table 22. Direct and indirect effect of yield components of bush cowpea

Characters	Vine length	Days to first flowering	Pod length	Pod girth	Pod weight	Pods per plant	Genotypic correlation with yield
Vine length	**-0.1209**	0.1254	-0.0029	0.0185	-0.1475	0.0081	-0.119
Days to first flowering	-0.0408	**0.3719**	0.0204	0.0487	0.0128	-0.3221	0.091
Pod length	0.0072	0.1551	**0.0490**	0.0944	0.4934	-0.4065	0.393
Pod girth	-0.0119	0.0968	0.0247	**0.1873**	0.2810	-0.3181	0.260
Pod weight	0.0273	0.0073	0.0370	0.0806	**0.6534**	-0.4188	0.387
Pods per plant	-0.0013	-0.1541	-0.0256	-0.0766	-0.3520	**0.7775**	0.168

Residue (R) = 0.7075

(Underlined figures are Direct effect)

Fig 6



Path diagram showing direct and indirect effect of yield components
on total yield of bush cowpea accessions
Y
X1
X2
X3
X4
X5
X6
-0.119
0.091
0.393
0.260
0.387
0.168
-0.1209
0.3719
0.0490
0.1873
0.6534
0.7775
0.3372
-0.0593
0.4171
0.0985
0.2602
0.5041
-0.2257
0.0196
0.7552
0.4300
0.0104
-0.4143
-0.5228
-0.4091
0.5387
0.7075
Residue

Vine length had low direct effect (-0.1209) and the genotypic correlation with yield also low (-0.1193). The rest of its effect on yield was contributed by indirect effect through days to first flowering (0.1254), pod length (-0.0029), pod girth (0.0185), pod weight (-0.1475) and pods per plant (0.0081).

Though days to first flowering had a genotypic correlation of 0.0910 with yield, the direct effect was 0.3719. Indirect effect of days to first flowering through other characters was negligible except pods per plant (-0.3221).

The direct effect of pod length on yield though low (0.0490), it showed high positive genetic correlation (0.3927). It also showed high positive indirect effect *via.* pod weight (0.4934) and high negative indirect effect *via.* number of pod per plant (-0.4065).

The direct effect of pod girth on yield was high (0.1873) and genotypic correlation with yield was also high (0.2598). Indirect effect on yield through vine length (-0.0119), days to first flowering (0.0968) pod length (0.0247), pod weight (0.2810), and number of pods per plant (-0.3181).

The genotypic correlation of pod weight on yield was high (0.3867). It was having high direct effect (0.6594) on yield. The indirect effect of pod weight through other characters was negligible except pods per plant which exhibited negative effect (-0.4188).

In the present study, pods per pod had the highest direct effect on yield (0.7775) and moderate positive correlation (0.1679). Indirect effect on yield through vine length, days to first flowering, pod length, pod weight , and number of pods per plant were -0.0013, -0.1541, -0.0256, -0.0766 and -0.3520 respectively.

The residue obtained was 0.7075 indicating that the selected six characters contributed the reaming 30 percent.

4.2.6 Selection Index

Yard long bean

Discriminant function analysis was adopted for the construction of selection index.

Selection index (I) was computed based on the seven characters *viz.*, vine length (X_1), days to first flowering (X_2), pod length (X_3), pod girth (X_4), pod weight (X_5), f pods per plant (X_6) and yield per plant (X_7).

$$I = 0.8580 X_1 + 4.4593 X_2 + 0.2965 X_3 + -2.2778 X_4 + 0.8229 X_5 + -0.9256 X_6 + 0.9314 X_7$$

Accordingly selection index values were worked out and presented in the table 23. The accession VS 34 (4567.19) recorded the maximum selection index value followed by VS 4 (4553.17) and VS 29 (4551.43). The lowest value was recorded by VS 22 (2525.29) followed by VS 20 (2838.65).

Bush cowpea

Discriminant function analysis was adopted for the construction of selection index for yield using fruit yield per plant (X_7) and the component characters *viz.*, vine length (X_1), days to first flowering (X_2), pod length (X_3), pod girth (X_4), pod width (X_5) and number of pods per plant (X_6). These component characters showed relatively stronger association with yield and could form a valuable selection index for yield in this crop.

The selection index, worked out in the present study is given below.

$$I = 0.9566 X_1 + 0.9798 X_2 + 1.1151 X_3 + 1.9063 X_4 + 0.4786 X_5 + 0.6706 X_6 + 0.9003 X_7$$

The selection index value for each accession was determined and they were ranked accordingly (Table 24). Five accessions *viz.*, VU 7 (1475.31), VU 1 (1468.72), VU14 (1426.92), VU 16 (1371.64) and VU 6 (1351.56) recorded high selection index values. Five accessions *viz.*, VU 3 (908.28), VU 24 (939.50), VU 11 (952.97), VU 21 (1007.05), VU 10 (1148.04) recorded low selection index values.

4.1.2.2 Screening for pests and diseases under field conditions

The crop was monitored for the incidence of collar rot and web blight. The crop was also monitored for other major pests and diseases like fusarium wilt (*Fusarium oxysporum.*), legume pod borer (*Maruca vitrata)* and cowpea aphid (*Aphis craccivora*) were the prominent ones exhibiting characteristic damage. (Plate 9)

Table 23 Yard long bean accessions ranked according to selection index

(Based on discriminant function analysis)

Accession	Index	Ranks in ascending order
VS 34	4567.19	1
VS 4	4553.17	2
VS 29	4551.43	3
VS 9	4320.99	4
VS 1	4291.98	5
VS 31	4281.93	6
VS 47	4232.93	7
VS 16	4202.38	8
VS 30	4200.56	9
VS 35	4153.19	10
VS 45	4036.58	11
VS 19	4010.69	12
VS 14	3993.08	13
VS 6	3991.07	14
VS 2	3960.61	15
VS 46	3948.67	16
VS 32	3937.68	17
VS 28	3900.94	18
VS 42	3801.12	19
VS 36	3789.93	20
VS 39	3788.47	21
VS 11	3763.85	22

Accession	Index	Ranks in ascending order
VS 40	3749.14	23
VS 44	3742.42	24
VS 23	3638.15	25
VS 15	3612.75	26
VS 38	3611.02	27
VS 8	3595.34	28
VS 21	3590.65	29
VS 3	3572.06	30
VS 7	3509.51	31
VS 10	3489.54	32
VS 27	3465.23	33
VS 37	3448.14	34
VS 24	3419.06	35
VS 12	3392.8	36
VS 13	3381.21	37
VS 5	3299.61	38
VS 33	3284.72	39
VS 18	3270.26	40
VS 43	3169.72	41
VS 41	3022.67	42
VS 20	2838.65	43
VS 22	2525.29	44

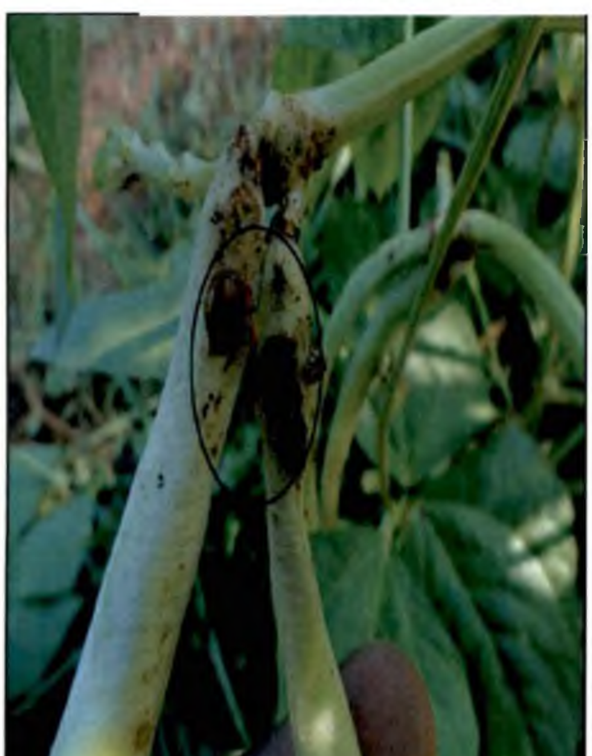
Table 24 Bush cowpea accessions ranked according to selection index

(Based on discriminant function analysis)

Accession	Index	Ranks in ascending order
VU 7	1475.31	1
VU 1	1468.72	2
VU 14	1426.92	3
VU 16	1371.64	4
VU 6	1351.56	5
VU 22	1350.27	6
VU 17	1333.83	7
VU 2	1290.76	8
VU 8	1265.53	9
VU 4	1257.67	10
VU 18	1241.98	11
VU 13	1207.84	12
VU 19	1198.24	13
VU 5	1196.97	14
VU 9	1184.4	15
VU 15	1158.91	16
VU 20	1152.57	17
VU 10	1148.04	18
VU 21	1007.05	19
VU 11	952.97	20
VU 24	939.5	21
VU 3	908.28	22

A) Collar rot

B) Fusarium wilt



C) Pod borer

D) Cowpea aphid

Plate 9. Incidence of other pests and diseases

4.1.2.2.1 Collar rot and web blight

Yard long bean

The crop was monitored throughout the growing period for the incidence of collar rot and web blight. Number of plants infected was counted and incidence of disease was calculated. Fourteen accessions had shown collar rot symptoms at seedling stage namely VS 1 (16.67 %), VS 2 (10%), VS 9 (8.33), VS 14 (10 %), VS 20 (9.09%), VS 21 (15.25%), VS 23 (16.67), VS 24 (10), VS 29 (26.65), VS 30 (25), VS 32 (10) and VS 40 (10%). Among these, VS 29 had shown highest incidence followed by VS 30. The rest of the accessions were free from collar rot incidence under field conditions.

There was no incidence of web blight throughout growing period.

Bush cowpea

Five accessions had shown collar rot incidence at seedling stage viz., VU 11 (5%), VU 17 (5.88), VU 19 (6.67) and VU 15 (11.11). There was no incidence of web blight growing period in bush cowpea also.

4.1.2.2.2 Fusarium wilt (Fusarium oxysporum)

There is very low incidence of *Fusarium* wilt both in yard long bean and bush cowpea. In yard long bean six accessions *viz*., VS 2 (9.35%), VS 20(12.5%), VS 29 (5%), VS 31 (18%), VS 34 (10%) and VS 46 (15%) had shown moderate symptoms. In bush cowpea, the four accessions *viz*., VU 1 (10%), VU 6 (18.5%), VU 15 (15.8%) and VU 24 (10%) had shown Fusarium wilt symptoms.

4.1.2.2.3 Legume pod borer pod borer (Maruca vitrata)

Among the pests the maximum damage was caused by pod borer. The incidence of pod borer yard long bean and bush cowpea was given in table 25 and 26 respectively

Yard long bean

The percentage of pod borer infestation on pods was maximum in VS 5 (44.57) followed by VS 22 (39.14) and minimum in VS 44 (15.68) followed by VS 15 (18.73). The general mean value for pod infestation was 28.54.

Bush cowpea

Table 25. Incidence of pod borer (%) in yard long bean

Accessions	Pod borer incidence (%)	Accessions	Pod borer incidence (%)
VS 1	33.61	VS 27	30.97
VS 2	34.55	VS 28	25.72
VS 3	26.42	VS 29	24.41
VS 4	24.94	VS 30	24.18
VS 5	44.51	VS 31	25.53
VS 6	33.67	VS 32	25.62
VS 7	27.54	VS 33	21.12
VS 8	28.24	VS 34	23.88
VS 9	32.85	VS 35	34.86
VS 10	36.32	VS 36	25.50
VS 11	26.40	VS 37	27.73
VS 12	20.81	VS 38	28.30
VS 13	33.63	VS 39	24.39
VS 14	23.76	VS 40	21.05
VS 15	18.73	VS 41	32.39
VS 16	26.50	VS 42	36.44
VS 18	23.65	VS 43	27.51
VS 19	28.47	VS 44	15.68
VS 20	32.78	VS 45	36.84
VS 21	25.20	VS 46	27.63
VS 22	39.14	VS 47	28.54
VS 23	29.57	CD	1.93
VS 24	38.26	Mean	28.59

Table 26. Incidence of pod borer (%) in bush cowpea

Accessions	Pod borer incidence (%)
VU 1	33.18
VU 2	27.01
VU 3	36.99
VU 4	23.15
VU 5	25.99
VU 6	28.52
VU 7	28.63
VU 8	30.90
VU 9	28.40
VU 10	30.30
VU 11	30.72
VU 13	28.88
VU 14	30.39
VU 15	26.88
VU 16	26.84
VU 17	25.77
VU 18	23.88
VU 19	29.89
VU 20	29.85
VU 21	20.70
VU 22	26.10
VU 24	17.44
CD	2.26
Mean	27.75

The percentage of *Maruca vitrata* infestation on pod ranged from 17.44 (VU 24) to 36.99 (VU 3) with general mean of 27.75.

4.1.2.2.4 Cowpea aphid (Aphis craccivora)

Yard long bean

More incidence of aphid was found during early fruiting stage. Ten accessions namely VS 16, VS 19, VS 20, VS 21, VS 24, VS 28, VS 33, VS 37, VS 41, VS 43 were resistant to cowpea aphid. However, high incidence was noticed in VS 10, VS 13, VS 18, VS 34, VS 36 and VS 46. (Table 27)

Bush cowpea

The accessions VU 7, VU 14 and VU 18 were resistant to cowpea aphid under field conditions, since these accessions were free from cowpea aphid. High incidence of cowpea aphid was noticed in the accessions VU 3, VU 11, VU 20 and VU 24. The rest of accessions had moderate attack (Table 28).

4.2.8 Cataloguing of germplasm

Yard long bean

All the 44 accessions were described morphologically using the modified descriptor developed from the standard descriptor for cowpea by IPGRI. The accessions were scored for 17 morphological characters on appropriate scales ranging from 0-9 (Table 29).

All the accessions had climbing habit with indeterminate growth pattern. The twining tendency in all accessions was pronounced except in VS 20, VS 22 and VS 23 which had intermediate twining tendency.

Plant pigmentation varied among the accessions. Accessions VS 6, VS 11, VS 18, VS 19, VS 21, VS 35, VS 39, VS 40, VS 41and VS 47 had very light red pigmentation on stem. Accessions VS 7, VS 13 and VS 23 had intermediate pigmentation and VS 33 had shown extensive pigmentation on stem. The rest of the accessions had plain green colour without any pigmentation.

Table 27. Scoring for cowpea aphid in yard long ban

Accession	Score
VS 1	5
VS 2	3
VS 3	5
VS 4	3
VS 5	3
VS 6	5
VS 7	3
VS 8	5
VS 9	5
VS 10	7
VS 11	3
VS 12	5
VS 13	7
VS 14	3
VS 15	3
VS 16	0
VS 18	9
VS 19	0
VS 20	0
VS 21	0
VS 22	3
VS 23	3

Accession	Score
VS 24	0
VS 27	5
VS 28	0
VS 29	3
VS 30	5
VS 31	3
VS 32	3
VS 33	0
VS 34	7
VS 35	5
VS 36	7
VS 37	0
VS 38	3
VS 39	3
VS 40	5
VS 41	0
VS 42	5
VS 43	0
VS 44	3
VS 45	3
VS 46	9
VS 47	3

Table 28. Scoring for cowpea aphid in bush cowpea

Accession	Score
VU 1	3
VU 2	5
VU 3	7
VU 4	3
VU 5	5
VU 6	3
VU 7	0
VU 8	5
VU 9	5
VU 10	3
VU 11	7
VU 13	5
VU 14	0
VU 15	3
VU 16	3
VU 17	5
VU 18	0
VU 19	5
VU 20	7
VU 21	3
VU 22	3
VU 24	7

Table 29. Genetic cataloguing of accessions of yard long bean used for the study

Accession	Growth habit	Growth pattern	Twining tendency	Leafiness	Plant pigmentation			Plant vigour	Plant hairiness
					Stem	Branch	Petiole		
VS 1	7	2	7	2	0	3	10	9	3
VS 2	7	2	7	2	0	1	1	9	3
VS 3	7	2	7	3	0	0	1	9	3
VS 4	7	2	7	3	0	0	0	7	3
VS 5	7	2	7	1	0	0	1	9	3
VS 6	7	2	7	1	1	1	3	9	3
VS 7	7	2	7	1	5	5	3	9	3
VS 8	7	2	7	3	0	0	3	7	3
VS 9	7	2	7	2	0	0	0	7	3
VS 10	7	2	7	2	0	0	1	9	3
VS 11	7	2	7	2	1	1	1	7	3
VS 12	7	2	7	3	0	0	3	7	3
VS 13	7	2	7	2	5	5	5	7	3
VS 14	7	2	7	2	0	0	3	7	3
VS 15	7	2	7	1	0	0	0	9	3
VS 16	7	2	7	3	0	0	0	7	3
VS 18	7	2	7	1	1	0	1	9	3
VS 19	7	2	7	2	1	3	1	9	3
VS 20	7	2	3	3	0	1	3	7	3
VS 21	7	2	7	1	1	1	3	9	3
VS 22	1	1	0	4	0	0	0	7	3
VS 23	7	2	5	3	5	1	3	7	3

Table 29. Continued…

Accession	Growth habit	Growth pattern	Twining tendency	Leafiness	Plant pigmentation			Plant vigour	Plant hairiness
					Stem	Branch	Petiole		
VS 24	7	2	7	3	0	1	1	7	3
VS 27	7	2	7	1	0	0	0	9	3
VS 28	7	2	7	2	0	1	1	9	3
VS 29	7	2	7	2	0	0	0	7	3
VS 30	7	2	5	1	0	0	0	9	3
VS 31	7	2	7	1	0	0	0	9	3
VS 32	7	2	7	3	0	0	0	7	3
VS 33	7	2	7	1	7	5	5	9	3
VS 34	7	2	7	1	0	1	3	9	3
VS 35	7	2	7	1	1	0	1	9	3
VS 36	7	2	7	1	0	0	0	9	3
VS 37	7	2	7	2	0	1	0	9	3
VS 38	7	2	7	1	0	0	0	9	3
VS 39	7	2	7	2	1	1	3	9	3
VS 40	7	2	7	1	1	1	1	7	3
VS 41	7	2	7	2	1	0	0	7	3
VS 42	7	2	7	1	0	0	0	7	3
VS 43	7	2	7	1	0	0	1	9	3
VS 44	7	2	7	1	0	0	0	7	3
VS 45	7	2	7	3	0	0	0	7	3
VS 46	7	2	7	3	0	1	1	7	3
VS 47	7	2	7	1	1	1	0	9	3

Table 29. Continue.....

Accession	Duration of flowering	Raceme position	Flower colour	Calyx colour	Pod attachment to peduncle	Immature pod pigmentation	Pod Curvature	Seed colour
VS 1	3	3	2	0	3	0	3	5
VS 2	3	3	2	0	3	0	3	6
VS 3	3	3	2	0	3	0	3	3
VS 4	3	3	2	0	3	0	3	1
VS 5	3	3	2	3	3	1	3	9
VS 6	3	3	3	5	3	5	3	3
VS 7	3	3	3	5	3	5	3	3
VS 8	3	3	2	3	3	1	3	9
VS 9	3	3	2	0	3	0	3	1
VS 10	3	3	2	3	3	1	3	9
VS 11	3	3	2	3	3	1	3	9
VS 12	3	3	2	0	3	0	3	3
VS 13	3	3	3	5	3	5	0	3
VS 14	3	3	2	0	3	0	3	1
VS 15	3	3	2	3	3	1	3	9
VS 16	3	3	2	0	3	0	0	1
VS 18	3	3	2	3	3	1	0	9
VS 19	3	3	2	3	3	1	5	9
VS 20	3	3	2	0	3	0	0	3
VS 21	3	3	2	0	3	0	3	3
VS 22	3	3	2	0	3	1	3	3
VS 23	3	3	2	0	3	0	3	3

Table 29. Continued....

Accession	Duration of flowering	Raceme position	Flower colour	Calyx colour	Pod attachment to peduncle	Immature pod pigmentation	Pod Curvature	Seed colour
VS 24	3	3	2	3	3	1	3	9
VS 27	3	3	2	0	3	1	3	9
VS 28	3	3	2	0	3	0	3	3
VS 29	3	3	2	0	3	0	3	3
VS 30	3	3	1	0	3	0	0	6
VS 31	3	3	1	0	3	0	3	6
VS 32	3	3	2	0	3	0	5	6
VS 33	3	3	3	5	3	5	3	3
VS 34	3	3	2	0	3	0	3	3
VS 35	3	3	3	3	3	1	3	9
VS 36	3	3	2	0	3	1	3	9
VS 37	3	3	2	0	3	0	3	3
VS 38	3	3	2	0	3	1	0	9
VS 39	3	3	3	3	3	0	3	9
VS 40	3	3	2	0	3	0	3	3
VS 41	3	3	2	0	3	0	0	3
VS 42	3	3	1	0	3	0	3	6
VS 43	3	3	2	0	3	1	3	9
VS 44	3	3	2	0	3	0	0	1
VS 45	3	3	3	0	3	0	3	3
VS 46	3	3	2	0	3	0	3	3
VS 47	3	3	2	0	3	0	3	1

All accessions were vigorous and glabrous. All the accessions showed synchronous flowering (< 15 days). Raceme position was throughout the canopy in all accessions.

Flower pigment pattern showed marked variation. The accessions VS 6, VS 7, VS 13 and VS 33 had mauve pink colour, accessions VS 30, VS 31, VS 42 had cream (white) colour whereas all other accessions had violet pigmentation. Calyx pigment pattern also showed significant variation. The accessions VS 6, VS 7, VS 13 and VS 33 had deeply pigmented calyx while VS 5, VS 8, VS 10, VS 11, VS 15, VS 18, VS 19, VS 24, 35 and VS 39 had light pigmented calyx and the rest had green calyx.

Immature pod colour belonged to the following categories - plain green, green with red tip, dark red. Most of the accessions had plain green pods. Dark red pigmented pods were the peculiarity of VS 6, VS 7, VS 13 and VS 33.

There was wide variation in seed colour among the accessions. Black seed colour observed in 12 accessions *viz.*, VS 5, VS 8, VS 10, VS 11, VS 15, VS 18, VS 19, VS 27 VS 35, VS 38, VS 39, and VS 43. Light brown seeds were noticed in six accessions namely, VS 4, VS 9, VS 14, VS 16, VS 44, and VS 47. Dual seed colour (brown and white) observed in VS 2, VS 30, VS 31 and VS 42. The rest of the accessions had brown seed colour. (Plate 10)

Bush cowpea

All the 22 accessions were described morphologically using the modified descriptor developed from the standard descriptor for cowpea by IPGRI. The accessions were scored for 17 morphological characters on appropriate scales ranging from 0-9 (Table 30).

Wide variation in growth habit *viz.*, acute erect, erect, semi erect, intermediate, semi-prostrate and prostrate was noticed in bush cowpea. All accessions were determinate except VU 15and VU 22 which showed indeterminate growth.

Slight twining tendency was noticed in VU 13, VU 14, VU 17, VU 18, VU 19, whereas intermediate in VU 15 and VU 22 and remaining accessions did not show twining tendency.

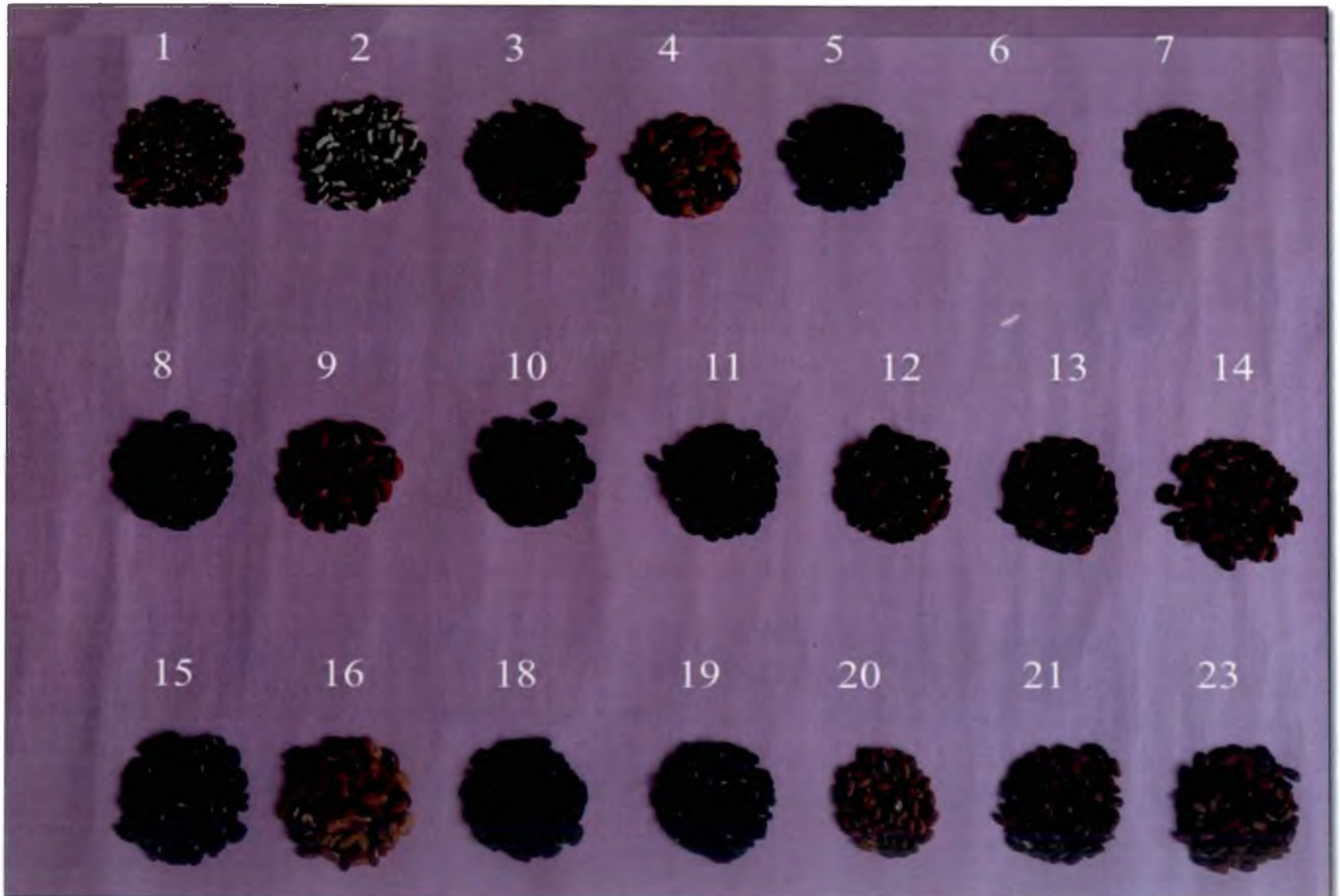


Plate 10. Variation in seed colour in yard long bean- Accessions VS 24 to VS 47

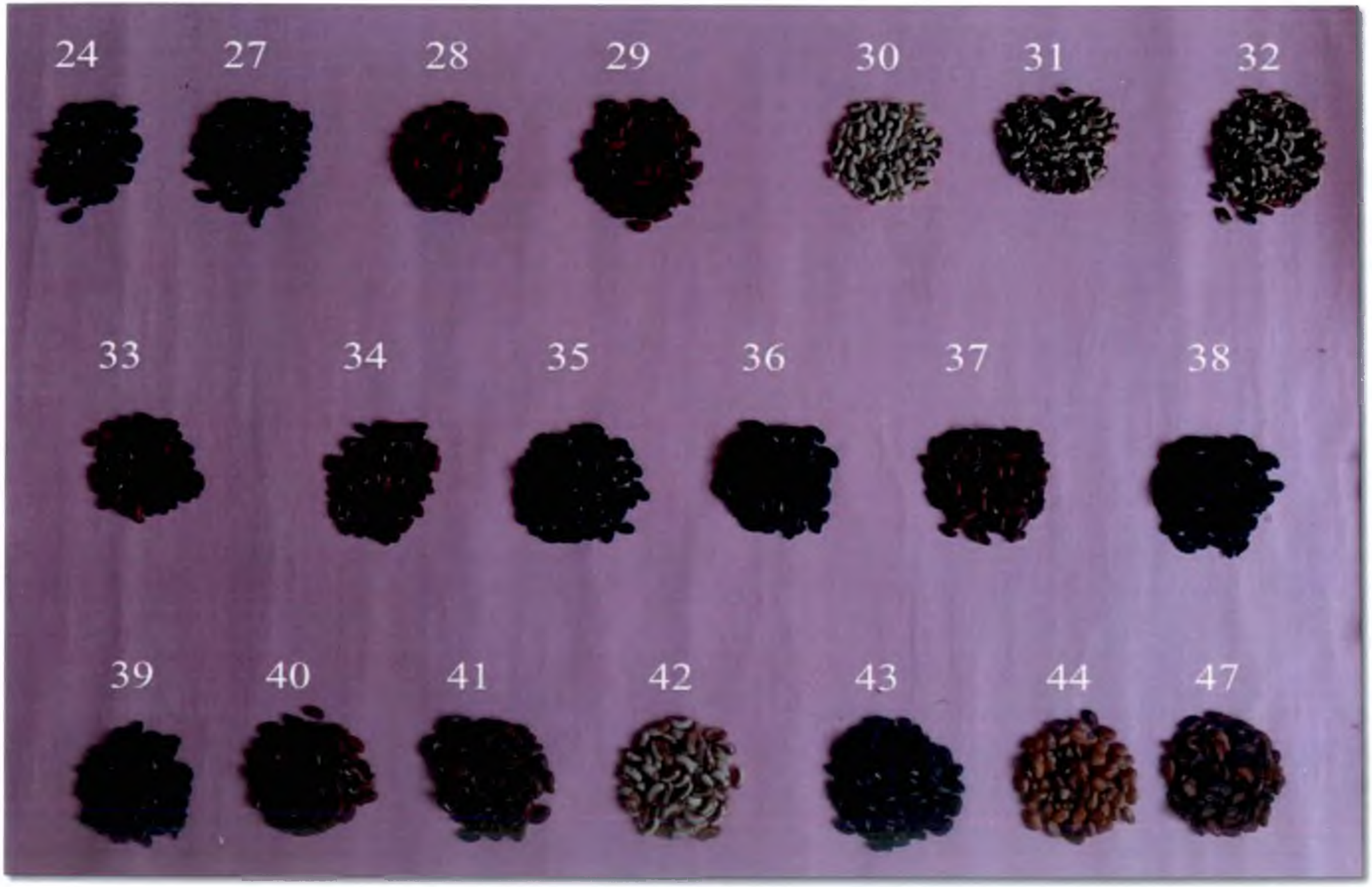


Plate 10. Variation in seed colour in yard long bean- Accessions VS 24 to VS 47

Table 30. Genetic cataloguing of accessions of bush cowpea used for the study

Accession	Growth habit	Growth pattern	Twining tendency	Leafiness	Plant pigmentation			Plant vigour	Plant hairiness
					Stem	Branch	Petiole		
VU 1	1	1	0	2	0	3	1	9	5
VU 2	1	1	0	1	0	0	0	9	3
VU 3	2	1	0	3	0	0	1	7	5
VU 4	2	1	0	1	0	0	1	9	5
VU 5	2	1	0	1	0	0	0	9	5
VU 6	5	1	0	2	0	0	0	9	5
VU 7	5	1	0	2	1	1	3	9	5
VU 8	1	1	0	3	1	1	1	9	5
VU 9	3	1	0	2	0	1	0	9	5
VU 10	4	1	0	2	0	0	1	9	5
VU 11	2	1	0	3	0	1	0	9	5
VU 13	5	1	3	1	1	1	3	9	5
VU 14	5	1	3	1	1	1	3	9	5
VU 15	5	2	5	2	1	3	1	9	5
VU 16	5	1	0	2	1	3	1	9	3
VU 17	5	1	3	2	1	1	3	9	5
VU 18	3	1	3	1	3	7	3	9	5
VU 19	5	1	3	2	0	3	1	9	5
VU 20	1	1	0	2	0	0	0	9	5
VU 21	1	1	0	1	0	1	1	9	5
VU 22	6	2	5	3	3	5	3	7	5
VU 24	1	1	0	3	0	1	1	7	5

Table 30. Continue…

Accession	Duration of flowering	Raceme position	Flower colour	Calyx colour	Pod attachment to peduncle	Immature pod pigmentation	Pod Curvature	Seed colour
VU 1	3	2	2	0	3	0	5	8
VU 2	3	1	2	0	3	0	3	1
VU 3	3	2	1	0	5	0	3	6
VU 4	3	2	2	0	5	0	0	8
VU 5	3	1	2	3	3	0	3	6
VU 6	3	1	2	0	3	0	0	4
VU 7	3	1	2	0	3	0	0	3
VU 8	3	2	1	0	3	0	3	2
VU 9	3	2	2	3	3	0	0	9
VU 10	3	1	2	0	3	0	0	7
VU 11	3	1	2	0	3	0	3	7
VU 13	3	1	2	0	3	0	0	8
VU 14	3	1	2	0	3	0	0	3
VU 15	3	3	4	3	3	0	0	3
VU 16	3	2	2	0	3	0	0	9
VU 17	3	1	4	0	3	0	3	8
VU 18	3	1	4	5	3	5	3	8
VU 19	3	2	2	0	3	0	5	8
VU 20	3	2	2	0	3	0	3	2
VU 21	3	1	2	0	5	0	0	6
VU 22	3	1	2	3	3	0	3	9
VU 24	3	2	2	0	3	0	3	8

Plant pigmentation was very light in seven accessions namely, VU 7, VU 8, VU 13, VU 14, VU 15, VU 16 and VU 17. In VU 18 and VU 22 pigmentation was moderate at the base and tips of petiole and remaining plain green colour.

Flower colour also showed marked variation. VU 3 and VU 8 had white flowers and others had violet colour.

Pod attachment to peduncle was 30-90^0 down from erect and remaining accessions were pendent. Except VU 18 all accessions had plain green colour without any pigmentation. VS 18 had uniform dark pink colour.

The variation in seed colour was comparatively low. Most of the accessions had cream coloured seeds (Plat 11).

4.2 Experiment II

This experiment on screening of vegetable cowpea accessions for collar rot and web blight resistance was conducted under artificial conditions in the net house of the Department of Plant Pathology. All accessions of both yard long bean and bush cowpea were screened under artificial conditions by inoculating the pathogen *Rhizoctonia solani* to confirm the resistance to collar rot and web blight. The field view of this experiment had given in Plate 12. The symptoms of collar rot and web blight was shown in plate 13 and plate 14 respectively.

4.2.1 Incidence of collar rot and web blight and related characters

Yard long bean

The mean values of the 44 accessions for the disease severity of collar rot and web blight studied under artificial conditions were presented in table 31.

Weekly observations were recorded for the incidence of collar rot. In first week after inoculation (WAI), disease was noticed in seven accessions *viz.*, VS 1 (75.02%), VS 2 (24.95%), VS 3 (25.57%), VS 8 (50.45%), VS 34 (24.98%), VS 35 (25.25%) and VS 45 (25.03%). There was no infection in the remaining accessions in the first week after inoculation (WAI). In second and third WAI, most of the accessions got infection by *R. solani*. Among all accessions VS 21 (99.41 %) had shown the highest disease incidence followed by VS 12 (99.39%). There was no incidence of collar rot at all in 12

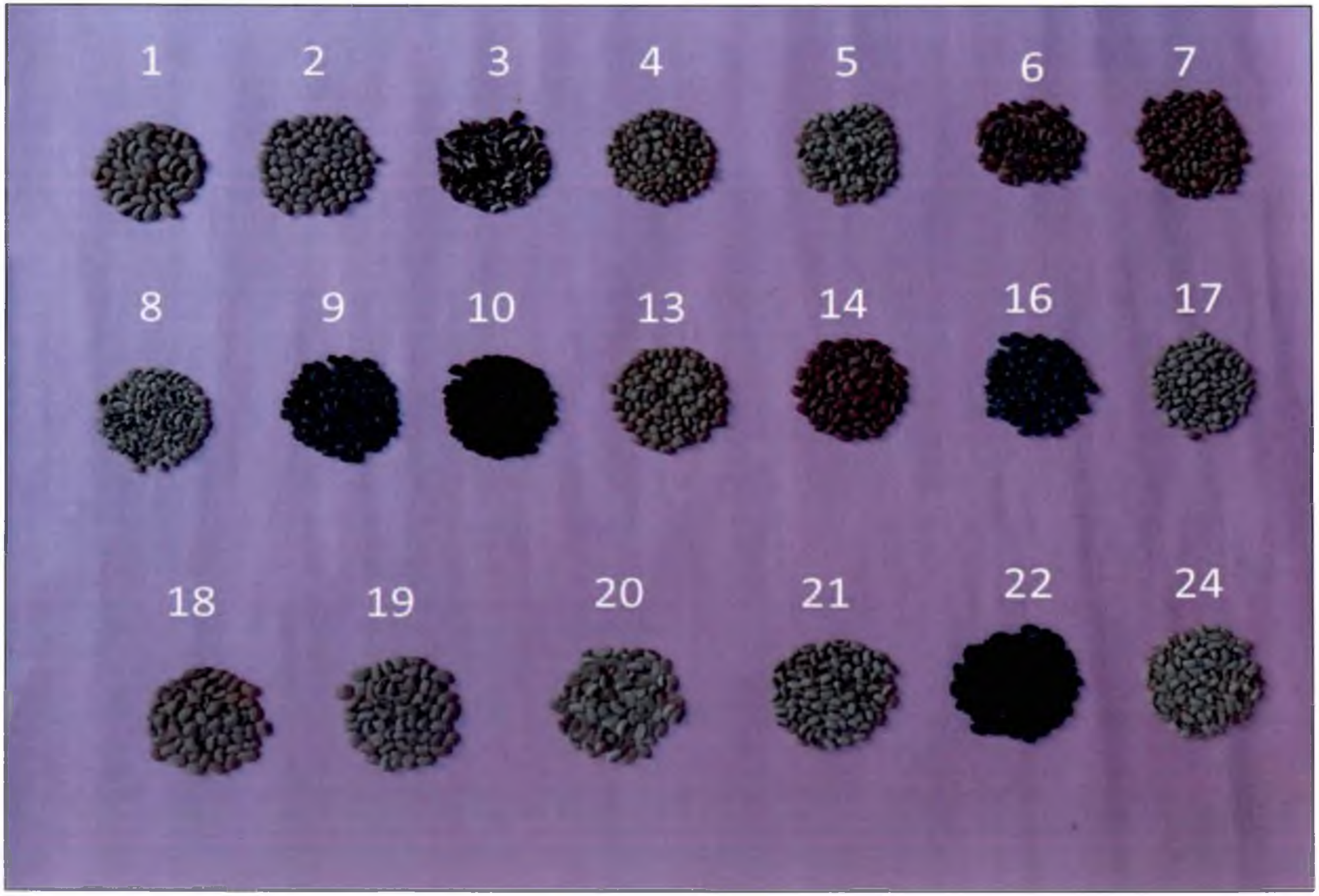


Plate 11. Variation in seed colour in bush cowpea- Accessions VU 1 to VU 24

Plate 12. Field view of Experiment II

Plate 13. Symptoms of collar rot udder artificial conditions

Plate 14. Different phases of web blight symptoms under artificial conditions

Table 31. Mean performance of 44 yard long bean accessions for collar rot and web blight disease under artificial conditions

Accessions	Collar rot disease incidence after inoculation			Length of lesion of collar rot	Breadth of lesion of collar rot	Web blight disease index
	I week	II week	III week			
VS 1	75.02(59.99)	75.02(59.99)	99.2(85.28)	2.15	1.35	34.75
VS 2	24.95(29.95)	75 (59.98)	99.23(85.68)	2.45	1.32	50.54
VS 3	25.57(30.35)	75.8(60.51)	98.8(84.54)	1.85	1.23	41.81
VS 4	0(0)	26(30.64)	26(30.64)	0.48	0.40	26.47
VS 5	0(0)	50.84(45.46)	50.84(45.46)	1.38	0.78	20.98
VS 6	0(0)	0(0)	0(0)	0.00	0.00	18.43
VS 7	0(0)	51.17(45.65)	51.17(45.64)	0.85	0.70	20.32
VS 8	50.45(45.24)	51.55(45.87)	99.04(85.14)	2.08	1.32	35.69
VS 9	0(0)	75.40(60.24)	75.40(60.24)	1.58	1.23	23.96
VS 10	0(0)	0(0)	0(0)	0.00	0.00	17.84
VS 11	0(0)	25.36(30.22)	50.83(45.46)	0.85	0.58	26.72
VS 12	0(0)	99.39(86.17)	99.39(86.17)	1.98	1.20	42.65
VS 13	0(0)	0(0)	0(0)	0.00	0.00	14.33
VS 14	0(0)	51.52(45.86)	51.52(45.86)	0.83	2.35	32.06
VS 15	0(0)	75.49(60.30)	75.49(60.30)	1.40	1.13	32.74
VS 16	0(0)	75.65(60.41)	75.65(60.41)	1.50	1.23	26.00
VS 18	0(0)	0(0)	0(0)	0.00	0.00	20.36
VS 19	0(0)	0(0)	0(0)	0.00	0.00	22.19
VS 20	0(0)	26.17(30.75)	50.96(45.54)	0.55	0.25	31.53
VS 21	0(0)	99.41(86.42)	99.41(86.42)	2.15	1.60	24.79
VS 22	0(0)	0(0)	0(0)	0.00	0.00	22.25
VS 23	0(0)	51.72(45.96)	99.81(88.74)	1.10	0.55	26.75

(Data in parenthesis showing transformed values)

Table 31. Continued...

Accessions	Collar rot disease incidence after inoculation			Length of lesion of collar rot	Breadth of lesion of collar rot	Web blight disease index
	I week	II week	III week			
VS 24	0(0)	74.31(59.52)	74.31(59.52)	1.70	0.92	33.96
VS 27	0(0)	49.89(44.92)	99.2(85.28)	1.18	0.83	36.98
VS 28	0(0)	25.33(30.20)	50.97(45.54)	0.45	0.23	23.14
VS 29	0(0)	50.96(45.54)	99.23(85.68)	0.95	0.75	28.17
VS 30	0(0)	49.67(44.79)	98.8(84.54)	1.03	0.65	24.44
VS 31	0(0)	74.95(59.94)	74.95(59.95)	1.60	1.03	22.27
VS 32	0(0)	0(0)	0(0)	0.00	0.00	34.76
VS 33	0(0)	0(0)	0(0)	0.00	0.00	33.43
VS 34	24.98(29.97)	99.04(85.14)	99.04(85.14)	2.45	1.40	44.41
VS 35	25.25(30.15)	25.36(30.22)	25.36(30.22)	0.40	0.40	38.27
VS 36	0(0)	25.09(30.04)	25.09(30.04)	0.30	0.20	35.47
VS 37	0(0)	0(0)	0(0)	0.00	0.00	21.00
VS 38	0(0)	0(0)	0(0)	0.00	0.00	17.97
VS 39	0(0)	0(0)	0(0)	0.00	0.00	21.35
VS 40	0(0)	49.36(44.61)	49.36(44.62)	1.05	0.75	32.74
VS 41	0(0)	51.39(45.78)	51.39(45.78)	1.58	0.75	29.67
VS 42	0(0)	98.8(84.54)	98.8(84.54)	2.43	1.63	46.39
VS 43	0(0)	0(0)	0(0)	0.00	0.00	23.81
VS 44	0(0)	24.76(29.83)	24.76(29.83)	0.58	0.43	21.97
VS 45	25.03(30.01)	49.09(44.46)	49.09(44.46)	1.05	2.58	33.11
VS 46	0(0)	51.02(45.57)	51.02(45.57)	1.03	0.78	27.87
VS 47	0(0)	99.23(85.68)	99.23(85.68)	2.00	1.35	53.78
Mean	5.71(4.78)	42.81(37.85)	51.70(45.21)	0.90	0.75	31.13
CD (5%)	0.485	1.029	0.994	1.18	1.98	3.15

(Data in parenthesis showing transformed values)

Table 32 Rating of yard long bean accessions against collar rot

Category	No.of accessions	Accessions
Moderately resistant	12	VS 6, VS 10, VS 13, VS 18, VS 19, VS 22, VS 32, VS 33, VS 37, VS 38, VS 39, VS 43
Tolerant	4	VS 4, VS 35, VS 36, VS 44
Moderately tolerant	10	VS 5, VS 7, VS 11, VS 14, VS 20, VS 28, VS 40, VS 41, VS 45, VS 46
Susceptible	5	VS 9, VS 15, VS 16, VS 24, VS 31
Highly Susceptible	13	VS 1, VS 2, VS 3, VS 8, VS 12, VS 21, VS 23, VS 27, VS 29, VS 30, VS 34, VS 42, VS 47

Table 34 Rating of bush cowpea accessions against collar rot in

Category	No.of accessions	Accessions
Moderately resistant	6	VU 2, VU 5, VU 7, VU 13, VU 16, VU 18
Tolerant	1	VU 15
Moderately tolerant	5	VU 4, VU 11, VU 14, VU 19, VU 24
Susceptible	6	VU 1, VU 3, VU 8, VU 10, VU 17, VU 20
Highly Susceptible	4	VU 6, VU 9, VU 21, VU 22

accessions *viz*., VS 6, VS 10, VS 13, VS 18, VS 19, VS 22, VS 32, VS 33, VS 37, VS 38, VS 39 and VS 43.

Based on the percentage of collar rot incidence, the accessions were grouped into five categories (Table 32).

To find out the severity of collar rot, the length and breadth of lesions developed under artificial inoculation were recorded. The length of lesion varied from 0 - 2.45 cm. VS 2 and VS 34 (2.45 cm) had the highest length of lesion followed by VS 42 (2.43 cm). Lowest length of lesion was recorded by VS 36 (0.3 cm) followed by VS 35 (0.4 cm). VS 45 (2.58 cm) had the highest breadth of lesion followed by VS 14 (2.35 cm). Breadth of lesion is lowest in VS 36 (0.20) followed by VS 28 (0.23 cm).

The plant disease index for web blight was highest in VS 47 (53.78) followed by VS 2 (50.54) and least in VS 13 (14.33) followed by VS 10 (17.84).

Bush cowpea

All the 22 accessions were screened under artificial conditions to study the incidence of collar rot and web blight caused by *R. solani* and the results were presented in table 33.

Only VU 4 (25.80%), VU 6 (75.43%), VU 9 (25.24%) were infected by *R. solani* in the first WAI. Collar rot incidence was highest in VU 9 (99.75%) followed by VU 21 (99.64%) and VU 6 (99.61%) in II and III week. There was no incidence of collar rot in VU 2, VU 5, VU 13, VU 16 and VU 18 throughout experiment.

Based on the percentage of incidence of collar rot, the bush cowpea accessions were also divided into five categories *viz*., moderately resistant, tolerant, moderately tolerant, susceptible, highly susceptible (Table 34).

To find out the severity of collar rot incidence, two parameters *viz*., length and breadth of lesion were studied.

The length of lesion was more in VU 22 (2.23 cm) followed by VU 6 (2.20 cm) and VU 21 (2.20 cm) and the length is lowest in VU 15 (0.70 cm) followed by VU 19 (0.75 cm). Significant variation was there in breadth of lesion also. It varied from 0.40 cm in VU 15 to 1.55 cm in VU 9.

Table 33. Mean performance of 22 bush cowpea accessions for collar rot and web blight disease under artificial conditions

Accessions	Collar rot disease incidence after inoculation			Length of lesion of collar rot	Breadth of lesion of collar rot	Web blight disease index
	I week	II week	III week			
VU 1	0(0)	75.15(60.08)	75.15(60.08)	1.43	1.00	22.02
VU 2	0(0)	0(0)	0(0)	0.00	0.00	17.12
VU 3	0(0)	74.31(59.52)	74.31(59.52)	1.40	1.05	31.72
VU 4	25.8(30.51)	47.71(43.67)	47.71(43.67)	1.08	0.55	25.90
VU 5	0(0)	0(0)	0(0)	0.00	0.00	27.69
VU 6	75.43(60.26)	99.61(87.47)	99.61(87.47)	2.20	1.28	39.18
VU 7	0(0)	0(0)	0(0)	0.00	0.00	19.39
VU 8	0(0)	76.29(60.84)	76.29(60.84)	1.80	0.83	31.06
VU 9	25.24(30.15)	99.75(88.56)	99.75(88.56)	2.10	1.55	43.60
VU 10	0(0)	74.94(59.94)	74.94(59.94)	1.68	1.30	28.48
VU 11	0(0)	51.33(45.74)	51.33(45.74)	1.05	0.75	31.50
VU 13	0(0)	0(0)	0(0)	0.00	0.00	23.06
VU 14	0(0)	50.95(45.53)	50.95(45.53)	1.28	0.80	34.75
VU 15	0(0)	25.46(30.29)	25.46(30.29)	0.70	0.40	36.69
VU 16	0(0)	0(0)	0(0)	0.00	0.00	33.96
VU 17	0(0)	74.9(59.91)	74.9(59.91)	1.63	0.97	25.27
VU 18	0(0)	0(0)	0(0)	0.00	0.00	23.08
VU 19	0(0)	49.34(44.60)	49.34(44.60)	0.75	0.63	27.51
VU 20	0(0)	75.47(60.29)	75.47(60.29)	1.68	0.92	25.77
VU 21	0(0)	99.64(87.58)	99.64(87.58)	2.20	1.13	36.63
VU 22	0(0)	99.06(85.26)	99.06(85.26)	2.23	1.48	43.14
VU 24	0(0)	50.92(45.51)	50.92(45.51)	1.03	0.70	34.43
Mean	5.75(5.49)	51.13(43.85)	51.13(43.85)	1.10	0.70	30.09
CD (5%)	0.314	1.269	1.269	1.223	0.789	1.48

(Data in parenthesis showing transformed values)

Among all accession, web blight was more severe in VU 9, VU 22 and VU 6 (43.60, 43.14 and 39.18 respectively). Web blight severity was less in VU 2 (17.12), VU 7 (19.39) and VU 1 (22.02).

4.2.2 Role of biochemical and anatomical characters in collar rot and web blight incidence

4.2.2.1 Mean performance of accessions for biochemical and anatomical characters

Yard long bean

The biochemical characters like proline and phenol and anatomical characters like trichome density, number of vascular bundles, cuticle thickness and stomatal density were shown in Table 35 (Plate 15 and Plate 16).

VS 45 had the highest proline content (35.56 μmoles/ g) followed by VS 13 (34.33 μ moles/g) while VS 2 had the lowest proline content (10.17 μ moles/g) followed by VS 47 (11.12 μ moles/g).

VS 10, VS 13, VS 45, VS 5, VS 44, VS 38 and VS 7 were superior in terms of phenol content (98.36, 96.50, 93.92, 93.23, 92.15, 91.38 and 90.18 mg/100g respectively). VS 47, VS 3, VS 4, VS 2, VS 8, VS 14 and VS 21 recorded low total phenol content in mg/100g (23.16, 28.09, 28.56, 29.08, 32.14, 32.29 and 32.40 respectively).

The accession VS 15 had the highest trichome density (12.79 per mm^2) whereas, VS 1 and VS 32 (8.87 per mm^2) had the lowest trichome density. There was a wide variation in number of vascular bundles. VS 19 had the highest number (17.78) while VS 40 had the lowest (13.47).

Out of the 44 accessions, VS 9 had the thickest cuticle (43.44 μm) while VS 3 recorded the lowest value (28.21 μm). Wide variation among accessions was noticed in stomatal density also. Highest stomatal density was found in VS 47 (3546.51 per cm^2) followed by VS 2 (3488.37 per cm^2) and lowest in VS 13 (2005.81 per cm^2) followed by VS 10 (2151.16 per cm^2).

Bush cowpea

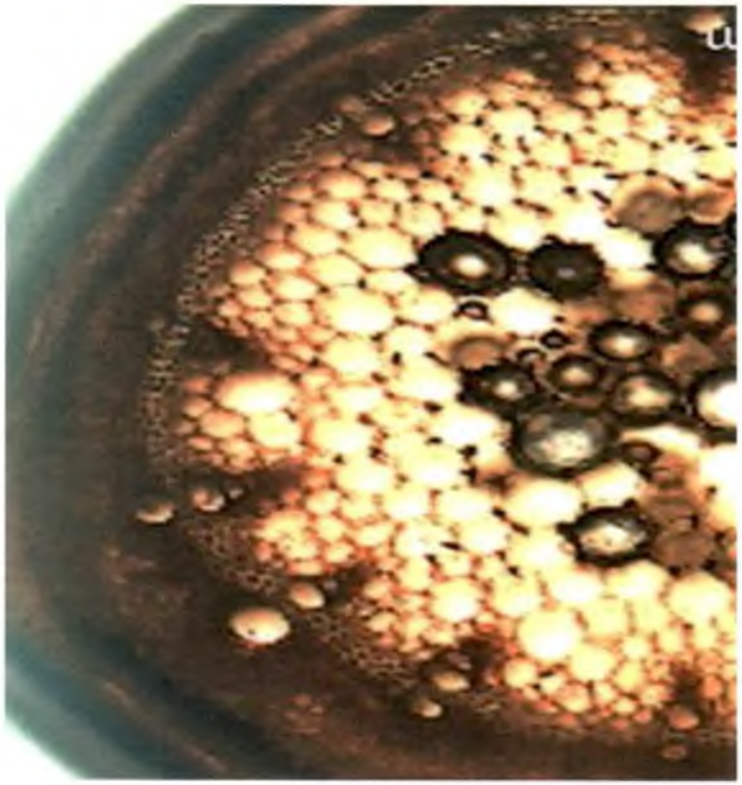
The biochemical and anatomical characters were showed in table 36.

Table 35. Mean performance of 44 yard long bean accessions for biochemical and anatomical characters

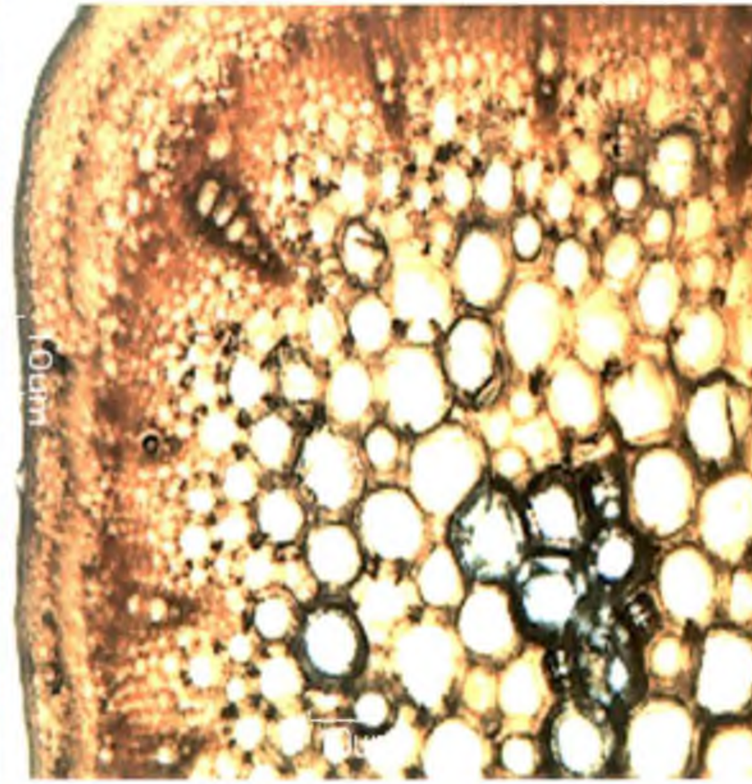
Accessions	Proline (μ moles/g)	Phenol (mg/100g)	Trichome density (mm^2)	No.of vascular bundle	Cuticle thickness(μm)	Stomatal density (cm^2)
VS 1	19.39	34.38	8.87	16.58	29.95	2819.77
VS 2	10.17	29.30	9.92	15.92	33.53	3488.37
VS 3	15.04	28.09	11.18	15.95	28.21	3081.39
VS 4	14.34	28.56	9.99	15.14	30.93	2703.49
VS 5	18.60	93.23	12.23	17.23	32.23	2296.51
VS 6	16.14	41.26	10.26	17.51	43.02	2383.72
VS 7	20.44	90.18	8.94	16.01	29.21	2325.58
VS 8	14.08	32.14	9.36	15.00	31.01	2936.05
VS 9	13.44	33.62	10.89	16.14	43.44	2441.86
VS 10	26.38	98.36	9.06	16.03	33.91	2151.16
VS 11	20.20	58.25	10.99	15.38	33.67	2470.93
VS 12	13.70	33.19	10.96	14.10	27.56	3197.67
VS 13	34.33	96.50	9.93	16.94	37.23	2005.81
VS 14	19.07	32.29	9.78	14.70	28.50	2441.86
VS 15	18.31	37.12	12.79	15.68	33.57	2470.93
VS 16	20.31	83.20	9.30	16.23	36.59	2616.28
VS 18	23.00	80.41	10.61	16.84	28.21	2441.86
VS 19	19.57	89.40	10.89	17.78	33.74	2674.42
VS 20	23.27	49.20	10.84	13.81	36.58	2703.49
VS 21	16.29	32.40	9.00	14.24	32.09	2383.72
VS 22	20.60	60.06	12.26	14.59	41.53	2441.86
VS 23	22.51	50.18	9.78	15.68	30.19	2441.86
VS 24	21.44	70.41	9.16	15.81	31.71	2761.63

Table 35. Continued...

Accessions	Proline (µ moles/g)	Phenol (mg/100g)	Trichome density (mm^2)	No.of vascular bundle	Cuticle thickness(µm)	Stomatal density (cm^2)
VS 27	18.39	47.20	10.29	15.00	35.64	3023.25
VS 28	19.23	43.40	11.77	14.18	29.25	2383.72
VS 29	26.25	33.19	11.21	15.60	28.93	3023.25
VS 30	19.34	91.29	10.64	15.21	33.52	2383.72
VS 31	27.57	31.28	9.46	14.78	35.62	2732.56
VS 32	15.52	61.25	8.87	15.64	36.58	2325.58
VS 33	14.53	23.29	10.60	15.80	32.09	2732.56
VS 34	12.87	32.69	11.73	14.51	31.24	3110.46
VS 35	17.56	60.40	11.31	17.53	35.80	3052.32
VS 36	12.27	59.39	10.09	17.11	29.00	2877.91
VS 37	17.22	88.35	11.02	15.01	28.55	2441.86
VS 38	23.40	91.38	9.39	15.92	33.30	2238.37
VS 39	14.46	61.26	10.96	15.60	35.80	2616.28
VS 40	14.77	40.40	11.73	13.47	28.33	2412.79
VS 41	15.55	50.31	9.78	15.69	42.44	2732.56
VS 42	11.29	28.38	8.94	14.81	29.20	3255.81
VS 43	15.29	32.32	12.24	15.01	33.17	2732.56
VS 44	21.39	92.15	11.57	15.21	28.54	2616.28
VS 45	35.36	93.92	10.87	14.77	38.23	2674.42
VS 46	15.38	31.31	10.95	15.58	34.91	2616.28
VS 47	11.12	23.16	9.00	14.79	33.16	3546.51
Mean	18.04	53.16	10.59	15.29	33.01	2739.48
CD (5%)	0.35	0.39	0.58	1.05	1.22	171.52

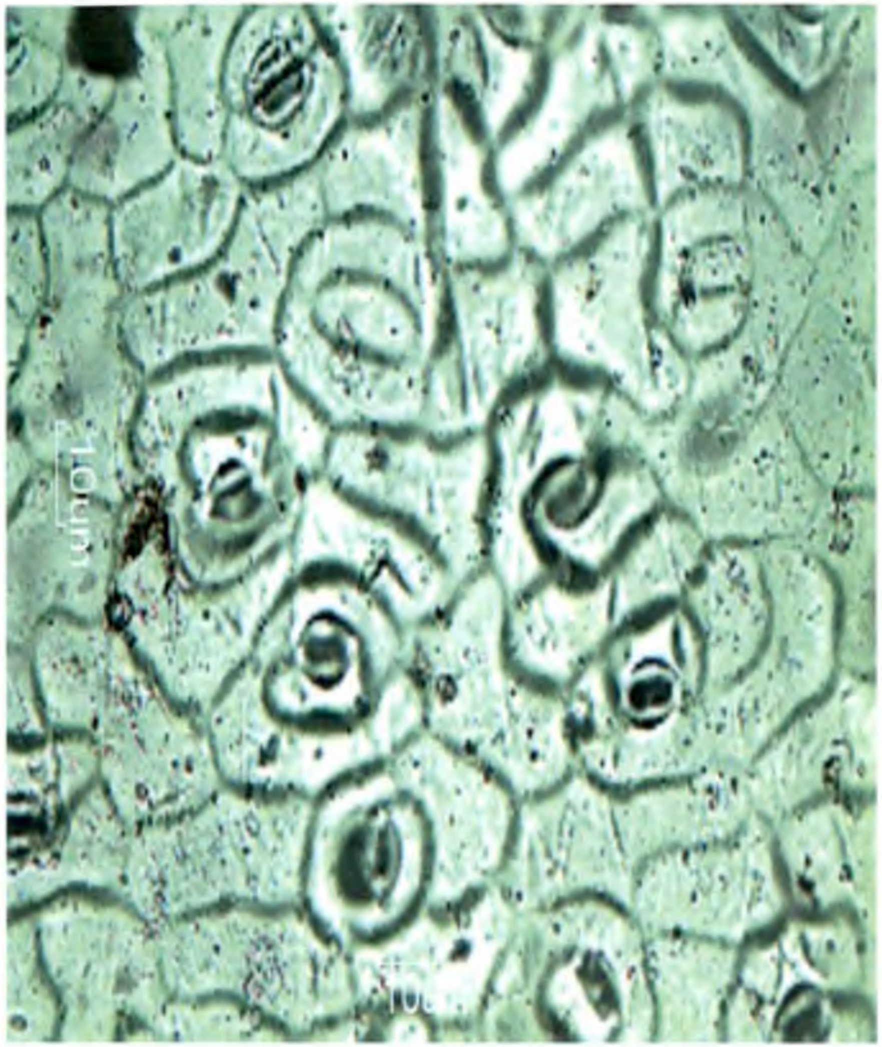


VS 13 (Moderately resistant accession)

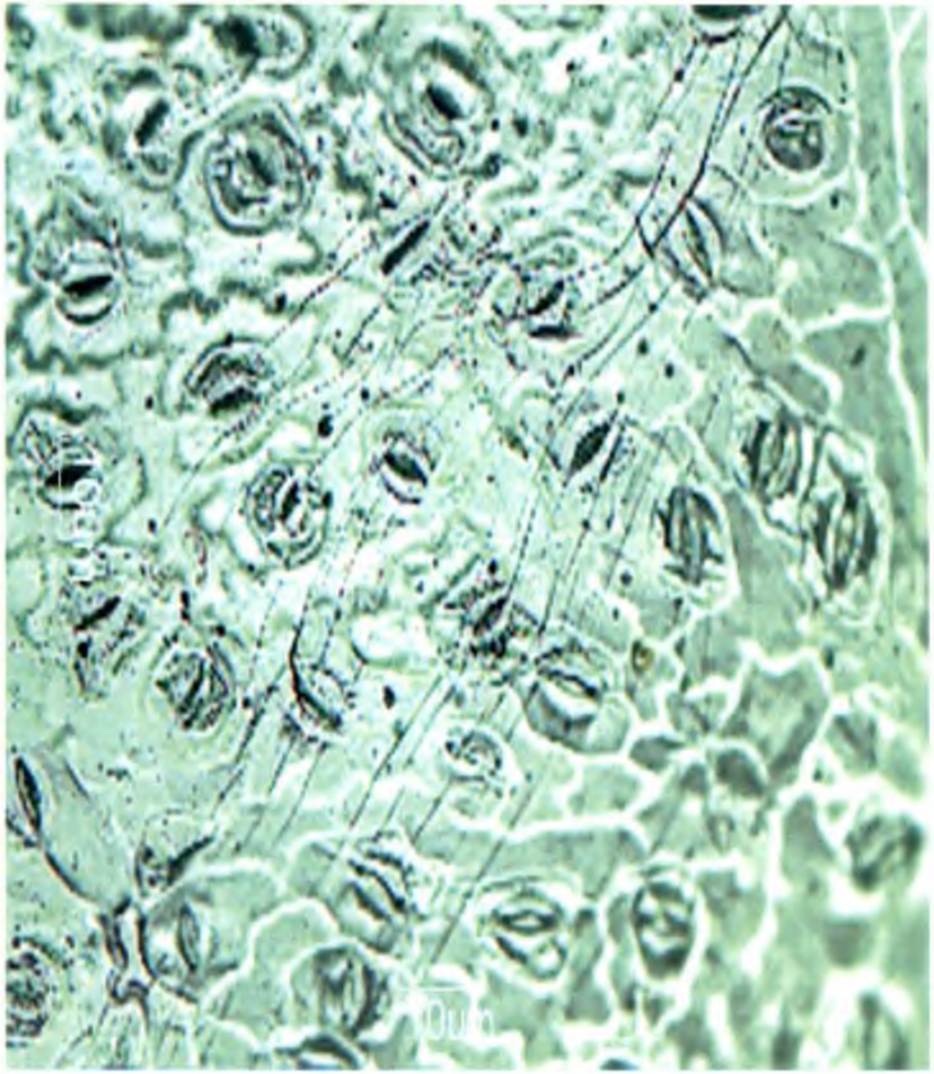


VS 34 (Highly susceptible accession)

Plate 15. Anatomical characters related to collar rot and web blight resistance



Low stomata density in VS 13



High stomatal density in VS 47

Plate 16. Stomatal density differences in susceptible and moderately resistant accessions

Table 36 Mean performance of 22 bush cowpea accessions for biochemical and anatomical characters

Accessions	Proline (µ moles/g)	Phenol (mg/100g)	Trichome density (mm^2)	No.of vascular bundle	Cuticle thickness(µm)	Stomatal density (cm^2)
VU 1	26.43	60.59	7.30	15.73	32.56	2383.72
VU 2	19.87	34.54	8.43	14.78	33.68	1947.67
VU 3	19.46	40.44	6.03	16.31	40.75	2906.98
VU 4	23.68	50.46	9.06	17.11	22.64	2645.35
VU 5	22.12	61.35	8.98	15.18	44.56	2151.16
VU 6	14.67	33.22	7.58	14.42	32.34	3401.16
VU 7	23.59	88.35	9.99	16.61	30.97	1976.74
VU 8	17.29	37.57	8.40	14.90	22.62	2470.93
VU 9	10.63	32.47	6.23	14.69	22.02	3255.81
VU 10	20.56	43.39	7.19	16.94	36.50	2180.23
VU 11	20.25	44.29	8.94	14.74	34.06	2529.07
VU 13	24.42	47.28	9.36	15.65	33.43	2354.65
VU 14	18.68	42.33	8.42	15.53	40.69	2470.93
VU 15	16.31	32.50	9.34	15.01	30.68	2558.14
VU 16	17.54	58.35	8.87	15.92	41.47	2383.72
VU 17	22.42	62.83	9.30	15.63	33.45	2732.56
VU 18	17.35	66.14	7.47	13.75	33.50	2180.23
VU 19	21.53	45.40	9.93	15.01	41.09	2470.93
VU 20	16.68	41.14	8.10	15.21	30.05	2441.86
VU 21	14.59	49.47	9.78	15.89	43.09	3023.25
VU 22	14.50	35.13	7.48	15.07	23.15	3139.53
VU 24	22.03	43.19	9.00	14.55	37.67	2296.51
Mean	19.30	47.75	8.41	15.39	33.68	2540.96
CD (5%)	0.460	0.710	0.660	1.098	1.310	204.660

Maximum proline was obtained for VU 1 (26.43μ moles/g), VU 4 (23.68 μ moles/g) and VU 7 (23.59 μ moles/g) and minimum for VU 9 (10.63 μ moles/g), VU 22 (14.50 μ moles/g) and VU 21 (14.59 μ moles/g). Highest phenol content was noticed in VU 7 (88.35 mg/100g) followed by VU 18 (66.14 mg/100g) and VU 17 (62.83 mg/100g). Lowest phenol content found in VU 9 (32.47 mg/100g) followed by VU 15 (32.50 mg/100g) and VU 6 (33.22 mg/100g).

Trichome density varied from 6.03 per mm^2 in VU 3 to 9.99 per mm^2 in VS 7. Number of vascular bundles was highest for VU 4 (17.11) followed by VU 10 (16.94) and lowest for VU 18 (13.75) followed by VU 6 (14.42). VU 5 and VU 21 were superior for cuticle thickness (44.56 and 43.09 μm respectively). VU 9 and VU 8 recorded less cuticle thickness (22.02 and 22.62 μm respectively). Stomatal density was highest in VU 6 (3401.16 per cm^2) followed by VU 9 (3255.81 per cm^2) and lowest in VU 2 (1947.67 per cm^2) followed by VU 7 (1976.74 per cm^2).

4.2.2.2 Genetic variability, heritability and genetic advance

The population means, range, genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV), heritability and genetic advance for the 12 characters were studied and are presented in table 37. (Fig. 7 and Fig 8) in yard long bean and Table 38 (Fig. 9 and Fig 10) in bush cowpea.

4.2.2.2.1 Incidence of collar rot and web blight

Yard long bean

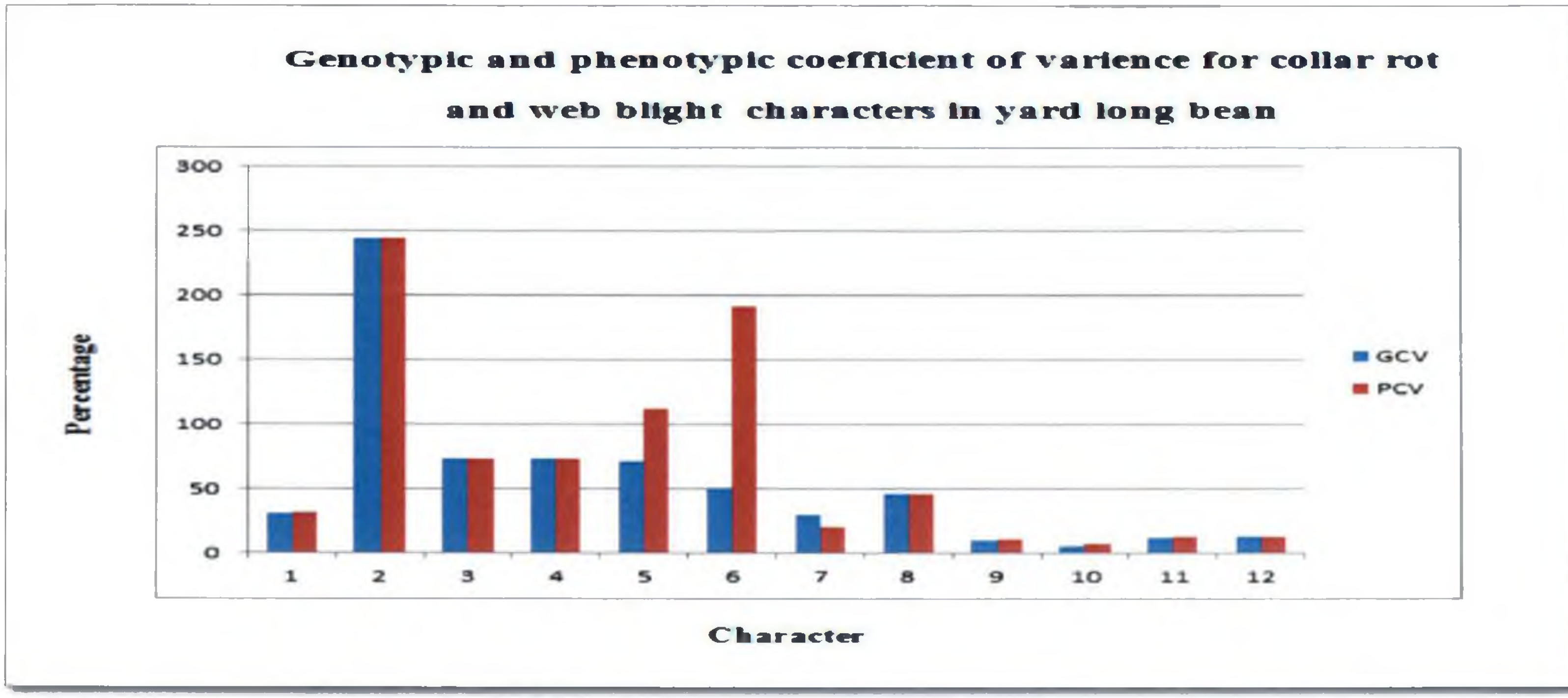
Incidence of collar rot at I WAI ranged from 0 – 75.02 per cent (VS 1) per cent with a mean of 5.71. The GCV was 244.62 and PCV was 244.62. Heritability and genetic advance was very high (99.97 and 29.27 respectively). In II WAI disease incidence ranged from 0 – 99.40 with an mean of 42.81. The GCV and PCV were 73.89 and 73.95 respectively. Heritability was 99.82 and genetic advance was 57.55. The range of disease incidence at III WAI found from 0 – 99.81. The overall mean was 51.70. GCV and PCV were 73.73 and 73.83 respectively and heritability was very high (99.72) with genetic advance 68.56.

Table 37. Estimates of genetic parameters for various characters in yard long bean

Characters	Range	Mean	GCV	PCV	Heritability (%)	Genetic Advance (GA) at 5%	Genetic advance as percentage of mean
Collar rot incidence I WAI (%)	0 - 75.02	5.71	244.59	244.62	99.97	1.67	29.27
Collar rot incidence II WAI (%)	0 - 99.40	42.81	73.89	73.95	99.82	24.64	57.55
Collar rot incidence III WAI (%)	0 - 99.81	51.70	73.73	73.83	99.72	35.45	68.56
Length of lesion (cm)	0 – 2.45	0.98	71.64	112.45	40.58	0.92	93.87
Breadth of lesion (cm)	0 -2.58	0.77	50.65	191.84	6.97	0.21	27.27
Disease index of web blight	14.33-53.78	29.5	30.84	31.77	94.25	18.2	61.69
Proline (μ moles/g)	10.17 – 35.36	18.62	29.48	20.83	99.79	11.3	60.68
Phenol (mg/100g)	23.16 – 98.36	54.5	46.22	46.23	99.98	51.89	95.21
Trichome density (per mm2)	8.87 – 12.79	10.44	10.11	10.87	86.52	2.02	19.35
No.of vascular bundles	13.47 – 17.78	15.56	6.06	7.75	61.06	1.52	9.77
Cuticle thickness(μm)	27.56 – 43.44	33.18	12.56	12.83	95.83	8.4	25.32
Stomatal density (per cm2)	2005.81- 3546.51	2663.85	12.66	13.47	88.34	652.86	24.50

WAI= Week After Inoculation

Fig 7



X1 = Disease index of web blight

X2 = Disease incidence of collar rot at I WAI (%)

X3 = Disease incidence of collar rot at II WAI (%)

X4 = Disease incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

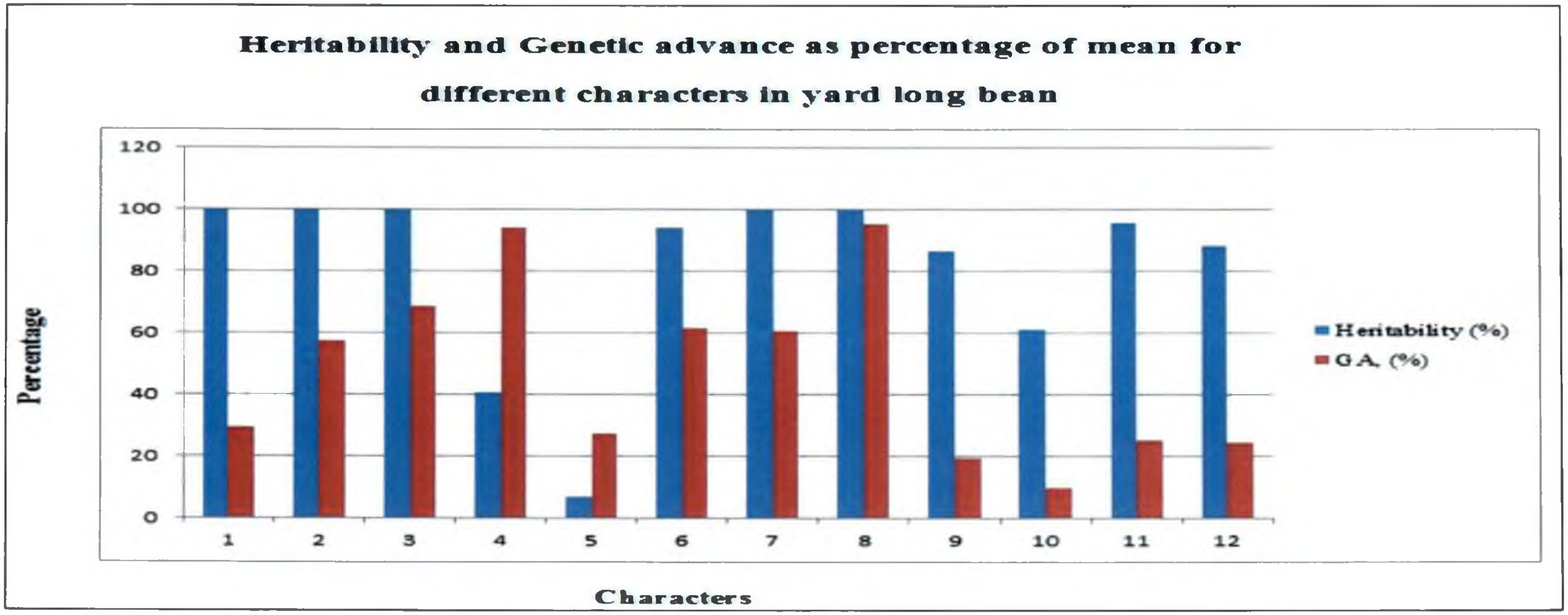
X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

X12 = Stomatal density (cm^2)

Fig 8



X1 = Disease index of web blight

X2 = Disease incidence of collar rot at I WAI (%)

X3 = Disease incidence of collar rot at II WAI (%)

X4 = Disease incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

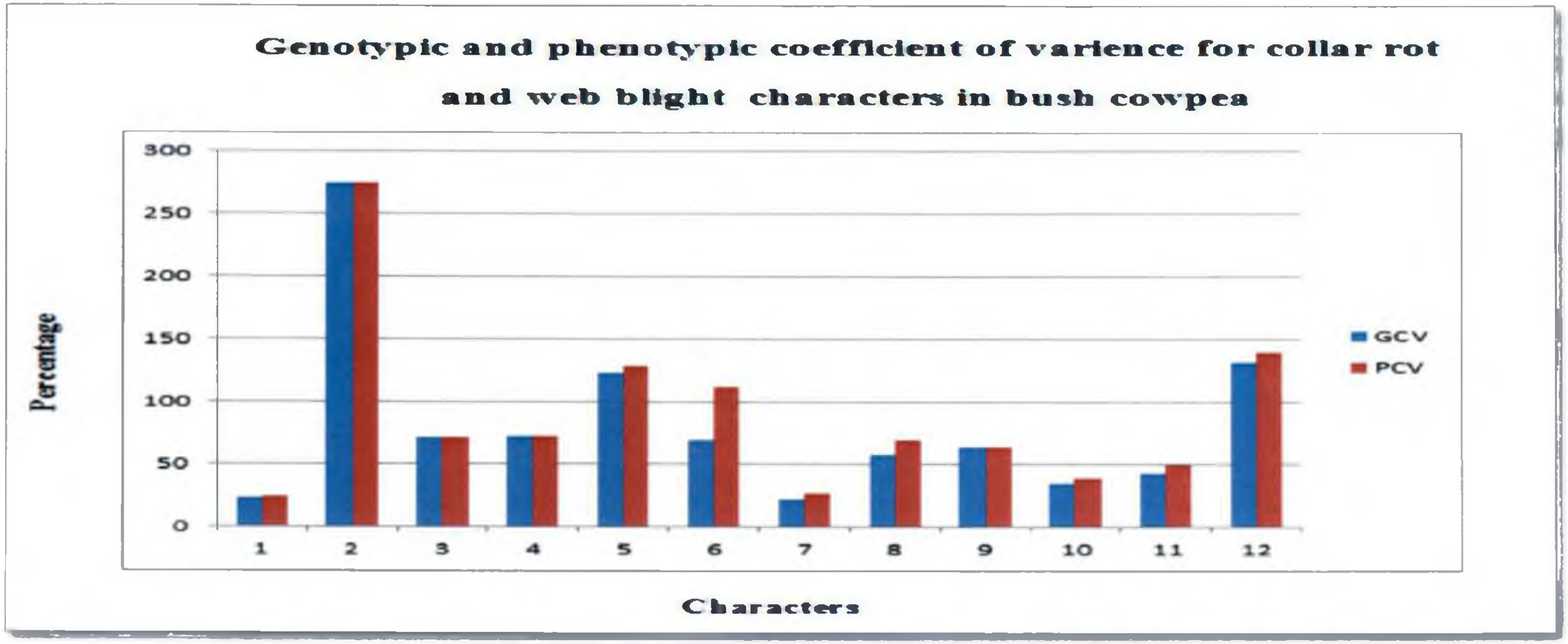
X12 = Stomatal density (cm^2)

Table 38. Estimates of genetic parameters for various characters in bush cowpea

Characters	Range	Mean	GCV	PCV	Heritability (%)	Genetic Advance (GA) at 5%	Genetic advance as percentage of mean
Collar rot incidence I WAI (%)	0-75.43	5.75	275.25	275.26	99.99	0.84	14.74
Collar rot incidence II WAI (%)	0-99.75	51.13	71.82	71.89	99.81	31.16	60.94
Collar rot incidence III WAI (%)	0-99.75	51.13	71.82	71.89	99.81	31.16	60.94
Length of lesion (cm)	0-2.23	1.1	123.25	128.8	91.64	0.78	70.57
Breadth of lesion (cm)	0-1.55	0.7	69.78	111.81	39.38	0.4	56.61
Disease index of web blight	17.12-43.60	30.09	24.03	24.28	97.92	0.83	2.75
Proline (μ moles/g)	10.63-26.43	19.3	22.92	27.05	70.94	9.55	49.48
Phenol (mg/100g)	32.47-88.35	47.75	57.93	69.71	68.08	28.39	59.46
Trichome density (per mm2)	6.03-9.99	8.42	64.17	64.28	99.66	3.56	42.30
No.of vascular bundles	13.75-17.11	15.4	34.82	39.08	78.84	6.75	43.83
Cuticle thickness(μm)	22.02-44.56	33.68	43.79	49.97	76.19	16.33	48.90
Stomatal density (per cm2)	1947.67-3401.16	2540.96	132.44	140.65	88.47	2228.92	87.72

WAI= Week After Inoculation

Fig 9



X1 = Disease index of web blight

X2 = Disease incidence of collar rot at I WAI (%)

X3 = Disease incidence of collar rot at II WAI (%)

X4 = Disease incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

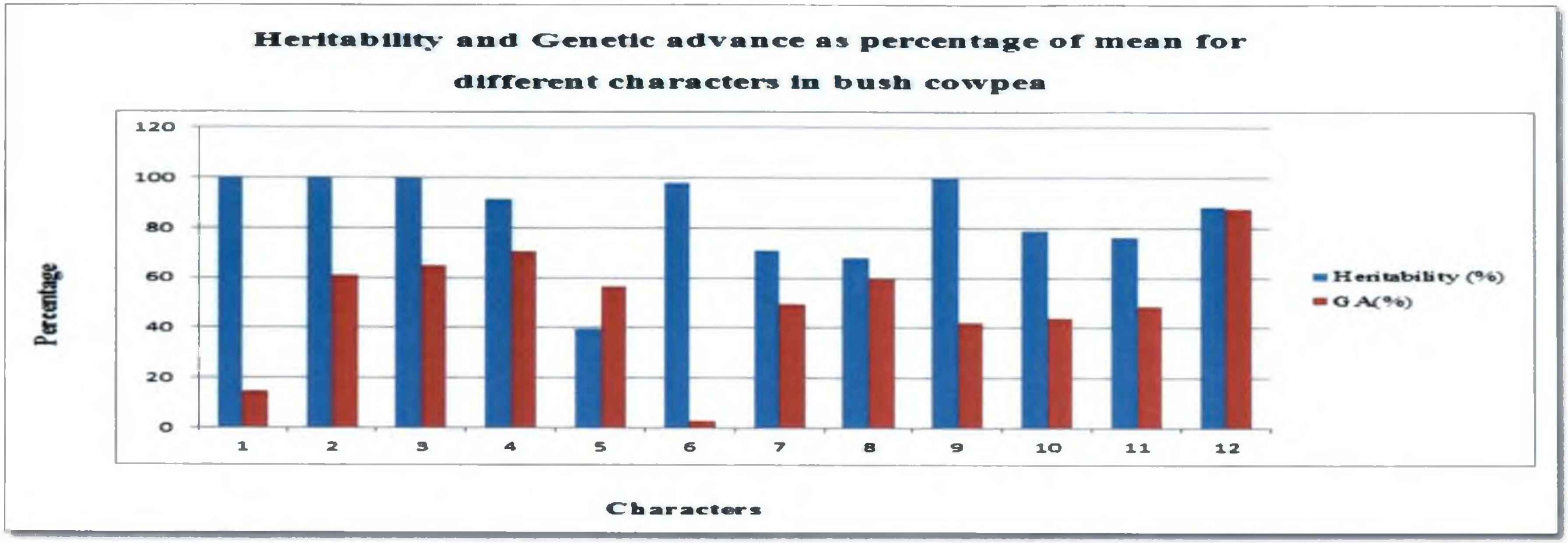
X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

X12 = Stomatal density (cm^2)

Fig 10



X1 = Disease index of web blight

X2 = Disease incidence of collar rot at I WAI (%)

X3 = Disease incidence of collar rot at II WAI (%)

X4 = Disease incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (μ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (μm)

X12 = Stomatal density (cm^2)

Length of lesion varied from 0 – 2.45 cm and the average mean was 0.98. GCV was 71.42 and PCV was 112.45. Heritability was moderate (40.58) and genetic advance was only 93.87. Breadth of lesion showed a range of 0 – 2.58 cm and the mean was 0.77. GCV was found to be 50.65 and PCV was 191.84. Heritability and genetic advance was very low (6.97 and 27.27 respectively).

The incidence of web blight showed a range of 14.33 – 53.78 with overall mean of 29.50. GCV, PCV, heritability and genetic advance was 30.84, 31.77, 94.25 and 61.69 respectively.

Bush cowpea

The range of collar rot at I WAI was 0-75.43 % and showed a mean value of 5.75. The GCV and PCV were 275.25 and 275.26 respectively. Heritability was very high (99.99%) and genetic advance was also high 14.74.The range and mean of disease incidence at II WAI were 0 to 99.75 and 51.13 respectively. GCV was 71.82 and PCV was 71.89. Heritability was 99.81 and genetic gain noted to be 60.94. Disease incidence at III WAI was also same as II WAI.

Length of lesion ranged from 0 – 2.23 cm with a mean value of 1.10 cm. The GCV and PCV were 123.25 and 128.80 respectively. Heritability was high as 91.64 per cent and genetic advance was 70.57. The ranges of breadth of lesion ranged from 0 – 1.55 cm with an overall mean of 0.70 cm. GCV was 69.78 and PCV was 111.81. Heritability was found to be 39.38 per cent. Genetic advance was high (56.61).

Disease index of web blight showed the range of 17.12-43.60 and mean was 30.09. GCV and PCV values were 24.03 and 24.28 respectively. Heritability was 97.92 per cent and genetic advance was very low(2.75).

4.2.3.3 Biochemical and anatomical characters

Yard long bean

Proline content showed a range of 10.17-35.56 μ moles/g and the mean was 18.62. GCV was 29.48 and PCV was 20.83. Heritability was very high (99.79) while genetic advance was moderate (60.68). Phenol content varied from 23.16-98.36 mg/100 g with a mean of 54.50. GCV was 46.22 and PCV was 46.23 and very high heritability and genetic advance (99.98 and95.21 respectively).

Trichome density varied from 8.87-12.79 per mm^2 and the mean was 10.44. GCV was 10.11 and PCV was 10.87. Heritability was 86.52 and genetic advance was 19.35. In case of number of vascular bundles, the range was 13.47-17.78 and mean value 15.56. GCV was 6.06 and PCV was 7.75. Heritability showed a just above moderate value of 61.06 per cent. Genetic advance was only 9.77.

Cuticle thickness ranged from 27.56-43.44 µm with 33.18 as the general mean. PCV and GCV were 12.83 and 12.56 respectively. Heritability was 95.83 per cent and genetic advance was 25.32.

The range of stomatal density varied from 2005.81-3546.51 per cm^2 with an overall mean of 2663.85. GCV was 12.66 and PCV was 13.47. Heritability was found to be 88.34 per cent. Genetic advance was 24.50.

Bush cowpea

Proline content showed a range of 10.63-26.43 µ moles/g and the mean was 19.30. GCV was found to be 22.92 and PCV was 27.05. Heritability was very high (70.94) and genetic advance was high (49.48). Phenol content varied from 32.47-88.35 mg/100 g and the mean was 47.75. GCV was 57.93 and PCV was 69.71. Heritability was 68.08 and genetic advance also high (59:46).

Trichome density varied from 6.03-9.99 per mm^2 and the mean was 8.42. GCV was 64.17 and PCV was 64.28. Heritability was 99.66 and genetic advance was 42.30. In case of number of vascular bundles, the range was 13.75 to 17.11 and the mean value was 15.40. GCV was 34.82 and PCV was 39.08. Heritability showed a just above moderate value of 78.84 per cent. Genetic advance was only 43.83.

Cuticle thickness ranged from 22.02-44.56 µm with 33.68 as the general mean. PCV and GCV were 43.79 and 49.97 respectively. Heritability was 76.19 per cent and genetic advance was moderate (48.90).

Stomatal density varied from 1947.67-3401.16 per cm^2 with an overall mean of 2540.96. GCV was 132.44 and PCV was 140.65. Heritability was found to be 88.47 per cent. Genetic advance was 87.72.

4.2.4 Correlation studies

The phenotypic, genetic and error correlation among collar rot, web blight, biochemical and anatomical characters were worked out and are presented in tables 39, 40and 41respectively in yard long bean and table 42, 43 and 44respectively in bush cowpea.

4.2.4.1 Phenotypic correlation

Yard long bean

Disease index of web blight had high positive correlation with incidence of collar rot at I WAI (0.422), incidence of collar rot at II WAI (0.619), incidence of collar rot at III WAI (0.596). It also had high positive correlation with length of lesion of collar rot (0.4838) and breadth of lesion of collar rot (0.269) and stomatal density (0.814).

High negative correlation obtained between disease index of web blight and proline content (-0.518), phenol content (-0.564), trichome density (-0.116), number of vascular bundle thickness (-0.217) and between cuticle thickness (-0.224).

Incidence of collar rot had shown very high positive correlation with length of lesion (0.680), breadth of lesion (0.318) and with stomatal density (0.531). It had high negative correlation with proline content (-0.226), phenol content (-0.468), trichome density (-0.165), number of vascular bundle thickness (-0.285) and between cuticle thickness (-0.263).

Length of lesion showed significant positive correlation with breadth of lesion (0.5319) and with stomatal density (0.429) and showed negative correlation with proline content (-0.249) and phenol content (-0.363)

Positive significant correlation was found between breadth of lesion and web blight disease index (0.269) and incidence of collar rot (0.680).

Table 39. Phenotypic correlation among collar rot, web blight, biochemical and anatomical characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000											
X2	0.422	1.000										
X3	0.619	0.259	1.000									
X4	0.596	0.359	0.910	1.000								
X5	0.484	0.335	0.714	0.680	1.000							
X6	0.269	0.234	0.362	0.318	0.532	1.000						
X7	-0.518	-0.066	-0.290	-0.226	-0.249	0.070	1.000					
X8	-0.564	-0.199	-0.468	-0.468	-0.363	-0.110	0.576	1.000				
X9	-0.116	0.087	-0.163	-0.165	-0.145	-0.059	-0.027	-0.014	1.000			
X10	-0.217	0.087	-0.301	-0.285	-0.175	-0.137	0.080	0.315	-0.104	1.000		
X11	-0.224	-0.101	-0.221	-0.263	-0.112	-0.024	0.143	0.081	0.010	0.168	1.000	
X12	0.814	0.385	0.524	0.531	0.429	0.177	-0.464	-0.536	-0.059	-0.090	-0.195	1.000

X1 = Disease index of web blight

X2 = Incidence of collar rot at I WAI (%)

X3 = Incidence of collar rot at II WAI (%)

X4 = Incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (μ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (μm)

X12 = Stomatal density (cm^2)

Table 40. Genotypic correlation among collar rot, web blight, biochemical and anatomical characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000											
X2	0.435	1.000										
X3	0.637	0.259	1.000									
X4	0.614	0.360	0.911	1.000								
X5	0.755	0.503	1.076	1.032	1.000							
X6	0.924	0.876	1.375	1.214	1.024	1.000						
X7	-0.536	-0.067	-0.290	-0.227	-0.376	0.238	1.000					
X8	-0.581	-0.199	-0.469	-0.468	-0.543	-0.398	0.577	1.000				
X9	-0.124	-0.091	-0.176	-0.174	-0.273	-0.300	-0.027	-0.014	1.000			
X10	-0.285	0.111	-0.388	-0.367	-0.360	-0.687	0.101	0.405	-0.094	1.000		
X11	-0.228	-0.102	-0.227	-0.268	-0.192	-0.069	0.146	0.083	0.011	0.228	1.000	
X12	0.881	0.410	0.560	0.568	0.680	0.683	-0.496	-0.571	-0.064	-0.183	-0.202	1.000

X1 = Disease index of web blight

X2 = Incidence of collar rot at I WAI (%)

X3 = Incidence of collar rot at II WAI (%)

X4 = Incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

X12 = Stomatal density (cm^2)

Table 41. Environmental correlation among collar rot, web blight, biochemical and anatomical characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000											
X2	0.019	1.000										
X3	0.109	-0.181	1.000									
X4	0.067	0.064	0.567	1.000								
X5	-0.022	-0.026	-0.058	-0.170	1.000							
X6	0.135	0.129	-0.045	-0.062	0.488	1.000						
X7	0.010	0.167	0.018	0.060	0.030	0.152	1.000					
X8	-0.110	-0.173	0.043	-0.014	-0.127	-0.442	0.029	1.000				
X9	-0.048	-0.037	0.001	-0.183	0.086	0.042	-0.130	-0.020	1.000			
X10	-0.008	0.089	0.020	0.002	0.026	0.007	0.045	-0.106	-0.152	1.000		
X11	-0.140	-0.183	0.075	-0.027	0.086	-0.030	-0.035	0.104	-0.002	-0.049	1.000	
X12	0.134	0.013	-0.084	-0.087	0.018	0.021	0.065	-0.074	-0.020	0.202	-0.129	1.000

X1 = Disease index of web blight

X2 = Incidence of collar rot at I WAI (%)

X3 = Incidence of collar rot at II WAI (%)

X4 = Incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

X12 = Stomatal density (cm^2)

Table 42. Phenotypic correlation among collar rot, web blight, biochemical and anatomical characters in bush cowpea

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000											
X2	0.357	1.000										
X3	0.637	0.396	1.000									
X4	-0.196	-0.273	-0.098	1.000								
X5	0.078	-0.028	-0.003	0.309	1.000							
X6	-0.161	-0.213	-0.075	0.090	0.274	1.000						
X7	-0.308	0.148	0.121	0.061	0.102	0.195	1.000					
X8	0.118	-0.193	0.249	0.044	-0.443	-0.292	-0.011	1.000				
X9	-0.084	0.232	-0.074	0.197	-0.631	0.192	0.512	-0.591	1.000			
X10	0.089	-0.159	0.286	-0.204	-0.459	-0.162	-0.024	0.818	-0.567	1.000		
X11	0.010	-0.216	0.225	-0.128	-0.438	-0.178	-0.079	0.771	-0.632	0.890	1.000	
X12	0.113	-0.260	0.188	-0.153	0.536	0.239	-0.417	0.714	-0.833	0.804	0.815	1.000

X1 = Disease index of web blight

X2 = Incidence of collar rot at I WAI (%)

X3 = Incidence of collar rot at II WAI (%)

X4 = Incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

X12 = Stomatal density (cm^2)

Table 43. Genotypic correlations among collar rot, web blight, biochemical and anatomical characters in bush cowpea

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X1	X12
X1	1.000											
X2	0.360	1.000										
X3	0.644	0.397	1.000									
X4	0.198	0.273	-0.098	1.000								
X5	0.081	-0.029	-0.004	0.329	1.000							
X6	-0.261	0.336	-0.116	0.143	0.420	1.000						
X7	0.370	0.175	0.141	0.074	0.120	-0.419	1.000					
X8	0.136	0.234	-0.299	0.056	-0.557	-0.500	-0.375	1.000				
X9	-0.084	0.232	-0.074	0.197	-0.661	-0.307	0.591	-0.734	1.000			
X10	0.114	-0.179	-0.321	-0.230	-0.543	-0.367	-0.285	0.911	-0.651	1.000		
X11	0.017	-0.248	-0.257	-0.145	-0.516	-0.298	-0.310	0.866	-0.733	0.952	1.000	
X12	0.127	-0.277	0.201	-0.163	0.595	0.476	0.570	0.918	-0.891	0.890	0.946	1.000

X1 = Disease index of web blight

X2 = Incidence of collar rot at I WAI (%)

X3 = Incidence of collar rot at II WAI (%)

X4 = Incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (μ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (μm)

X12 = Stomatal density (cm^2)

Table 44. Environmental correlations among collar rot, web blight, biochemical and anatomical characters in bush cowpea

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1.000											
X2	-0.037	1.000										
X3	0.091	0.190	1.000									
X4	0.074	-0.056	0.143	1.000								
X5	0.026	-0.068	0.024	-0.351	1.000							
X6	0.017	-0.085	-0.053	0.005	0.092	1.000						
X7	0.002	-0.025	0.109	-0.049	0.036	-0.067	1.000					
X8	0.081	0.001	0.113	-0.090	-0.017	-0.073	0.818	1.000				
X9	-0.144	-0.073	0.055	0.063	-0.022	-0.031	0.473	0.390	1.000			
X10	-0.173	-0.004	0.039	-0.018	0.022	0.123	0.761	0.578	0.367**	1.000		
X11	-0.073	0.006	0.075	-0.059	-0.051	-0.037	0.565	0.535	0.242	0.678	1.000	
X12	-0.116	0.001	-0.037	-0.023	0.001	0.162	0.190	0.008	0.190	0.386	0.232	1.000

X1 = Disease index of web blight

X2 = Incidence of collar rot at I WAI (%)

X3 = Incidence of collar rot at II WAI (%)

X4 = Incidence of collar rot at III WAI (%)

X5 = Length of lesion (cm)

X6 = Breadth of lesion (cm)

X7 = Proline content (µ moles/g)

X8 = Phenol content (mg/100g)

X9 = Trichome density (mm^2)

X10 = Number of vascular bundles

X11 = Cuticle thickness (µm)

X12 = Stomatal density (cm^2)

Bush cowpea

Disease index of web blight showed significant positive correlation with incidence of collar rot at I week (0.357), and II week (0.637) while it exhibited negative correlation with proline content (-0.308).

Significant positive correlation was found between incidence of collar rot and length of lesion (0.309).

Length of lesion showed positive correlation with breadth of lesion (0.274) and stomatal density (0.536). It had negative correlation with phenol content (-0.443), cuticle thickness (-0.438), trichome density (-0.631) and number of vascular bundles (-0.459).

4.2.4.2 Genotypic Correlation Coefficients

Yard long bean

Genotypic correlation coefficients were in general higher than phenotypic correlation for the characters under study.

High positive correlation was obtained between disease index of web blight and collar rot incidence at I WAI (0.435), II WAI (0.637), III WAI (0.614), Length of lesion (0.755), breadth of lesion (0.924) and with stomatal density (0.881). Disease index of web blight was showed significant negative correlation with proline content (-0.536), phenol content (-0.581), trichome density (-0.124), number of vascular bundle (-0.285) and with cuticle thickness (-0.228).

Incidence of collar rot had high positive correlation with length of lesion (1.032) breadth of lesion (1.214) and with stomatal density (0.568). It had significant negative correlation with proline content (-0.290), phenol content (-0.486), trichome density (-0.174), number of vascular bundle (-0.367) and with cuticle thickness (-0.268).

The length of lesion was noticed significant positive correlation with breadth of lesion (1.024), web blight disease index (0.755), with incidence of collar rot (1.032) and with stomatal density (0.568). Significant negative correlation was found between length of lesion and proline content (-0.376), phenol content (-0.543), trichome density (-0.273), number of vascular bundle (-0.359) and with cuticle thickness (-0.192).

The breadth of lesion had significant positive correlation with stomatal density (0.683). Significant negative correlation was found between breadth of lesion and phenol content (-0.543), trichome density (-0.299) and number of vascular bundles.

Bush cowpea

Positive correlation was found between disease index of web blight and collar rot (0.360).

The collar rot had high positive correlation with breadth of lesion (0.336) and stomatal density (0.201). It has negative correlation with phenol content (-0.299), vascular bundle thickness (-0.321) and cuticle thickness (-0.257).

Length of lesion had positive correlation with breadth of lesion (0.420) and with stomatal densities (0.595). It had significant negative correlation with phenol content (-0.557), trichome density (-0.661), number of vascular bundle (-0.543) and with cuticle thickness (-0.516).

High positive correlation was found between breadth of lesion and stomatal density (0.476). Significant negative correlation was noted with proline content (-0.419), phenol content (-0.500), trichome density (-0.307), number of vascular bundles (-0.367) and with cuticle thickness (-0.298).

4.2.4.3 Environmental correlation coefficients

Since phenotypic and genotypic correlation was highly significant and closes so, there is a less chance of environmental affect. 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.

DISCUSSION

5. DISCUSSION

Investigations were conducted at Department of Olericulture, College of Agriculture, Vellayani to study the variability in vegetable cowpea for yield, quality and resistance to collar rot and web blight and to elucidate the morphological, anatomical and biochemical basis of resistance. The study was carried out as two experiments *viz.*,

1. Evaluation of vegetable cowpea germplasm for variability, yield, quality and tolerance to pests and diseases.
2. Screening vegetable cowpea germplasm for collar rot and web blight resistance under artificial conditions.

The experimental results are discussed under different headings.

5.1 Evaluation of vegetable cowpea germplasm

5.1.1 Performance of the accessions

In the present investigation, analysis of variance revealed significant difference among the 44 accessions of yard long bean and 22 accessions of bush cowpea for all the growth, flowering, pod, yield and quality characters indicating scope for improving the population for these characters.

5.1.1.1 Growth and yield characters

Yield is the most important character of a crop which varies with genotypes. In the present study, accessions VS 29 and VS 30 of yard long bean and VU6 and VU 2 of bush cowpea were superior for yield. In the case of pod length and weight, VS 45 and VS 4 of yard long bean and VU 20 and VU 1 of bush cowpea were superior. VS 29 and VS 30 of yard long bean and VU 8 and VU 7 of bush cowpea were superior for pods per plant. Similar differential response for yield and yield attributes in different accessions of cowpea was reported by Kutty *et al.* (2003), Manju (2006), Madhukar (2006), Jithesh (2009) and Manggoel (2012).

5.1.1.2 Quality and Biochemical characters

Quality characters are very important in any crop because quality characters impart nutritional quality of the produce. In the present study, different accessions showed variation in quality characters like protein content and keeping quality. Highest protein content of 9.22 percent was recorded by VS 29 and lowest by VS 32 (3.17 percent) in yard long bean. In bush cowpea, VU 18 was superior in pod protein content (8.60 percent). A range of 4.61 to 5.94 percent for protein content was reported by Resmi (1998); 3.50 to 8.75 percent by Manju (2006) and 3.53 to 8.72 percent by Jithesh (2009).

5.1.2 Variability studies

The magnitude of variability present in a population 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 the genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential. The PCV and GCV are two parameters used to measure the variability present in a population.

In the present investigation, for majority of the characters, magnitude of GCV and PCV were closer both in yard long bean and bush cowpea, suggesting greater contribution of genotype rather than environment. So the selection of superior types can very well be based on the phenotypic values. Such a closer PCV and GCV for different characters were earlier reported by Manju (2006), Madhukumar (2006) and Jithesh (2009) in yard long bean and Nehru and Manjunath (2001) and Girish *et al.* (2006) in bush cowpea.

In the current study, highest PCV and GCV was recorded for days to first harvest followed by pod weight, pod borer infestation, pod protein content, pod length, pods per plant, and yield per plant in yard long bean. In bush cowpea highest PCV and GCV was recorded for pod weight followed by vine length, pods per plant, pod length and yield per plant which indicates that there exist high genetic variability and better scope for improvement of these characters through selection.

Comparatively low GCV was observed for days to first flowering, length of terminal leaf let, length of lateral leaf let, breadth of terminal leaf let, breadth of lateral leaf let, seeds per pod and primary branches per plant in yard long bean and days to first harvest, days to first flowering, peduncle length, seeds per pod, length of lateral leaf let, and keeping quality in bush cowpea, indicating low variability which limits the scope for further improvement through selection.

The study revealed high estimates of GCV for pod weight which was earlier reported by Vidya (2000) Lovely (2005), Manju (2006) and Jithesh (2009) in yard long bean and Sobha and Vahab (1998), Hazra *et al.* (1999), Rangaiah (2000), Ajith (2001)and Narayankutty *et al.* (2003) in bush cowpea. GCV for pod length was also high in the present study, which was supported by the findings of Lovely (2005) and Jithesh (2009) in yard long bean and Sreekumar *et al.* (1996), Hazra *et al.* (1999) and Kalaiyarasi and Palanisamy (2000b) in cowpea.

High PCV and GCV for pod yield per plant observed in this study was supported by similar findings of Resmi (1998), Vidya *et al.*(2000), Jyothi (2001), Lovely (2005), Madhukumar (2006) and Manju (2006) and Jithesh (2009) in yard long bean and Sobha and Vahab (1998) in bush cowpea.

In the present study, pods per plant had high estimates of GCV and PCV. Similar results were reported in cowpea by Harshavardhan and Savithramma (1998b), Jyothi (2001), Rangaiah (2000), Selvam *et al.* (2000), Narayankutty *et al.* (2003), Madhukumar (2006) and Jithesh (2009).

From the foregoing discussions, it is clear that the characters *viz.*,podweight, pods per plant, pod length and yield per plant offer good scope for selection in vegetable cowpea.

5.1.3 Heritability and genetic advance

The variability existing in a population is the sum total of heritable and non-heritable components. A high value of heritability indicates that the phenotype of that trait strongly reflects its genotype. The magnitude of heritability indicates the effectiveness with which selection of the accessions can be made based on the phenotype.

In the present investigation, the heritability estimates were high for all characters except for primary branches per plant and length of terminal leaflets, which had moderate heritability in yard long bean, whereas in bush cowpea, all characters studied showed high heritability.

High heritability for primary branches per plant observed in the present study is in agreement with the findings of Sawant (1994), Ram and Singh (1997), Ajith (2001), Kalaiyarasi and Palanisamy (2000b) and Philip (2004) in cowpea.

Vine length showed high heritability in the present study. It was supported by Vidya (2000), Tyagi *et al.* (2000), Ajith (2001), Nehru and Manjunath (2001), and Venkatesan *et al.* (2003).

High genetic advance was noted for pod yield per plant, vine length, pods per plant and pod length while pod weight showed moderate genetic advance in yard long bean whereas in bush cowpea, yield per plant showed highest genetic advance followed by vine length and pods per plant. However, all other characters recorded low genetic advance.

In the present study, pods per plant, pod yield per plant and pod length recorded high heritability coupled with high genetic advance in both yard long bean and bush cowpea indicating the presence of additive gene action. Similar results were reported by Lovely (2005), Manju (2006),Suganthi and Murugan (2008), Jithesh (2009).

High heritability and low genetic advance of characters is indicative of dominant gene action suggesting the possibility of genetic improvement through hybridization. In the present study high heritability and low or moderate genetic advance was observed for days to first flowering and days to first harvest in both yard long bean and bush cowpea.

High heritability for peduncle length was noticed by Ram and Singh (1997) in cowpea. Pod protein content showed high heritability in yard long bean by Madhukumar (2006) and Jithesh (2009).

5.1.4Correlation studies

Correlation coefficient measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. It provides information on the nature and extent of relationship between all pairs of characters. So when the breeder applies selection for a particular character, not only it improves that trait, but also those characters provides a reliable measure of genetic association between them, which is useful in the breeding programmes.

In the present study, yield had significant positive phenotypic and genotypic correlation with primary branches, pod weight and pods per plant in yard long bean while in bush cowpea, high and positive phenotypic and genotypic correlation of yield was observed with peduncle length, pod length, pod girth and weight.

Vine length had positive correlation with leaf dimensions like length of terminal leaflet and lateral leaflets which is in agreement with the results of Manju (2006).

A positive correlation of pods per plant with pod yield per plant and 100-seed weight was noticed in the present study. Similar results were reported by many workers (Resmi, 1998; Panicker, 2000; Vidya, 2000; Lovely, 2005; Madhukumar, 2006; Manju, 2006; and Jithesh, 2009 in yard long bean and Rangaiah and Mahadevu, 2000; Kutty *et al.*, 2003 and Philip 2004 in bush cowpea).

Pod length was positively correlated with vine length, days to first flowering and peduncle length. There was a positive correlation between yield per plant and primary branches per plant and number of pods per plant.

Pods per plant were negatively correlated with peduncle length, pod length and pod weight.

Pod characters and seed characters were negatively correlated with pods per plant indicating that selection for increased pod length, pod girth, or pod weight will result in reduction in number of pods per plant.

The positive genotypic association of yield per plant with pod girth observed in this study was in line with the finding of Sobha (1994), Harshavardhan and Savithramma (1998b) Ajith (2001) and Jithesh (2009).

In this study, pod length had high positive genotypic correlation with seeds per pod. This was in agreement with the reports of Chattopadhyay *et al.* (1997) and Philip (2004) in cowpea and Sreekumar *et al.* (1996) and Jithesh (2009) in yard long bean.

5.1.5Path coefficient analysis

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

In the present investigation, the highest positive and direct effect on yield was exerted by pods per plant, followed by pod weight, pod length and vine length in yard long bean.

In bush cowpea also, the highest positive and direct effect on yield was exerted by pods per plant followed by pod weight, days to first flowering, and pod girth.

High direct effect of pods per plant on yield is in accordance with earlier findings of Resmi (1998) and Vidya (2000), Lovely (2005), Madhukumar (2006), and Jithesh (2009) in yard long bean and Kutty *et al.* (2003), Subbaiah *et al.* (2003), Venkatesan *et al.* (2003), Philip (2004),and Udensi *et al.* (2012b) in bush cowpea.

The positive direct effect of pod weight on yield observed in the study was supported by Sobha (1994), Chattopadhyay *et al.* (1997), Ajith (2001), Kutty *et al.* (2003), and Subbiah *et al.* (2003) in cowpea and Resmi (1998), Vidya (2000) and Jithesh (2009).

The positive direct effect of vine length, pod length and pod girth on yield observed in the study was in agreement with the findings of Manju (2006) and Udensi (2012b).

From the study it is evident that selection of genotypes based on pods per plant is most effective for improving yield of yard long bean and bush cowpea.

5.1.6 Selection index

Discriminant function analysis developed by Fisher (1936) gives information on the proportionate weightage to be given to a yield component. Thus, selection index was formulated to increase the efficiency of selection by taking into account the important characters contributing to yield. According to Hazel (1943), a selection based on suitable index was more efficient than individual selection based on individual characters.

The seven characters *viz.,*vine length, days to first flowering, pod length, pod girth, pod weight, number of pods per plant and yield per plant which were used for path coefficient analysis was selected for ranking the accessions of both yard long bean and bush cowpea.

Based on the selection index values, top ranking accessions namely VS 34 (4567.19), VS 4 (4553.17), VS 29 (4551.43), VS 9 (4320.99), VS 1 (4291.98), VS 31 (4281.93), and VS 47 (4232.93) were identified as superior ones in yard long bean.

In bush cowpea, VU 7 (1475.31) was ranked first followed by VU 1 (1468.72), VU 14 (1426.92), VU 16 (1371.64) VU 6 (1351.56) and VU 22 (1350.27).

Identification of superior accessions of vegetable cowpea based on discriminant function analysis was also done by Resmi (1998), Manju (2006) and Jithesh (2009).

5.1.7 Genetic cataloguing

Genetic cataloguing based on standard descriptor helps to describe the morphological features of an accession easily and thus helps in the exchange of information about new accessions in a more clearway.

The 44 yard long bean and 22 bush cowpea accessions upon cataloguing showed distinct variation among each other with respect to vegetative, inflorescence, pod and seed characters.

All yard long bean accessions showed indeterminate growth pattern. During vegetative stage all of them were vigorous and leafy. Some of the accessions had purple or red pigmentation on stem, branches, and petioles. The pendent pods were found distributed throughout the canopy in all accessions.

Association between flower colour and immature pod pigmentation was noticed. All accessions having white or cream flowers gave rise to plain green pods having seeds with brown and white patches, while pods with red tips were associated with lightly pigmented calyx and black seeds.

There is wide variation in growth pattern of bush cowpea. Most of the accessions had determinate growth pattern. All were vigorous and leafy at vegetative stage. Slight pigmentation was found on stem, petiole and branches in some accessions. Most of the genotype had violet coloured flowers with green colour pod and creamy white coloured seeds.

Cataloguing of vegetable cowpea was also attempted by Resmi (1998), Gopalakrishnan (2004) and Manju (2006).

5.1.8 Screening for pests and diseases pests and diseases

5.1.8.1 Collar rot and web blight

Rhizoctonia solani is an important pathogen of cowpea (*Vigna unguiculata*) worldwide. Cowpeas are especially susceptible to seedling diseases caused by *R. solani* when planted in, moist soils coupled with high temperature and humid conditions (Thies *et al.*, 2006).

Among 44 accession of yard long bean only 12 namely, VS 1, VS 2, VS 9, VS 14, VS 20, VS 21, VS 23, VS 24, VS 29, VS 30, VS 32 and VS 40 were infected with *R. solani* and shown collar rot symptoms, the remaining accessions were free from collar rot. All the accessions were free from web blight. In bush cowpea, among 22 accessions only four (VU 11, VU 15, VU 17 and VU 19) had shown collar rot symptoms and none of the accessions showed web blight symptoms. This may be due to high temperature coupled with low relative humidity. *R. solani* is a ubiquitous soil born pathogen with wide host range. The expression of symptoms may vary with climatic conditions. Generally, *R. solani* requires high temperature and relative humidity. Under these conditions the pathogen is more active and cause severe disease symptoms. But due to less rain fall (less relative humidity) throughout the crop growth, the disease incidence was very low.

5.1.8.2 Other pests and diseases

i. Fusarium wilt

Fusarium wilt caused by *Fusarium oxysporum,* a systemic disease leading to collapse of the entire plant affects the cowpea all over the world. In this study among 44 accessions of yard long bean, seven had moderate incidence of fusarium wilt. In bush cowpea, four out of 22 accessions were moderately affected by fusarium wilt.

The rest of the accessions were free from this fungal disease. Low humidity during the growing period may be the reason for low incidence of the disease.

ii. Pod borer

Legume pod borer, *Maruca vitrata* (Fab.), the most important post-flowering pest of cowpea in the tropics, is a major limiting factor in cowpea cultivation in all seasons. In high rain fall areas, the crop loss due to the pest goes even up to 80 percent (Jackai and Adalla, 1997).

Analysis of variance revealed significant differences among accessions for pod borer incidence. The percentage of pod borer incidence ranged from 15.68 to 44.57 and 17.44-36.99 in yard long bean and bush cowpea respectively. Among 44 accessions of yard long bean, VS 5 had highest pod borer infestation. In bush cowpea VU 3 had highest infestation. On the other hand, VS 44 in yard long bean and VU 24 in bush cowpea had comparatively low pod borer damage. The findings are in line with Resmi (1998),Manju (2006) and Jithesh (2009)who reported variability in pod borer incidence in yard long bean.

It is observed that webbing together of flowers and pods, a typical symptom of heavy incidence of pod borer. Resmi (2006) and Jithesh (2009) also observed the same.

Singh (1978) reported that cowpea varieties with long upright peduncles that hold pods away from the canopy as well as from each other suffers less damage by pod borer. Oghiakhe *et al.*, (1992) also reported that the pod borer damage was less in varieties with wide pod angle. This means that varieties with indeterminate growth habit, especially yard long bean types having short peduncles and closely placed pods that are held within the canopy were suffered severely with pod borers than bush cowpea. In the present investigation also, of pod borer incidence in yard long bean (28.59) was more than bush cowpea (27.75).

Genetic parameters for pod borer incidence were also studied. High heritability coupled with high genetic advance was noticed for pod borer incidence in both yard long bean and bush cowpea which offers scope for identifying resistant varieties through selection.

iii. Aphid

At flowering and early fruiting stage, most of the accessions were attacked by cowpea aphid (*Aphis craccivora*). Their adults and nymphs aggregate and suck sap from flowers, tender fruits and stem leading to yellowing, weakening and drying of pods and stem. High incidence was noticed in VS 10, VS 13, VS 18, VS 34, VS 36 and VS 46 in yard long bean and VU 3, VU 11, VU 20 and VU 24 in bush cowpea. The other accessions were free or moderately affected by cowpea aphid in both yard long bean bush cowpea.

5.2 Screening vegetable cowpea accessions for collar rot and web blight under artificial conditions

Collar rot and web blight of cowpea was first reported from Kerala by Lakshmanan *et al.* (1979). *R. solani* was indicated as the causal agent of the disease. Collar rot is initially manifested in the collar region of the plants right from the seedling stage. Collar rot begins as brownish – black lesions at soil level near collar region girdling the base of the stem leading to yellowing and drooping of leaves and rotting of roots. White mycelial growth often studded with small sclerotia is characteristically seen on the affected regions. Web blight appears as small circular light greyish-brown spots on leaf lamina which enlarges to oblong or irregular water soaked areas. Later shot hole symptoms are produced or the spots coalesce to cover entire leaf area resulting in shedding of leaves.

The disease results in a loss of photosynthetic area or total collapse of the crop depending upon the region of pathogen attack. *R. solani* incidence incurred yield loss of 10-60 per cent in horse gram (Dubey and Mishra, 1990), 30 per cent in urdbean (Sharma, 1999) and 6.66 to 75.35 per cent in mung bean. Fungicidal application even today remains as the easiest and best proven practical method to manage diseases caused by *R. solani.* Chemical control has been reported to be effective against the disease by Upamanyu *et al.* (2004).

Breeding for disease resistance is an excellent approach to overcome economic losses caused by pathogens in plants. Although plant disease can be controlled with chemicals, biological control and cultural practices such as crop rotation, tillage, plant density and clean seeds; resistant varieties tend to be the best option for low producer cost disease control. To initiate the search for resistance to disease, identification of sources of resistance is needed and the development of a technique to screen putative lines is the first step.

Collar rot and web blight symptoms are expressed in two phases caused by *R. solani*. Normally, collar rot phase of the disease is more severe and widespread than the web blight phase under normal conditions (Bhadrasree, 2007).

Screening experiments by various workers have indicated highly differential response of cowpea germplasm to the attack of collar rot and web blight in cowpea (Thies *et al.*, 2006; Berland *et al.*, 2009) and in common bean (Pamela, 2010). In the present investigation, the accessions showed significant variation for the incidence of collar rot and web blight.

Screening was done in open condition by giving artificial inoculation to all accessions. Even though sufficient number of sclerotia of *R. solani* was there in that inoculum none of the plant had shown collar rot and web blight symptoms even 30 days after inoculation. This may due to adverse climatic conditions like very high temperature and low relative humidity in the atmosphere. Under these conditions the plants did not show symptoms. So, once again this experiment was conducted under net house conditions and maintained favourable conditions like high humidity for pathogen development. By this time the plants had shown disease symptoms and the incidence and the disease development was studied.

Collar rot incidence ranged from 0 to 99.81 per cent and web blight disease index ranged from14.33-53.78. However, 12 accessions *viz.,* VS 6, VS 10, VS 13, VS

18, VS 19, VS 22, VS 32, VS 33, VS 37, VS 38, VS 39, VS 43 of yard long bean and six accessions *viz.,* VU 2, VU 5, VU 7, VU 13, VU 16 and VU 18 of bush cowpea did not develop any symptoms even after 21 days of inoculation. Based on these variations the accessions were categorized in to moderately resistant, tolerant, moderately tolerant, susceptible and highly susceptible. The above mentioned 12 accessions of yard long bean and six accessions of bush cowpea were categorized as moderately resistant. These accessions could very well be utilized in inter varietal crossing programme in cowpea for incorporating resistance to collar rot. For web blight effective resistant source could not be identified. Hence, screening for web blight resistance may be carried out by adding new genotypes from grain and wild cowpea sub species like *V. unguiculata* subsp. *dekindtiana*, and *V. unguiculata* subsp. *stenophylla.* Disease progress of collar rot was shown in Fig 11 and Fig12 in yard long bean and bush cowpea respectively.

Earlier epidemiological studies on collar rot and web blight showed that the infected leaves falling to the soil contaminate the soil and become soil borne inoculum which survives in the soil and it initiate infection later (Thies *et al.*, 2006; Berland *et al.*, 2009).

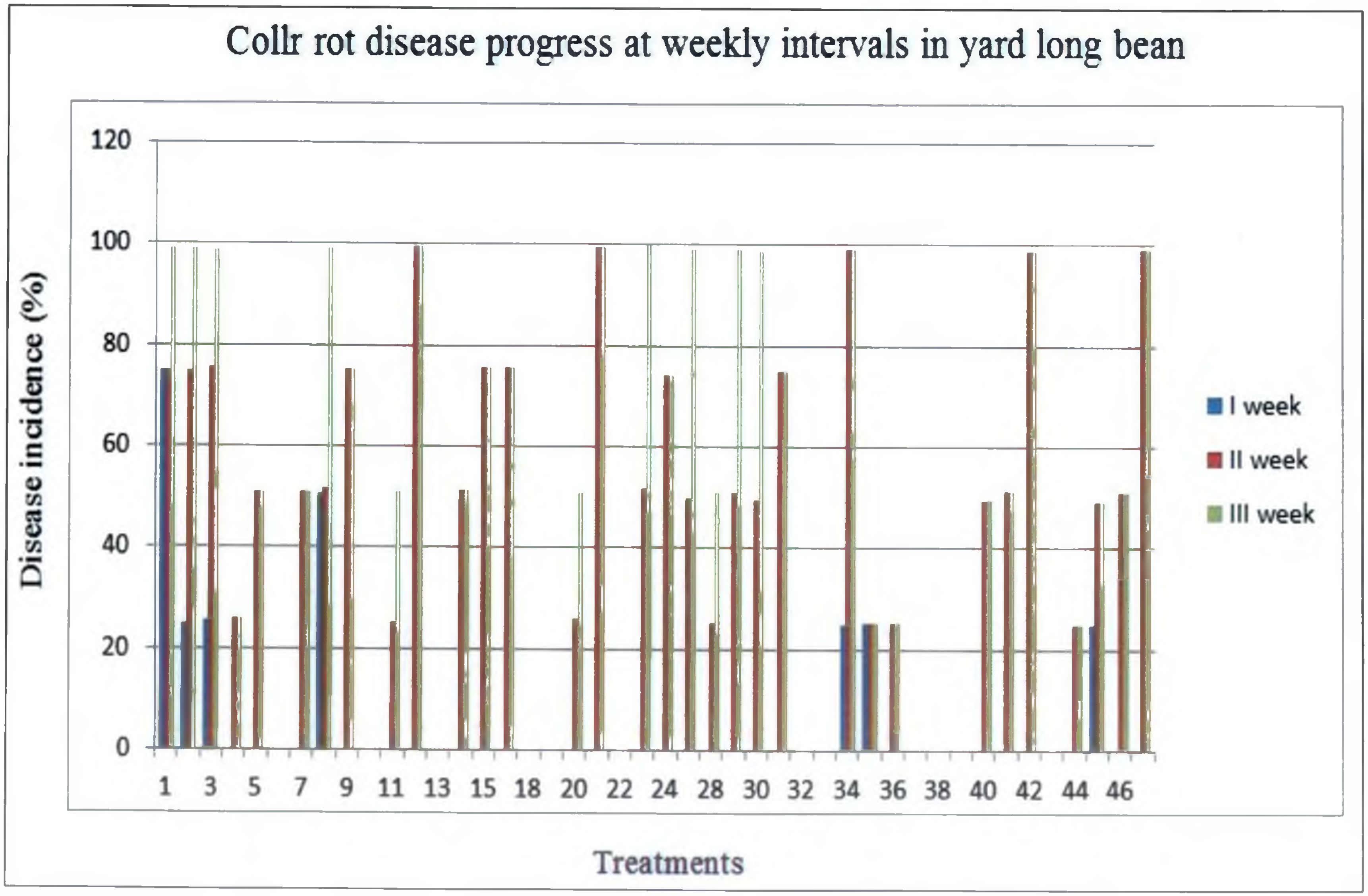
5.2.1 Basis of resistance to collar rot and web blight

5.2.1.1Role of plant characters

Discernment of morphological characters of plants conferring resistance or tolerance to collar rot and web blight is important in breeding for resistance. Morphological basis of resistance include factors such as pigmentation on leaf and stem, fruit colour and flower colour.

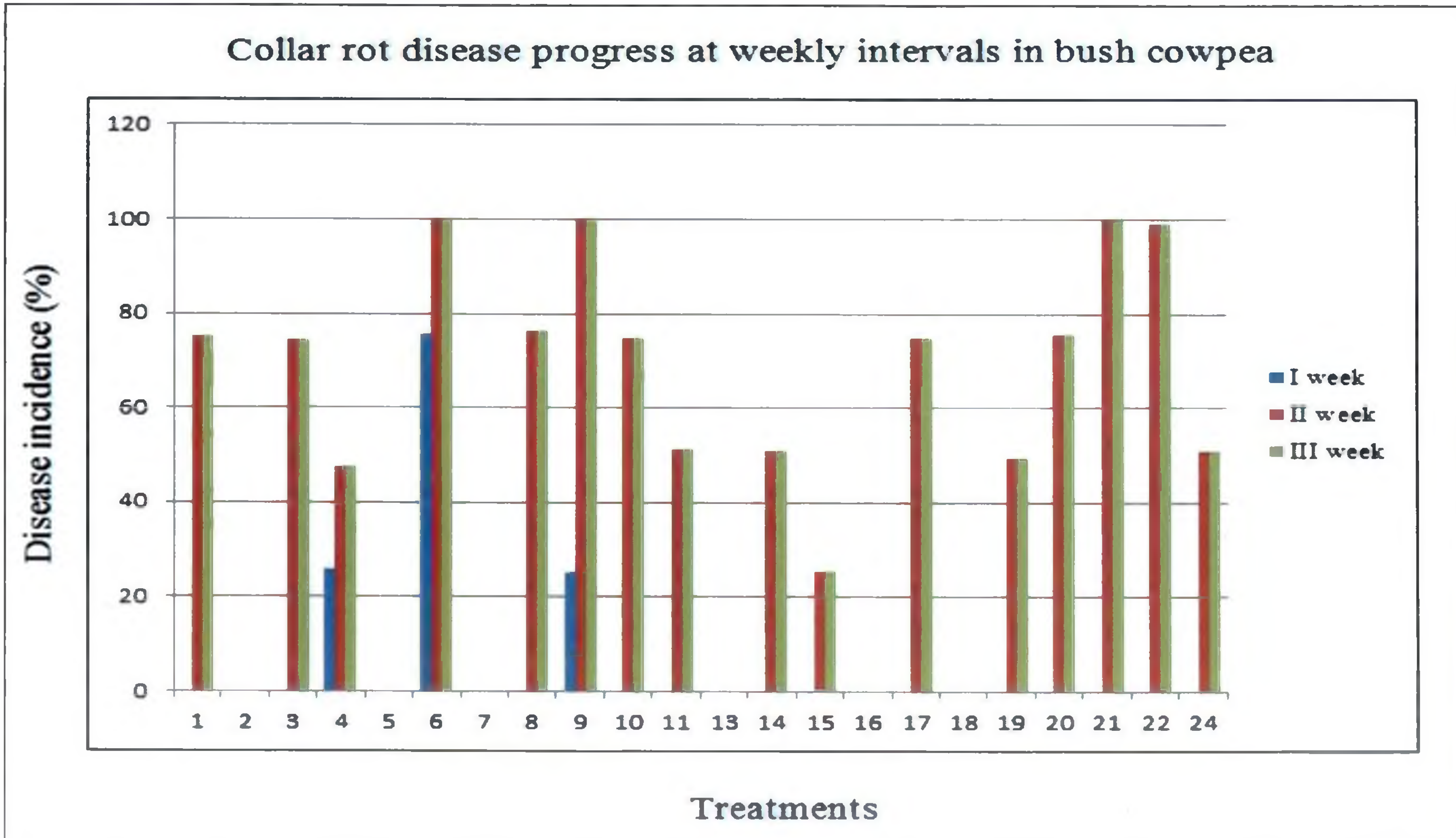
In the present investigation, pigmentation on leaf had no correlation with collar rot and web blight infection. Therefore, it may be suggested that pigmentation on leaf is not associated with collar rot and web blight incidence. The accessions, which had red pigmentation on stem, had shown moderate resistance or tolerance to collar rot. Pod pigmentation also showed a significant role in resistance/tolerance. All red

Fig 11



Collr rot disease progress at weekly intervals in yard long bean
Disease incidence (%)
120
100
80
60
40
20
0
1
3
5
7
9
11
13
15
18
20
22
24
28
30
32
34
36
38
40
42
44
46
Treatments
I week
II week
III week

Fig 12



Collar rot disease progress at weekly intervals in bush cowpea
Disease incidence (%)
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
13
14
15
16
17
18
19
20
21
22
24
I week
II week
III week
Treatments

podded accessions (VS6, VS 7, VS 13, and VS 33 in yard long bean and VU 18 in bush cowpea) had moderate resistance to collar rot. Accessions with light green and green coloured pods were most susceptible to collar rot and web blight.

In general varieties with high collar rot incidence were showing high web blight incidence also.

5.2.1.2 Role of anatomical characters

More number of well-developed vascular bundles was observed in moderately resistant and tolerant accessions compared to susceptible ones. This may offer mechanical protection by vascular bundles. This study also revealed that high trichome density and cuticle thickness provide resistance to collar rot and web blight. Similar findings were earlier reported in lentil for rust resistance by Reddy and Khare (1984) and in chickpea for Aschochyta blight by Iqbal *et al.*,(2002).

In the present study, there is a negative correlation between collar rot and web blight incidence and cuticle thickness. This finding is in corroboration with the earlier reports in grams for blight reaction (Ahmad *et al.*, 1952) and for Mycosphaerella blight (Hafiz, 1952).

This study also revealed that more number of stomata increases incidence of collar rot and web blight. Reddy and Khare (1984) observed higher stomatal density in the lentil cultivars susceptible to rust as compared to resistant ones. In the present study, highest stomatal density was observed in VS 47 and VU 6 (susceptible accessions) and lowest in VS 10 and VU 2 (resistant accessions) which indicated that the stomatal density had positive correlation with disease incidence.

5.2.1.3 Role of biochemical characters

In the present study, an attempt was made to evaluate the role of biochemical characters like phenol and proline in imparts resistance/ susceptibility to the disease. Total phenol content of leaf was markedly and positively correlated with resistance to collar rot and web blight in both yard long bean and bush cowpea, which was in conformity with earlier works of Todkar *et al.* (2005) and Lozoya-Saldana *et al.*

(2007). The phenols are oxidized by polyphenol oxidases to produce the toxic quinines and other oxidation products (Hung and Rohde, 1973), which might have imparted tolerance to disease.

Proline content also was positively correlated with resistance to the collar rot and web blight, which was reported previously by Feng Ming and Zhong (2005) and Matysik *et al.* (2002). This means that high proline content increases resistance collar rot and web blight. The proline content also had high negative association with stomata density. As leaf stomatal density increases, the plant will be more exposed to environmental stress, leading to increased proline production.

The present study clearly shows that accessions having high phenols and proline imparts resistance and could be utilized in breeding cowpea lines tolerant to collar rot and web blight. It is essential to strike proper balance between genotype with yield and pod quality coupled with resistance attribute.

Development of collar rot was meager when accessions were screened under field conditions. However, the accessions which were susceptible in field condition were also susceptible under artificial conditions. So it appears that accessions may behave differently under controlled and field conditions (Akem and Kabbabeh, 2000).So further field screening should be done under different climatic conditions to confirm resistance before involving these accessions in hybridization programmes.

The top performers based on *per se* performance and selection index values namely VS 34, VS 4 and VS 29 of yard long bean and VU 7, VU 1 and VU 14 of bush cowpea could be recommended for cultivation in locations where collar rot and web blight is not a serious problem after further multi-locational trials.

The study revealed that, though total resistance to the collar rot and web blight disease caused by *R. solani* could not be located in cowpea accessions, high level of tolerance was identified in some accessions. The results also indicate that the biochemical and anatomical features were distinct for tolerant accessions. These results usher hope for further exploitation of such tolerant ones in breeding programmes to evolve high yielding disease resistant lines.

SUMMARY

6. SUMMARY

The study entitled "Screening of vegetable cowpea (*Vigna unguiculata* (L) Walp.) germplasm for yield, quality and resistance to collar rot and web blight" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2011-2012. The data for the study were collected from field experiments and net house experiments.

In the first experiment, 44 yard long bean and 22 bush cowpea accessions collected from different parts of Kerala, State Agricultural Universities and Department of Olericulture, College of Agriculture, Vellayani were evaluated for genetic variability, yield, quality and tolerance to pests and diseases in two separate experiments laid out in randomized block design (RBD) with three replications.

Observations were recorded on different biometric characters *viz.*, vine length, primary branches, length and breadth of leaflets, petiole length, days to first flowering, days to first harvest, peduncle length, pod length, pod girth, pod weight, pods per plant and yield per plant. In screening for collar rot and web blight, observations were recorded on the basis of disease incidence and plant disease index with the help of score chart.

Analysis of variance revealed significant difference among the accessions of both yard long bean and bush cowpea for all the characters studied. VS 29 recorded highest yield per plant (1127.52 g) and pods per plant (87.09). Pod weight (67.06 g) and pod length (91.67 cm) was highest in VS 45.

In bush cowpea, VU 6 (310.41 g) was the highest yielder. Pods per plant was highest in VU 8 (70.30) and pod weight in VU 20 (12.44 g).

Phenotypic and genotypic coefficients of variation were high for days to first harvest, pod weight, pod protein and pod borer infestation in yard long bean and in bush cowpea for pod weight, vine length, seeds per pod and pod length while genotypic coefficient of variation was low for days to first flowering in yard long bean and peduncle length in bush cowpea.

Heritability estimates were high for all the characters studied except for primary branches per plant and length of terminal leaflet in yard long bean while, in bush cowpea all characters had high heritability values. In yard long bean heritability was highest for 100 seed weight (99.89 %) and lowest for primary branches per plant (58.09%). In bush cowpea highest value was recorded for pod weight (99.55%) and lowest value recorded for petiole length (61.53%).

At genotypic level yield per plant showed high positive correlation with pods per plant, primary branches per plant, pod length and pod weight in yard long bean whereas in bush cowpea, yield per plant showed high positive correlation with pod length, pod weight, pod girth, peduncle length and length and breadth of terminal and lateral leaflets.

Path coefficient analysis revealed that pods per plant, pod weight, pod length and vine length in yard long bean and pods per plant, pod weight, pod girth and days to first harvest had high direct effect as well as indirect effect through other characters on yield per plant.

In the present study, selection index was worked out and the top ranking accessions were VS 34, VS 4, VS 29 and VS 9 in yard long bean and VU 7, VU 1, VU 14 and VU 16.

The top performers based on per se performance and selection index values namely VS 34, VS 4 and VS 29 of yard long bean and VU 7, VU 1 and VU 14 of bush cowpea could be recommended for cultivation after further multi-locational trails.

In field condition, among 44 accession of yard long bean only 12 namely, VS 1, VS 2, VS 9, VS 14, VS 20, VS 21, VS 23, VS 24, VS 29, VS 30, VS 32 and VS 40 were infected with *R. solani* and shown collar rot symptoms, the remaining accessions were free from collar rot. All the accessions were free from web blight. In bush cowpea, among 22 accessions only four (VU 11, VU 15, VU 17 and VU 19) had shown collar rot symptoms and none of accession showed web blight symptoms.

Analysis of variance revealed significant differences among accessions for pod borer incidence.

The accessions of both yard long bean and bush cowpea were morphologically catalogued using the standard descriptor developed by IPGRI. The results revealed distinct variations among the accessions with respect of vegetative, floral, pod and seed characters.

In experiment II, the accessions were screened for collar rot and web blight disease resistance under artificial conditions by inoculating the pathogen *Rhizoctonia solani* to all accessions at seedling stage. This study revealed that remarkable variation exists in the incidence of the disease in both yard long bean and bush cowpea. Based on these variations the accessions were categorized in to moderately resistant, tolerant, moderately tolerant, susceptible and highly susceptible. Twelve accessions of yard long bean namely, VS 6, VS 10, VS 13, VS 18, VS 19, VS 22, VS 32, VS 33, VS 37, VS 38, VS 39 and VS 43 and six accessions of bush cowpea (VU 2, VU 5, VU 7, VU 13, VU 16 and VU 18) were rated as moderately resistant for collar rot; four accessions of yard long bean and accession VU 15 of bush cowpea were tolerant and 10 accessions of yard long bean and five accessions of bush cowpea were was moderately tolerant to collar rot. In terms of plant disease index for web blight, VS 47 (53.78) and VS 2 (50.54) of yard long bean and VU 9 (43.60), VU 22 (43.14) of bush cowpea were severely affected.

An attempt was made to unravel the basis of resistance to collar rot and web blight by study in morphological, anatomical and biochemical characters.

Morphological characters like pod colour, stem pigmentation and flower pigmentation were related to collar rot and web blight resistance. Light green and green coloured pods were comparatively more susceptible than red coloured ones. Stem pigmentation also showed significant effect on resistance or tolerance to collar rot and web blight. The accessions which were having red pigmentation on stem were comparatively resistant to collar rot.

More number of vascular bundles, cuticle thickness and trichomes density were observed in moderately resistant accessions of yard long bean and bush cowpea compared to susceptible ones to collar rot and web blight. The accessions which were having high stomatal density were highly susceptible to collar rot and web blight.

Biochemical characters like phenol and proline were also responsible for resistance to collar rot and web blight. High amount of phenol and proline were contributing moderate resistance or tolerance to collar rot and web blight. The accessions which were more susceptible to collar rot were also susceptible to web blight.

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*Originals not seen

APPENDICES

Appendix- I

1. Vegetative characters	
1.1 Growth habit	-1. Acute erect/ 2.Erect / 3.semi/ 4.Intermediate/ 5.Semi-erect/ 6.Prostat 7.Climbing
1.2 Growth pattern	-1.Determinate/ 2.Indeterminate
1.3 Twinning tendency	-0.None/ 3.Slight/ 5.Intermediate/ 7.Pronounced
1.4 Plant vigour	-3.Non vigorous/ 4.Intermediate/ 7.Vigorous/ 9.Very vigorous
1.5 Leafiness	-1.Vigorously leafy/ 2.Leafy/ 3.Intermediate/ 4.Sparce, leaf size average or above/ 5.Sparce, leaf size small
1. 6Plant pigmentation	-0.None/ 1.Very slight/ 3.Moderate at the base and tips of petioles/ 5. Intermediate/ 7.exensive/ 9.Solid
1.7. Plant hairiness	-3.Glabrescent/ 5.Short appressed hairs/ 7.Pubescent to hirsute
2. Inflorescence and fruit characters	
2.1 Duration of flowering	-1.Asynchronous/ 2.Intermediate/ 3.Synchronous
2.2 Raceme position-	-1. Mostly above canopy/ 2.In upper canopy/ 3.Throughoutcanopy
2.3 Flower colour	-1.White/ 2.Violet/ 3.Mauve pink/ 4.Others
2.4 Calyx colour	-0.green/ 3.Light pigmented/ 5.Deeply pigmented
2.5 Pod attachment to peduncle	-3.Pendent/ 5.30-90° down from erect/ 7.erect
2.6 Immature pod pigmentation	-0None/ 1.Pigmented tip/ 2.Pigmented sutures/ 3.Pigmented valves, green sutures/ 4.splashesof pigment/ 5.Uniformly pigmented/ 6.Other
2.7 Pod curvature	-0.Strait/ 3.Slightly curved/ 5.Curved/ 7.Coiled
2.8 Seed colour	-1.Light brown/ 2. Light brown and white/ 3.Brown/ 4.Brown with strips/ 5.Brown with white tip/ 6.Brown and white/ 7.Dark brown/ 8.Creamy white/ 9.Black

SCREENING OF VEGETABLE COWPEA (*Vigna unguiculata* (L) Walp) GERMPLASM FOR YIELD, QUALITY AND RESISTANCE TO COLLAR ROT AND WEB BLIGHT

By

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ABSTRACT

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The present investigation on "Screening of vegetable cowpea (*Vigna unguiculata* (L) Walp.) germplasm for yield, quality and resistance to collar rot and web blight" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2011-2012. The objective of the study was to assess the genetic variability for yield, quality and resistance to collar rot and web blight and elucidating the morphological, anatomical and biochemical basis of collar rot and web blight resistance. The study was conducted in two separate experiments.

1. Evaluation of cowpea accessions for genetic variability, yield, quality and resistance or tolerance to pests and diseases.
2. Screening vegetable cowpea accessions for collar rot and web blight resistance under artificial conditions.

In experiment I, 44 accessions of yard long bean and 22 bush cowpea accessions were collected from different parts of country and grown in the field in RBD with three replications as two separate experiments. Analysis of variance revealed that significant difference among the accessions for all the characters studied. Among the accessions, VS 29 (Malappuram local) had the highest yield (1127.52 g) and pods per plant (87.09), while VS 45 was noted that highest pod length, pod girth and pods weight.

Correlation studies revealed that characters like primary branches per plant, pods per plant, pod length and pod weight in yard long bean and length and breadth of leaflets, peduncle length, pod length, pod girth and pod weight in bush cowpea observed high positive correlation with yield, whereas peduncle length, days to first harvest and 100 seed weight in yard long bean were negatively correlated with yield. The path coefficient analysis indicated that pods per plant, pod weight, and pod length had direct effect on yield per plant.

Phenotypic and genotypic coefficients of variation were high for days to first harvest, pod weight, pod protein and pod borer infestation in yard long bean and in bush cowpea for pod weight, vine length, seeds per pod and pod length while genotypic coefficient of variation was low for days to first flowering in yard long bean and peduncle length in bush cowpea.

In yard long bean VS 34 followed by VS 4, VS 29, VS 9 and VS 1 were having the highest selection index values based on discriminant function analysis. VU7, VU 1, VU 14, VU 16 and VU 6 were having the highest selection index values in bush cowpea.

On screening the accessions for legume pod borer resistance, VS 44 in yard long bean and VU 24 in bush cowpea were found to be most tolerant, while VS 5 in yard long bean and VU 3 were more susceptible.

In field condition, among 44 accession of yard long bean only 12 namely, VS 1, VS 2, VS 9, VS 14, VS 20, VS 21, VS 23, VS 24, VS 29, VS 30, VS 32 and VS 40 were infected with *R. solani* and shown collar rot symptoms, the remaining accessions were free from collar rot. All the accessions were free from web blight. In bush cowpea, among 22 accessions only four (VU 11, VU 15, VU 17 and VU 19) had shown collar rot symptoms and none of accession showed web blight symptoms.

Experiment II was conducted in net house by artificially inoculating the pathogen to all the accessions which were used in experiment I. In screening for collar rot and web blight, the incidence ranged from 0 to 99.81 per cent and 14.32 to 53.78 per cent for collar rot and web blight respectively in yard long bean whereas in bush cowpea collar rot ranged from 0 to 99.64 per cent and web blight ranged from 17.12 to 43.60 per cent. However, 12 accessions of yard long bean *viz.,* VS 6, VS 10, VS 13, VS 18, VS 19, VS 22, VS 32, VS 33, VS 37, VS 38, VS 39 and VS 43 and six accessions of bush cowpea *viz.*, VU 2, VU 5, VU 7, VU 13, VU 16 and VU 18 showed moderately resistance to collar rot and web blight.

In both yard long bean and bush cowpea, high positive phenotypic and genotypic coefficient of variation were noticed between collar rot and web blight resistance and proline content phenol content, trichome density, cuticle thickness and number of vascular bundles, while negative correlation was observed with stomatal density.

The study revealed that moderately resistant accessions had more number and well developed vascular bundles, high trichome density and cuticle thickness and less stomatal density compare to susceptible ones. High phenol and proline content were responsible for tolerance to collar and web blight resistance. Pod colour was related to collar rot tolerance. Light green and green coloured pods were more susceptible compared with red pod accessions in yard long bean as well as bush cowpea.