IDENTIFICATION OF YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) GENOTYPES SUITABLE FOR POLYHOUSE CULTIVATION

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KERALA, INDIA

2015

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by

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DEPARTMENT OF OLERICULTURE

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2015

DECLARATION

I, hereby declare that this thesis entitled **"IDENTIFICATION OF YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) GENOTYPES SUITABLE FOR POLYHOUSE CULTIVATION"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis, entitled **"IDENTIFICATION OF YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) GENOTYPES SUITABLE FOR POLYHOUSE CULTIVATION"** is a record of research work done by independently by Ms. Litty Varghese (2013-12-105) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	Per cent
>	Greater than
<	Less than
µg	Microgram
CD	Critical difference
COC	Copper oxy chloride
cm	Centimeter
cm^2	square centimetre
et al.	And others
Fig.	Figure
g	Gram
GA	Genetic advance
GCV	Genotypic coefficient of variation
h^2	Heritability
Ha	Hectare
ha^{-1}	Per Hectare
hrs	Hours
ID	Internal diameter
i.e.	That is
IPGRI	International Plant Genetic Resource Institute
KAU	Kerala Agricultural University
Kg	Kilogram
Klux	Kilo lux
L	Litre
M	Metre
m^{-2}	Per meter square
Mg	Milligram
Ml	Milliliter
Mm	Millimeter
mm^2	square millimeter
Max.	Maximum
Nm	Nanometer
No. of	Number of

^{0}C	Degree Celsius
OTC	Open top chamber
PCV	Phenotypic Coefficient of Variation
Ppm	Parts per million
Q	Quintal
RH	Relative humidity
Sec	Seconds
s^{-1}	Per second
SE	Standard error
sp.	Species
t	Ton
UV	Ultra violet
var.	Variety

INTRODUCTION

I. INTRODUCTION

Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) also known as 'asparagus bean', 'chinese long bean' and 'snake bean' is one of the most popular and remunerative vegetable crop traditionally grown in the humid tropics of Kerala. It is a distinct form of cowpea grown for its immature pods. The traditional vernaculars *viz*., 'Achingapayar', 'Kurutholapayar', 'Vallipayar' and 'Pathinettumaniyan', used to refer yard long bean indicate that Kerala is the land of this crop. Perhaps it is the only vegetable evenly distributed and preferred in all the 14 districts of Kerala. The crop, native of central West Africa is now extensively cultivated in many countries in South East Asia such as Taiwan, Philippines, Indonesia, Thailand, India, Pakistan, Bangladesh and South China. 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. But the quality and productivity is low during the monsoon periods due to heavy rainfall and unfavorable conditions resulting in increased vegetative growth and incidence of pests and diseases. The growing demand for yard long bean had led to large scale intensive cultivation. This in turn, resulted in heavy crop loss. Hence in the present scenario of high demand for quality vegetables and drastically shrinking land holdings in the state, protected cultivation is the best alternative and drudgery less approach for using land and other resources more efficiently.

Protected cultivation is a unique and specialized form of agriculture in which the micro climate surrounding the plant is controlled partially or fully, as per the requirement of the plant species grown (Mishra *et al*., 2010). The main objectives of protected cultivation are, to protect the crop against biotic (pests, diseases and weeds) and abiotic (temperature, humidity, light) stresses and to ensure round the year production of high-value vegetables. Usually in open field conditions, plants experience short cropping season but under protected conditions, the environmental factors are controlled or altered to a desirable extent to provide long growing period for the crop. It can reduce the amount of water and chemicals used in production of high value vegetables compared to open field conditions. It has the potential of fulfilling the requirements of small growers as it can increase the yield manifold. It supports the production of high quality and clean products. Management and control of insect – pests, diseases and weeds is easier under protected condition. However, profitability in protected cultivation depends upon the choice of structure, selection of crop, selection of varieties, production technology and market price.

Kerala has a tropical humid weather characterized by high rainfall and humidity. The intense rainfall during June- September is a limiting factor for vegetable cultivation. High cost of labour, rapid urbanization, small size of holdings and quality conscious consumers are some of the factors favouring protected cultivation in Kerala. Rain shelters and modified naturally ventilated polyhouse are recommended protected structures for vegetables (Kutty *et al.,* 2014). Naturally ventilated polyhouse is a zero-energy model greenhouse with natural ventilation from sides and top. Saw toothed design has the maximum ventilation and is most effective and suitable for crop production. The important vegetables grown under protection in Kerala are cucumber, yard long bean, capsicum, tomato, cabbage, cauliflower and leafy vegetables.

The temperature inside a conventional polyhouse is 4-5^{o} C higher than the ambient condition. As the microclimate inside the polyhouse is modified, the varieties suitable for open condition may not perform well under polyhouse condition. Therefore, it is imperative to develop suitable varieties/hybrids to enhance the productivity of vegetables.

The success of any breeding programme largely depends on the extent of genetic variability available in a breeding population. Also the degree of transmission of these characters from one generation to next can be ascertained by partitioning the total variability into heritable and non heritable components, with the aid of suitable genetic parameters like coefficient of variation, heritability and genetic advances. An estimate of interrelationship between yield with other traits is of immense help to a breeder. Correlation studies would facilitate effective selection for simultaneous improvement of one or many yield contributing components. Apart from these, path analysis and discriminant function analysis helps to determine the extent of improvement that could be made in yield contributing characters.

Hence the present investigation was attempted with the following objectives

1. To evaluate the yard long bean genotypes under naturally ventilated polyhouse for yield, quality and resistance to pests and diseases
2. To assess the genetic variability present in yard long bean
3. To study correlation and path analysis of different characters
4. To rank the genotypes based on selection index

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) belonging to the family fabaceae is as important vegetable crop grown all over Kerala. But the productivity of crop is limited by a complexity of biotic (pest and diseases) and abiotic (rainfall, temperature, relative humidity and light intensity) factors. To overcome these problems protected cultivation is the most appropriate strategy. In yard long bean, attempts were made to study the genetic variability for various productive traits, inheritance of these traits and correlation between yield and its components. The literature pertaining to protected cultivation and variability studies were reviewed and presented in this chapter under the two major heads.

2.1. Protected cultivation of vegetables

2.2. Variability studies in cowpea

2.1 PROTECTED CULTIVATION OF VEGETABLES

Conventional crop production in the open field is highly risky due to environmental stress such as extreme solar radiation, high rainfall, high surface wind, weed competition and incidence of pests and diseases (Kamaruddin, 2007). Protected cultivation is the modification of natural environment to achieve maximum plant growth. In this system, various factors of the environment such as air, temperature, atmospheric gas composition, humidity, nutrient factor etc. are controlled (Prabhu *et al.,* 2010). Greenhouse vegetable production make use of recent advances in technology to control the environment for maximizing crop productivity and quality of the produce (Wani *et al.*, 2011). The influence of protected cultivation on plant growth, yield, quality and incidence of pest and diseases of vegetables is given below.

2.1.1 Growth Characters

Growth characters like plant height, number of branches, leaf length and breadth, intermodal length, peduncle length, leaf area and leaf area index of different vegetables were altered under protected cultivation.

Nagoata *et al*. (1979) observed increased plant height of tomato under 20 and 40 per cent shade compared to those grown under normal light conditions. Higher growth rate of tomato under greenhouse has been reported by Papadopoulos and Ormorod (1991). The plant growth and development at earlier stages was faster in tomato plants under shade than open place (Chowdhury and Bhuyan, 1992). Sharma and Tiwari (1993) reported that tomato plants grown under 50 per cent shade exhibited better growth in terms of plant height and dry matter production compared to those grown in open field. In a field trial conducted in tomato, Hazarika and Phookan (2005) found that plants under plastic rain shelter had higher growth rate compared to open condition. Tomato plants grown under shade exhibited better growth in terms of plant height and dry matter production compared to those in open field (Thangam and Thamburaj, 2008). Kavitha *et al*. (2009) reported that the growth characters like plant height and number of primary branches in tomato were higher under shade net as compared to open field condition. Kittas *et al*. (2009) studied the influence of shade on growth of tomato and observed an increase of about 40 per cent in LAI compared to open field cultivation.

Bhatt and Rao (1993) studied the response of bell pepper under polyhouse to night temperature and reported that the higher temperatures have more adverse influence on net photosynthesis than lower temperature leading to decreased production of photosynthates above a certain temperature. Marsin and Osvald (1997) observed that capsicum plants grown under low plastic tunnels produced taller plants compared to unprotected condition. Megharaja (2000) reported increased plant height and number of branches in capsicum under polyhouse condition compared to open field condition. Ganiger (2010) studied the response of bell pepper to organic nutrition under different environments and observed that the crop under shade house condition put forth better growth than open field condition in terms of plant height (90.34 cm and 67.98 cm, respectively) and plant spread (50.33 cm and 44.37 cm, respectively). Kumar and Arumugam (2010) found that polyhouse grown chillies exhibited better performance on growth characters like plant height (165.84 cm), number of branches (47.21) and internodal length (12.12 cm) compared to open conditions (80.33 cm, 35.50 cm and 7.86 cm, respectively). Pintu (2014) reported increased plant height, number of primary branches and leaf area index in chilli under polyhouse condition than open.

Gimenes *et al.* (1994) observed an increase in all growth parameters of lettuce grown under tunnels and under 30 per cent shade. Srichandran *et al*. (2006) observed increase in growth parameters of cauliflower under shade net condition than open. Dixit (2007) studied the performance of leafy vegetables like spinach, amaranthus, fenugreek and coriander under field and green house conditions and reported that plant height, number of leaves per plant, number of branches, length of leaves and width of leaves were higher for plants grown under greenhouse condition compared to those in the open field. Cultivation of cauliflower under polyhouse results in maximum plant height (69.5 cm) and the minimum was recorded in open condition (Pradhan *et al.*, 2008).

The plant height, number of branches, number of leaves per plant, intermodal length, leaf area and leaf area index were influenced by growing environment. All these characters of vegetables like chilli, brinjal, tomato, bhindi, cluster bean and cucumber were higher under shadenet house than open field (Rajasekar *et al.*, 2013). Kaddi *et al*. (2014) reported that in cucumber the vine length and number of leaves were significantly higher under naturally ventilated polyhouse and insect proof net house compared to open field in both seasons.

2.1.2 Yield Characters

Protected cultivation results in increased yield and yield attributes in vegetables. Yield attributes like fruit length, fruit girth, fruit weight, number of fruits per plant of different vegetables were altered under protected cultivation, which resulted in higher yield.

Hazra and Som (1999) found that the percentage of unmarketable fruit yield or poor quality fruits obtained was almost nil under polyhouse condition compared to open condition. Higher yield under polyhouse condition was reported by Kanthaswamy *et al*. (2000) in cucumber and sprouting broccoli and Ganesan (2002) in tomato. Vegetable like cucumber, bottle gourd, bitter gourd and sponge gourd have been raised as off season crop during winter under subtropical climate of Pant Nagar and average yields of 129,136, 65 and 52 t ha^{-1}, respectively were obtained (Prabhu *et al*., 2009).

Three cowpea varieties were evaluated under polyhouse, out of which the variety E'jiangdou was the best with the highest total yield, earliest yield, and highest total output value and economic benefit under low tunnel system (Chen *et al.,* 2001). Peksen (2002) reported that when the cowpea genotypes G10 and G18 were grown under protected condition, both of them were suitable for green pod production. But the G10 gave higher green pod yield per plant (271.9 g) than G18 (191.8 g). Average pod weight of the G10 genotype (7.2 g) was higher than the G18 genotype (3.1 g). Kutty *et al.* (2014) reported that the average productivity of yard long bean under polyhouse in Kerala is 33 t ha^{-1}.

Aruna and Sudagar (2009) carried out a study to evaluate the performance of capsicum varieties under polyhouse conditions and reported that all varieties showed better performance under polyhouse conditions. Bhatnagar *et al.* (1990) reported that the yield of capsicum was high under greenhouse compared to open field. Mean marketable yield of sweet pepper (4.62 kg m^{-2}) was high under plastic cover as compared to open (3.4 kg m^{-2}) and harvesting was early under plastic cover as compared to open field (Buczkowska, 1990). Nimje and Shyam (1991) reported that three vegetable crop sequence of okra- capsicum-capsicum gave capsicum yield of 105 t $ha^{-1}annum^{-1}$ inside the green house when compared to 38 t $ha^{-1}annum^{-1}$ under open field. Marsin and Osvald (1997) reported more fruits $plant^{-1}$ from *Capsicum annuum* when gown under plastic tunnel. A field experiment conducted by Jeevansab (2000) revealed that the fruit yield of capsicum differed significantly with the growing environments and it was found that fresh fruit yield (30.5 t ha^{-1}) was highest under polyhouse than that of open field condition (12 t ha^{-1}). Megharaja (2000) observed higher fruit length, fruit breadth, fruit volume, fruit weight and total fruits number in capsicum under polyhouse condition compared to open field. Capsicum crop grown in the naturally ventilated polyhouse showed four times more yield and yield components compared to those grown in the field (Nagalakshmi *et al*., 2001).

Vethamoni and Natarajan (2008) reported that in sweet pepper cultivars more number of fruits per plant were observed under 35 per cent shade (22.35) than open condition (5.7). Under 50 per cent shaded condition maximum fruit length (12.68 cm) fruit girth (23.65 cm) and fruit weight (203.13 gm) was reported. Yellavva (2008) reported that the yield parameters like number of fruits per plant, fruit yield per plant, total fruit yield, fruit weight, fruit volume and shelf life of capsicum was significantly higher under naturally ventilated polyhouse. Characters like individual fruit weight (199.6 g), fruit length (10.54 cm) and yield per plant under polyhouse were maximum for Arka Mohini, a capsicum variety (Aruna and Sudagar, 2009). Kumar and Arumugam (2010) observed that fruit length (14.52 cm), average fruit weight (11.68 g) and number of fruits per plant (73.47) was maximum under naturally ventilated polyhouse compared to open conditions (10.16 cm, 9.66 g and 57.56, respectively) and the percentage of yield increase in polyhouse grown chilli was about 175.85 per cent over open field. Singh *et al*. (2011) studied performance of sweet pepper (*Capsicum annuum*) varieties under protected and open field conditions in Uttarakhand and it was observed that average crop duration (200 days), fruit diameter (5.14 cm), number of fruits per plant (42.0), individual fruit weight (49.85g), fruits yield per plant (2.12 kg) and yield per m^{-2} (12.75 kg) was higher under polyhouse compared to open field condition. Singh *et al*. (2012) reported a loss of 51.30 per cent of fruit yield in capsicum in open field condition compared to polyhouse condition, whereas in terms of economic loss there was 74.19 per cent saving in yield. The yield of sweet pepper was higher under shadenet house due to high relative humidity, which enhanced vegetative growth and improved fruit production (Rajasekar *et al.*, 2013). Singh *et al*. (2013) studied the effect of low poly-tunnel on the yield and harvesting span of sweet pepper and reported that fruit number plant^{-1} (18.9), total yield (278.2 q ha^{-1}) and harvesting span (93 days) were significantly more in low plastic nonperforated tunnel compared to unprotected and February transplanted crops. More number of flowers and high fruit set per cent resulted in high number of fruits and yield in capsicum hybrids under naturally ventilated polyhouse (Kumar *et al*., 2014). Pintu (2014) reported that chilli grown under polyhouse situation recorded significantly higher fruit length (11.77cm), number of fruits per plant (110.67), fruit yield per plant (604.08 g) and total fruit yield (29.54 t ha^{-1}). Polyhouse cultivation recorded significantly maximum growth, yield and fruit quality of capsicum as compared to shade house condition (Biradar *et al*., 2015).

Bowen and Frey (2002) carried out an experiment to study the performance of plasticultured tomato, it was observed that plants grown using polyethylene mulch and mini-tunnels had shown larger and more productive fruit with thicker pericarps and higher water content. Mashego (2001) conducted a study to evaluate the effect of different types of shade netting as well as full sunlight on tomato production and it was found that the highest number of fruit plant^{-1} (47) was produced under shaded condition compared to open field condition. Tomato crops grown under polyhouse conditions were earlier to flower and had higher yield than those in the field (Nagalakshmi, *et al*., 2001). In the case of tomato, average fruit weight (99.43 g), number of fruits per plant (43.49) and fruit yield per plant and total yield was the highest (4.32 and 45.67 Kg) in polyhouse (Kumar and Arumugam, 2010). In high rainfall area of Jorhat, tomato yields were observed to be 60-70 per cent higher under polyhouse and the flowering, fruit setting and fruit maturity in polyhouse tomato plants were advanced by about 3, 4 and 5 days, respectively than open field condition (Parvej *et al.,* 2010). Cultivation of tomato under the polyhouse produced 136.12 per cent more yield per ha and 188.93 per cent more fruits per plant compared to open field cultivation (Kanwar, 2011). Sharma *et al.* (2011) identified tomato hybrids with high yield and quality under low cost plastic greenhouse for year round production.

Minimum days required for curd initiation in cauliflower under polyhouse was 60.3 and highest yield per hectare was 54.79 ton under polyhouse (Pradhan *et al.*, 2008). Tropical cabbage hybrids were evaluated in open and polyhouse condition for their performance (Malu, 2011). The results revealed that net head weight was maximum for NS 43 inside polyhouse, maximum head length was observed for the hybrid Disha (14.26 cm) and harvest index was maximum for NS 43 (67.70). The study concluded that NS 43 is ideal for protected condition. Cabbage, cauliflower, trailing tomato and capsicum were grown in polyhouse and the results showed that total yield per unit area and early flowering was attained in polyhouse than in open condition (KAU, 2013).

Lange and Combark (1997) studied the effect of using plant covers and soil mulches on yield of seedless watermelon and it was reported that, with the use of plastic covers in August and September a higher yield of 76 t ha^{-1} was obtained in watermelon compared to uncovered plants (49 t ha^{-1}). Kaddi *et al*. (2014) reported that in cucumber the number of seeds per fruit was significantly higher in insect proof net house (204.15) and naturally ventilated polyhouse (188.35) as compared to open condition (126.05). The fruit weight, fruit length and fruit width were significantly higher under naturally ventilated polyhouse and insect proof net house compared to open field in both the seasons.

2.1. 3 Quality Characters

Protected cultivation results in the production of high quality vegetables. Various workers reported that quality characters like shelf life, capsaicin content, TSS and ascorbic acid content were higher under protected condition.

Capsicum fruits obtained from polyhouse had higher ascorbic acid compared to fruits of open field (Jeevansab, 2000). Yellavva (2008) conducted a study on capsicum and revealed that plants under naturally ventilated polyhouse had higher shelf life compared to other conditions. The capsicum fruits from shade house cultivated plants recorded less physiological loss in weight and was found to be high in ascorbic acid compared to fruits obtained from open field conditions (Ganiger, 2010). Pintu (2014) reported that chilli grown under polyhouse with fertigation recorded higher shelf life (12.00 days), capsaicin (1.43 %) and ascorbic acid (108.74 mg 100 g^{-1}).

Ahluwalia *et al*. (1996) reported that quality of tomato obtained from greenhouse condition was better compared to open field condition. Mahajan and Singh (2006) conducted a study on tomato under low cost naturally ventilated greenhouse and greenhouse tomato fruits were found to be superior than fruits of open field crop in view of fruit size, TSS content, ascorbic acid content and p^H. Thangam and Thamburaj (2008) reported a decrease in ascorbic acid content under shade in tomato.

High nutrition value of leafy vegetables produced in trenches under cold desert condition of Leh was reported by Yadav *et al*. (1999). Thapa *et al.* (2013) conducted an experiment to determine the growth, yield and quality of sprouting broccoli under polyhouse and open field condition with four hybrid varieties. Results indicated that the plants grown in the polyhouse were superior than those grown in the field. Quality attributes like, chlorophyll a, chlorophyll b, total chlorophyll, reducing sugar, non-reducing sugar and total sugar were also found significantly increased in polyhouse grown crops.

2.1.4 Pest and Disease Incidence

Protected structures act as physical barrier and play a key role in integrated pest management by preventing spread of insect pests and viruses causing severe damage to the crop (Singh *et al*., 2003).

Under open field, vegetables were highly susceptible to insect (white fly, mites, aphid, fruit fly, borers, cutworm, hoppers and beetle) attack, which caused about 30-40 per cent loss in vegetable yield (Satparthy *et al*., 1998; Singh, 1998). Ganesan and Subhasini (2001) observed that by growing crops under polyhouse, it was easy to protect the crops against pests and diseases under extreme climatic conditions.

Singh *et al.* (2009) reported a minimal incidence of fruit borer and vector white fly in tomato plants grown under polyhouse structure. Singh *et al*. (2012)

conducted an experiment on insect-pest incidence in tomato and capsicum under open field and polyhouse conditions. The results revealed that the incidence of insect-pest was minimum under polyhouse condition as compared to open field condition. Kittas *et al*. (2009) studied the influence of shade on disease incidence on tomato, and observed a reduction of about 50 per cent incidence of disease than that under open field condition. Sing *et al*. (2011) reported that tomato plants grown in polyhouse experienced minimum incidence of bacterial wilt (3.08%) and blossom end-rot in fruits (4.32%) whereas it was maximum in open field condition, 75 per cent and 16 per cent, respectively.

Singh *et al*. (2005) reported that the pest affected plants and disease incidence through insect vectors in cucumber, summer squash and okra were low under protected condition compared to open condition and thereby savings of insecticide and money was higher under protected cultivation.

2.1.5 Meteorological Parameters

Meteorological parameters like maximum and minimum temperatures, relative humidity and light intensity were modified under protected condition. Kamaruddin *et al.* (2006) conducted a study under naturally ventilated tropical green house and the air temperature, wind speed, RH, light intensity and carbon dioxide were in the range of 30-40°C, 0.5-3.0 m s^{-1}, 53-83 per cent, 170-1400 x 10^3 lux and 300-400 ppm, respectively.

Smith *et al*. (1984) reported that under shade nets the air temperature was lower than that of the ambient air depending on the shading intensity. Gent (1990) conducted an experiment with tomato under floating row cover and observed that plant temperature under row cover was about 3-10ºC higher than those grown in the open. Ganesan (2002) observed that day temperature was higher under UV stabilized plastic film than the open environment. In a study conducted in polyhouse, Cheema *et al*. (2004) reported that the early and higher yield of different vegetable crops inside the polyhouse was mainly because of higher temperature (more than 4-9°C) compared to the nearby open field during winter months. Burt (2005) reported that optimum temperatures for fruit set was between 16 °C and 21 °C and for fruit development night temperatures of 15–17 °C and day temperatures of 24–30 °C were best. Comparison of the microclimatic parameters which affect the growth and physiology of plants was done in three conditions *viz*. open field, polyhouse and OTCs. Study revealed that increase in minimum as well as maximum temperature, relative humidity and soil temperature throughout the season were significantly higher inside the polyhouse. But CO_2 concentration varied according to the diurnal variation (Chaturvedi *et al*., 2010). The mean maximum and minimum temperature inside 3 meter ridge height green house is always higher than the 3.5 and 4 meter greenhouse and the maximum curd weight of 1501.70 g per plant in cauliflower was obtained in 4.5 meter height green house (Suseela and Rangaswami, 2011). Rahman and Inden (2012) conducted an experiment to study the effect of temperature stress on capsaicin content in sweet pepper cultivars. The six cultivars of sweet pepper were grown under two growing conditions of high temperature stress and low temperature and it was observed that capsaicin increased with increase in temperature. Mean weekly temperature during summer and winter were higher under open field conditions than in the shade net house. Lower temperature in the shade net house increased the plant height, number of branches, internodal length, average fruit weight and yield per plant (Rajasekar *et al*., 2013).

According to Yadav *et al.* (2014), the temperature inside the polyhouse is 6-10 ^{0}C higher than outside during winter. The cold waves during winter season (December to February) do not enter inside the polyhouse and inside environment become conducive for quick germination of vegetable seeds and growth of seedlings. The mean weekly minimum and maximum air temperature were found to be higher by 2 to 9°C inside the polyhouse than open field (Kumari *et al*., 2014).

Nimje and Shyam (1991) reported that relative humidity at 8 am was found to be lower inside the greenhouse except from May to August and the light intensity inside the greenhouse was also lower than in the open condition. A study was conducted to find out the relation between relative humidity with height of the greenhouse and the results revealed that among the three green houses, 4.5 m height greenhouse recorded higher relative humidity and was found to decrease with decrease in height (Suseela and Rangaswami, 2012). Rajasekar *et al.* (2013) conducted an experiment at TNAU, to screen ten vegetables for cultivation under shade net house (33% shade) and open field for year round production of vegetables. Relative humidity was always higher under shade net house than in open field during both seasons. Kumari *et al.* (2014) reported that relative humidity was always higher in the open field (2 to 7%) than protected condition.

Rylski and Spigelman (1986) reported that under field condition during summer, a reduction in radiation of approximately 26 per cent had a significant impact and increased production in *Capsicum annuum* compared with exposure to full sunlight. Lower amount of available PAR (photosynthetically active radiation) under polyhouse could not affect the growth and yield of tomato (Aberkain *et al*., 2006). Rajasekar *et al* (2013) conducted an experiment at TNAU, to screen ten vegetables for cultivation under shade net house and open field for year round production of vegetables. Light intensity in the shade net house was lower than in the open field. The maximum available light intensity inside the polyhouse was about 30 to 40 per cent lower than that of the open field. These microclimatic conditions inside the polyhouse favoured the performance of tomato and fruit yield obtained from the polyhouse was 65 t ha^{-1} against 33 t ha^{-1} from the open field (Kumari *et al*., 2014)

Weather parameters contributed for 78.24 to 84.65 per cent of total variation in the population of mite (Mandal *et al.,* 2006). Nandini (2010) and Monica *et al.* (2014) reported that the mite population showed high positive correlation with maximum temperature and negative correlation with relative humidity. On the other hand, Shah and Shukla (2014) reported that mite population had negative correlation with temperature and positive correlation with relative humidity.

2.1.6 Economics of Cultivation

Megharaja (2000) reported that capsicum grown under greenhouse resulted in highest net profit (Rs. 7,698 100 $m^{-2}crop^{-1}$) compared to open condition (282 100 m^{-2} $crop^{-1}$) with a cost benefit ratio of 1:1.46 as compared to open condition 1:0.24. Growing capsicum under polyhouse was not only productive (7614.60 kg 500 m^{-2} $year^{-1}$) compared to shade net house (3108.00 kg 500 $m^{-2}year^{-1}$) but also profitable in obtaining fruits of excellent quality fetching relatively higher price (Yellavva, 2008). Murthy *et al*. (2009) reported that production of capsicum under naturally ventilated polyhouse was higher and total net returns (undiscounted) for six years period was found to be Rs.115.4 lakhs ha^{-1} with an annual average net return of Rs.19.2 lakhs ha^{-1} with a benefit cost ratio of 1.8: 1. In capsicum, Singh *et al*. (2011) found that gross returns (Rs 211.81 m^{-2}), net returns (Rs 158.16 m^{-2}) and B: C ratio (1.0: 3.81) was higher under protected conditions compared to open condition. Pintu (2014) reported that in chilli among growing conditions, maximum net return (Rs 5.22 lakhs ha^{-1}) and B: C ratio (2.42) was obtained from polyhouse, than open condition (3.31 lakhs ha^{-1} and 1.62 respectively) and among varieties, Vellayani Athulya recorded maximum net return of Rs 4.95 lakhs ha^{-1} and B: C ratio of 2.30.

Singh *et al*. (2009) carried out a study on tomato inside naturally ventilated green house and the B: C ratio and net return per meter were worked out as 1.92 and Rs.72/- respectively, which clearly showed that the greenhouse vegetable cultivation was worth making the investment.

A study carried out on musk melon and summer squash by Singh *et al*. (2005) revealed that the plastic low tunnel technology for off season cultivation of musk melon and summer squash was highly profitable and suitable with a BC ratio of 3.98: 1 for muskmelon and 3.96: 1 for summer squash in their off season cultivation. It was also observed that growing of parthenocarpic cucumber under naturally ventilated green house was feasible with B: C ratio of 1:2.29 in peri urban areas of northern India and yield of about 80 quintals of high quality fruits of cucumber were harvested from 3 crop together with higher yield of okra.

2.2 GENETIC VARIABILITY STUDIES

Assessment of genetic parameters like variability, coefficient of variation, heritability and genetic advance, correlation studies, path analysis and selection index were important to formulate the selection programmes for improvement of yield.

2.2.1. Variability

Variability in vegetative, yield and quality characters were reported by various workers in vegetable cowpea and are reviewed here under.

2.2.1.1. Variability in Vegetative Characters

Variability in plant height was reported in cowpea by Sudhakumari, (1993) and Hazra *et al*. (1996). Mehta and Zaveri (1998) noticed high magnitude of genetic variability in cowpea for number of branches. Significant variability was noticed for plant height and number of branches per plant (Sobha and Vahab, 1998). Wide range of variation for plant height in cowpea was reported by Rangaiah and Mahadevu (2000); Tyagi *et al.* (2000) and Singh and Verma (2002). High variability was noticed among 50 cultivars of cowpea for plant height (324.13-652.47 cm) and number of branches per plant (2.1-5.4) (Vidya, 2000). Ajith (2001) reported that high range of variability in bush cowpea for plant height and number of primary branches per plant. Plant height was maximum for VU 10 (21.8cm) and minimum in VU 4 (15.93), VU 18 had the largest number of primary branches (5.4) and VU 19 had lowest number (1.93). High range of genetic variability was recorded for plant height and number of branches per plant in 50 genotypes of cowpea (Anbuselvam *et al*., 2001). Jyothi (2001) noticed broad spectrum of variability for number of branches per plant (2.5-6.4) and plant height (457- 510 cm) in cowpea. Significant variation in plant height was observed by Purushotham *et al.* (2001) in cowpea. Wide variabity among 50 yard long bean genotypes for main stem length and primary branches per plant was reported by Lovely (2005) and Jithesh (2009). High genetic variability was recorded for vine length, primary branches per plant, petiole length, leaflet length and breadth in 44 accessions of yard long bean and 22 accessions of bush cowpea (Sivakumar, 2012).

2.2.1.2 Variability in Yield Characters

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. In the case of days to flowering the mean value recorded ranged from 48.37 days to 55.93 days, number of pods per cluster value ranged from 1.9 to 2.13, mean value of pod length ranged from 31.68 cm to 40.22 cm and number of seeds per pod values recorded between 15.03 to 17.76. Significant variability was noticed among different cowpea cultivars for day to flowering, number of pods per plant, number of seeds per pod, pod length, 100 seed weight and yield per plant (Sudhakumari, 1993).

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

Significant variation in 102 accessions of vegetable cowpea genotypes for all yield characters studied except for dry pod yield was reported by Harshavardhan and Savithramma (1998a). Mehta and Zaveri (1998) noticed high magnitude of genetic variability in segregating generations of cowpea for number of clusters, number of pods and seed yield. Length of pod was maximum in VS 21 (54.29 cm) and minimum in VS4 (35.5 cm), pod girth was maximum for VS 14 (31.62 mm) and minimum for VS 18 (21.24), pod weight ranged between 15.3 g to 37.14g, maximum number of pods was recorded in VS4 (8.9) and minimum in VS 13(4.29) and pod yield per plant varied between 0.77 to 2.96 kg. Significant variability was noticed for days to 50 per cent flowering, 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.

Dwivedi *et al.* (1999) reported 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 in bush cowpea. Significant variability among 32 genotypes of cowpea was reported by Backiyarani *et al.* (2000) for days to 50 per cent flowering and yield per plant. 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. Tyagi *et al*. (2000) reported that days to 50 per cent flowering, 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 yard long bean for days to flowering (40.07- 52.33), number of pods per plant (14.13-45.53), number of inflorescence per plant (12.53-23.73), number of pods per inflorescence (1.67 – 4.47), pod length (32.33 – 57.07), and number of seeds per pod (16.73- 21.4) (Vidya, 2000).

Ajith (2001) reported that the characters, days to 50 per cent flowering, 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. Days to 50 per cent flowering varied from 44.33 to 54 days. Number of pod clusters per plant varied from 8.4 to 16.20, number of pods per cluster was maximum in VU 2 (3.2) and minimum in VU 13 (1.93), pod length ranged between 10 cm and 23.6 cm, pod girth ranged from 20.20 mm to 33.57 mm and pod weight from 4.5 g to 9.5 g. Yield per plant varied from 130 g to 215.73 g.

High range of genetic variability was recorded for days to 50 per cent flowering, 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 inflorescence per plant (7.5- 16.5), number of pods per plant (66.7 – 95.8), number of seeds per pod (16.4-19.5), 100 seed weight (8.5 – 16.8) and yield per plant (868 – 1020 g) in cowpea. In cowpea, Kavita *et al*. (2003) reported high range of genetic variability for days to 50 per cent flowering, which varied between 48.5 and

56.5 days. A wide range of variation was observed in almost all the characters studied in a set of 740 germplasm of cowpea including both indigenous and exotic origin (Mishra *et al.,* 2003).

All the ten yield related characters *viz*., days to 50 per cent flowering (65.17-90.40), pods per plant (3-70.37), pod length (2.67- 14.5 cm), seeds per pod (31.83-122.53), grain yield per plant (12.93-535.67 g) and 100 seed weight (0.3277- 0.7853) exhibited wide range of variation among the 50 genotypes of cowpea studied by Philip (2004). High range of variability for all important yield traits among different genotypes of yard long bean was reported by Resmi *et al.* (2004). High genetic variability was observed for pods per cluster which ranged from 0.42 in VS 21 to 4.78 in VS 19, yield per plant 21.03 in VS 8 to 406.06 in VS41, pod weight varied from 3.27 g in VS 7 to 26.49 in VS 20, pods per plant range was 3.09 in VS 21 to 45.41 in VS 30 and clusters per plant varied between 3.12 in VS 20 and 22.32 in VS 14 in yard long bean (Lovely, 2005). Nine genotypes of cowpea were studied for genetic variability and the results revealed that 100 seed weight varied between 12.3 and 29.3, days to first open flower was 4.03-82.52, Pod length (cm) varied between 12.77-15.11, Pod weight (g) varied between 4.57-8.95 and number of pod per plant was 3.47-6.37 (Omoigui *et al*., 2006).

Jithesh (2009) reported 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. Pod length ranged from 12.88 to 52.72 cm, pod weight from 8.2 to 27.73, pods per plant varied from 5.73 to 14.33, pod cluster per plant ranged from 4.07 to 9.13, pod yield per plant the ranged from 170.33 g to 415.33 g and 100 seed weight ranged from 7.33 to 19.73 g. Cobbinah (2011) reported that in bush cowpea pod length varied from 153.7 to 157.72 mm, pod girth from 7.84 to 8.66 mm, 100 seed weight from 11.44 to 14.32 g, number of pods per plant from 22.76 to 26.37 and seed yield per plant from 20.04 to 23.53.

Manggoel *et al.* (2012) studied ten cowpea accessions, and reported significant variability for days to 50 per cent flowering (43.87-62.45), flowers per plant (65.55-74.56), pods per plant (42.78-50.54), seeds per pod (9.58-14.88), pod length (15.75-19.58) and 100-seed weight (13.68-18.65). Sivakumar (2012) reported that among the 44 accessions of yard long bean pod length ranged from 27.13-91.67 cm, pod girth ranged between 2.47-4.63 cm, pod weight was ranged from 38.73- 67.06 g, pods per plant ranged from 19.3-87.09 and average yield ranged between 500.51-1127.5 g per plant. In bush cowpea also wide variability was recorded for all the yield characters. In cowpea number of seeds per pod, 100-seed weight, pod length, days to 50 per cent maturity, seed yield, number of leaves per plant contributed significantly to the total genetic variability. Yield and yield related traits contributes 82.23 per cent of total variability (Udensi and Edu, 2015).

2.2.1.3 Variability in Quality Characters

Wide range of genetic variability was reported for protein content in cowpea by Aghora *et al.* (1994). Significant variability among 32 genotypes of cowpea was reported by Backiyarani *et al.* (2000) for total chlorophyll content. Wide range of genetic variability was reported for protein content in cowpea by De *et al*. (2001); Kalaiyarasi and Palanisamy (2001). High genetic variability was reported in cowpea for keeping quality (2-5.50 days), pod protein (3.5 – 8.5) and pod fiber (1.95 – 3.72%) (Manju, 2006). Jithesh (2009) reported high variability among 50 yard long bean accessions for leaf chlorophyll content (1.12- 1.86 mg/g), pod protein (3.74- 8.72) and crude fibre content (1.96-5.26). Among the 44 yard long bean accessions the protein content was highest in VS 29 (9.22%) and least in VS 32 (3.17) and VS 5 had highest keeping quality (5.17) and VS 12 had least (3.07). In bush cowpea, protein content was highest in VU 18 (8.60 %) and least in VS 17 (3.69 %) and VU 24 had highest keeping quality (4.83 days) and VU 11and VU 16 had least (2.57 days) (Sivakumar, 2012).

2.2.1.4 Pest and Disease Incidence

Cowpea is subjected to a number of pests and diseases. Among diseases, collar rot and web blight caused by *Rhizoctonia solani* and fusarium wilt caused by *Fusarium* spp and among pests legume pod borer, *Maruca vitrata* (Fab.), cowpea aphid (*Aphis craccivora*) and red spider mite (*Tetranyches spp.)* were important.

Collar rot is the most common one causing severe economic losses in India (Shahina *et al*., 2003). 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. Thies *et al*. (2006) reported that cowpeas are more susceptible to seedling diseases caused by *R. solani* when planted in cold, moist, spring soils. Remarkable variation exists in the incidence of collar rot disease in yard long bean as reported by Sivakumar (2012).

Fusarium wilt is a major problem in the cultivation of cowpea (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. 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. Among 44 accessions of yard long bean, seven had moderate incidence of fusarium wilt as reported by Sivakumar (2012).

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). The percentage of pod borer incidence ranged from 15.68 to 44.57 and 17.44-36.99 in yard long bean (Sivakumar, 2012).

At flowering and early fruiting stage, cowpea was 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 of cowpea aphid was noticed in yard long bean by Sivakumar (2012).

Red spider mite (*Tetranychus spp.*) were reported in cowpea. Higher mite population was associated with high temperature and low relative humidity was reported by Monica *et al.* (2014).

2.2.2 Coefficients of Variation

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.

2.2.2.1 Coefficients of Variation for Vegetative Characters

PCV and GCV were high for plant height in cowpea (Sawant, *et al*., 1994; Harshavardhan and Savithramma (1998a); Hazra *et al.,* 1999). Selvam *et al.* (2000) reported high GCV, and PCV for plant height and number of branches per plant for 50 cowpea genotypes. High phenotypic and genotypic coefficients of variation were reported for main stem length and number of primary branches. GCV value for main stem length was 67.36 and number of primary branches was 29.17 and PCV values were 67.43 and 30.38 for main stem length and number of primary branches respectively (Ajith, 2001). The PCV was highest for primary branches (Nehru and Manjunath, 2001). High GCV and PCV were observed for plant height (Venkatesan *et al*., 2003; Girish *et al.,* 2006; Eswaran *et al*., 2007). Moderate values for GCV and PCV were reported in 44 accessions of yard long bean for characters like vine length, primary branches per plant, petiole length, length and breadth of leaflets and peduncle length. In 22 accessions of bush cowpea high GCV and PCV were reported for vine length only, all other characters had moderate values (Sivakumar, 2012).

2.2.2.2 Coefficients of Variation for Yield Characters

High value of GCV were also recorded for number of pods clusters and 100 seed weight. PCV and GCV were high for seed yield per plant, pods per plant and 100 seed weight in cowpea (Sawant, *et al*., 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 Natarajan (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).

In a study with 30 different genotypes of yard long bean, Resmi (1998) observed significant difference among the genotypes for all the 24 characters studied. The highest PCV was recorded for pod yield per plant (30.56) followed by number of pods per kilogram (26.54) and number of inflorescence per plant (25.16). The highest GCV was recorded for pod yield per plant (29.5) followed by number of pods per kilogram (26.5). Harshavardhan and Savithramma (1998a) recorded high PCV and GCV for green pod yield and pods per plant in cowpea. 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.

In cowpea characters such as 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 and pod weight recorded high PCV and GCV, which was low for days to first flowering. The maximum value of genotypic coefficient of variation was recorded for yield of vegetable pods per plant (27.53) followed by number of pods per inflorescence (24.92) and number of pods per plant (24.83). The highest phenotypic coefficient of variation was observed for yield of vegetables pods per plant (28.95) followed by number of pods per plant (26.39) and number of pods per inflorescence (25.60) (Vidya, 2000). Selvam *et al.* (2000) reported high GCV, and PCV for number of pods and seed yield for 50 cowpea genotypes.

High phenotypic and genotypic coefficients of variation were reported for pod weight. GCV value for pod weight was 22.43 and PCV value 24.22 respectively (Ajith, 2001). The PCV was highest for pods per plant followed by cluster 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). 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. A close association between phenotypic and genotypic variances were noticed for several characters in cowpea. Pod weight had the highest PCV (79.74) and GCV (79.12) followed by yield per plant (62.33 and 57.84 respectively) (Manju, 2006). Girish *et al.* (2006) reported high GCV and PCV for pods per plant.

The characters *viz.,* 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). Twenty diverse genotypes of vegetable type cowpea were evaluated, where phenotypic coefficient of variation was greater than genotypic coefficient of variation for number of cluster per plant, diameter of pod and number of seeds per pod manifested high heritability coupled with low genotypic coefficient of variation and genetic advance. In general the phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters (Tamgadge *et al.,* 2008). 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.

PCV was very high for the character pod length (35.94). The pod weight (34.94), pod yield (23.87), pods per plant (23.43), pods per plant (23.10) and 100 seed weight (21.87) also had high PCV indicating a high degree of variation. High GCV was observed for pod length (35.42) followed by pod weight (34.66), pods per plant (22.64), pod clusters per plant (22.23), pod yield per plant (21.13) and 100-seed weight (21.12) in yard long bean indicate that there exists high genetic variability and better scope for improvements of these characters through selection (Jithesh, 2009).

Adewale *et al.* (2010) studied the grain yield components of eleven cowpea genotypes. The total phenotypic variation for seeds/pod, 100 seed weight and pod yield are as follows: 11.12, 0.71, 41.28, 11.35 and 4.31 per cent respectively. In this study, the proportion of GCV in the PCV ranged between 68.42 (in pod length) - 99.88 (in 100 seed weight). Most of the traits exhibited fairly high to high GCV: PCV. Higher GCV: PCV denotes that the trait is much under the influence of genetic rather than environmental.

Sivakumar (2012) conducted a study in 22 diverse genotypes of bush cowpea and reported that high phenotypic coefficient of variation were observed for pod weight (37.84), pod length (25.03) and pods per plant (23.64). High genotypic coefficient of variation was observed for pod weight (37.52), pod length (24.7) and pods per plant (22.26). In 44 genotypes of yard long bean high phenotypic coefficient of variation was observed for pod weight (37.83), pod length (25.03) and pods per plant (23.64). High genotypic coefficient of variation was observed for pod weight (37.52), pod length (24.70) and pods per plant (22.26). In cowpea seed yield and number of clusters had high PCV and GCV (Pravin *et al.*, 2013). Days to first harvest recorded the highest GCV and PCV followed by pod weight, pod length, pods per plant and yield (Sivakumar and Celine, 2014).

2.2.2.3 Coefficients of Variation for Quality Characters

Jithesh (2009) reported that in yard long bean low GCV and PCV were reported for leaf chlorophyll content (12.3), followed by protein content (20.05) and crude fiber content of pods (25.66). Sivakumar (2012) reported that high GCV and PCV for protein content and moderate for keeping quality in 44 accessions of yard long bean. In bush cowpea moderate GCV and PCV was observed for protein content and keeping quality.

2.2.3. 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 per cent), moderate (30-60 per cent) and high (above 60 per cent) 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.

2.2.3.1 Heritability (H^2) and Genetic Advance (GA) for Vegetative Characters

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 a study with genotypes of cowpea on eight characters, Sharma (1999) observed high genetic advance for plant height (86.49%). 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 (95.85 per cent) and genetic advance (38.68) as reported by Vidya (2000). High heritability (92.21%) and high genetic advance (57.65) for primary branches per plant was reported by Ajith (2001) in bush type vegetable cowpea. High heritability coupled with high genetic advance for several characters was reported in bush type of vegetable cowpea. Plant height heritability was 96.33 and genetic advance was 53.89 and primary branches per plant 83.98 and 57.18 respectively (Philip, 2014). Anbumalarmathi *et al.* (2005) reported high heritability and genetic advance for plant height and primary branches per plant. Girish *et al.* (2006) reported high heritability and genetic advance for plant height. High heritability coupled with high genetic advance as per cent of mean was noticed for characters plant height, number of branches, and number of leaves, leaf length, stem thickness, leaf weight, stem weight and leaf stem ratio in cowpea (Mary and Gopalan, 2006). In yard long bean Jithesh (2009) reported that peduncle length had high heritability (99.46) and high genetic advance. In cowpea high genetic advances in the two crosses were reported for number of branch per plant (60.6; 59.8) and length of peduncle (61.4; 57.1) (Aremu, 2011). High heritability and genetic advances in yard long bean for vine length (94.37 & 35.23) and peduncle length (85.62 & 34.46) and in bush cowpea high values for vine length (97.42 & 64.32), length of terminal leaflets (94.29 & 34.08) were reported by Sivakumar (2012). High heritability and genetic advances was reported in cowpea for peduncle legth (Nwosu *et al.,* 2013).

2.2.3.2 Heritability (H^2) and Genetic Advance (GA) for Yield Characters

In a study of 35 genotypes of cowpea conducted by Sharma *et al.* (1988), the heritability values ranged from 46.9 per cent for green pod yield to 98.0 per cent for days to 50 per cent maturity. Evaluating 15 genotypes of cowpea under eight environments, Damarany (1994) reported high heritability values for weight of seeds per plant (94.4 per cent), number of pods per plant (85.9 %) and 100- seed weight

(83.3 per cent). Sreekumar *et al.* (1996) observed high heritability and low genetic advance for days to flowering.

In cowpea moderate to high heritability values of pods/plant and seeds/pod and their highly significant positive correlations suggested that pods /plant and seeds/pod are major yield contributing components by Uguru (1995). 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 that it can be effectively selected in the early generations of improvement of the crop.

In a study with genotypes of cowpea on eight characters, Sharma (1999) observed high genetic advance for days to 50 per cent pod maturity (34.73) followed by days to 50 per cent flowering (34.12) and days to 50 per cent pod formation (33.63). 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. Pod weight had high heritability (94.77 per cent) followed by number of pods per inflorescence (94.70%), pod length (91.76 per cent), number of inflorescence per plant (90.78%), yield of vegetable pods per plant (90.43 per cent) and number of pods per plant (88.48%). Genetic advance as percentage mean was high for yield of vegetable pods per plant (53.93) followed by pods per inflorescence (49.82) and number of pods per plant (48.13) (Vidya, 2000).

High heritability (85.64) and low genetic advance (4.88) 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 in bush type of vegetable cowpea. Fruit per plant heritability was 96.19 and genetic advance was110.83, fruit length 96.56 and 64.6, fruit girth 95.92 and 55.33, fruit weight 97.63 and 81.6, 100 seed weight 99.85 and 45.54 respectively by Philip (2004). High heritability coupled with high genetic advance was observed for pod yield per plant, pods per kg, inflorescence per plant and pod weight (Resmi *et al*., 2004)

Anbumalarmathi *et al.* (2005) reported high heritability and genetic advance for days to 50 per cent flowering and pod clusters per plant.

High heritability and medium genetic advance for days to 50 per cent flowering was reported by Awopetu and Aliyu (2006). Girish *et al.* (2006) reported high heritability and genetic advance for pods per plant. He also reported high heritability and low genetic advance for days to 50 per cent flowering. Broad-sense heritability estimate (h^2) was 98.9 per cent for 100-seed weight, 94 per cent for duration of reproductive phase, 84.5 per cent for days to first flower, 83.9 per cent for days to maturity, and 77.3 per cent for harvest index. The results of the pod development rate showed that varietal differences exist among cowpea genotypes (Omoigui *et al.,* 2006).

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 per cent flowering.

In yard long bean, Jithesh (2009) reported high heritability for the characters like pod weight and seeds per pod (98.41) except crop duration (66.21) followed by days to 50 per cent flowering and pods per cluster. He also reported that the characters trichome number (80.71) and pod length (71.89) had 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).

Idahosa *et al.* (2010) reported that among the parental lines of cowpea highest genetic variance was found in seed yield (57977.5). In all other genetic parameters, high heritability was observed except for 100–seed weight which was moderately inherited (42.2%). In cowpea genetic advance in the two crosses were very high for seed yield (60.1; 56.7) for the two crosses when selection was made at F3 with response in F4 (Aremu, 2011). High heritability coupled with high genetic advance were observed for all characters in bush cowpea. The heritability and genetic advances values as follows, pod length (97.44 & 50.25), pod girth (93.14 & 26.92), pod weight (98.34 & 76.64), pods per plant (88.68 & 43.14), yield per plant (83.92 & 34) and 100-seed weight (99.89 & 29.34) (Sivakumar, 2012).

Studies on genetic variability, heritability and genetic advance were carried out with five genotypes of cowpea cultivated at two agroecological environments. Result revealed that the high heritability and genetic advance as per cent of mean were shown by clusters per plant, pods per plant, pod length, dry pod weight, hundred seed weight, seed per pod, number of seeds per plant and seed yield per plant indicating that these traits were controlled by additive genetic effects and could be dependable for grain improvement in cowpea (Nwosu *et al.,* 2013). High heritability and genetic advances were observed for 100 seed weight, seeds per pod length, pod weight, yield per plant and number of pods per plant in yard long bean (Sivakumar and Celine, 2014).

2.2.3.3 Heritability (H^2) and Genetic Advance (GA) for Quality Characters

High heritability for pod protein (96.22) was reported in cowpea by Manju (2006). In yard long bean Jithesh (2009) reported that high heritability for pod protein content and high genetic advances for leaf chlorophyll content and crude fiber content of pods. Pod protein had high heritability (99.51) and genetic advance (58.97) and for keeping quality high heritability (96.26) and moderate genetic advances (28.85) were reported by Sivakumar (2012) in yard long bean. In bush cowpea high heritability and genetic advance for pod protein and keeping quality.

2.2.4 Correlation Studies in Cowpea

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.

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. 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, *et al.,* 1994). 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). 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. Character association studies in cowpea indicated a very high positive association of green pod yield with pods per plant (Harshavardhan and Savithramma, 1998b). 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. 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). 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. 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.

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). 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. 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. Rangaiah and Mahadevu (2000) noted highly significant and positive association of yield in cowpea with clusters per plant, pods per plant and pod weight. Yield per plant in cowpea showed high positive correlation with pod yield per plant (0.7654) followed by number of pods per inflorescence (0.6504), pod weight (0.4942), length of harvest period (0.3398), pod girth (0.2855), pod length (0.2740) and number of primary branches (0.2590) (Vidya, 2000).

Ajith (2001) reported high positive genotypic correlation for pods per plant (0.8972), pod weight (0.6325), pods per cluster (0.4255), pod clusters per plant (0.3250) and pod girth (0.3061) with pod yield per plant in cowpea. Stoilova and

Lozanov (2001) reported that high positive correlation were found in cowpea between the weight of plants without pods and pods per plant.

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.

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). 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.

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. 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. 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. Correlation studies revealed that characters like pod length (0.593), pod girth (0.544), pod weight (0.560), pods per plant (0.444), seeds per pod (0.515), 100 seed weight (0.416), number of harvests (0.279) and pod protein (0.252) observed high positive genotypic correlation with yield, whereas peduncle length (-0.499) was negatively correlated with yield (Manju, 2006). 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.

Seed yield per plant had high significant positive correlation with harvest index at phenotypic and genotypic levels (Eswaran *et al.,* 2007). Alege and Mustapha (2007) reported that positive correlations were obtained between leaf number and stem diameter, leaf number and number of seeds per pod, number of branches and plant height in cowpea. So, it can be inferred that those characters with positive correlations are influenced and controlled by similar gene combinations and environmental factors.

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 (0.4669), pods per plant (0.4393), seeds per pod (0.1626) and 100-seed weight (0.165).

Manggoel *et al.* (2012) reported that positive correlation was 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. Yield had significant positive phenotypic correlation with primary branches (0.249), pod weight (0.158) and pods per plant (0.545) and high genotypic correlation with primary branches (0.325), pod length (0.030), pod weight (0.173), pod girth (0.141) and pods per plant (0.482) (Sivakumar, 2012)

Udensi *et al*. (2012a) reported correlation coefficient on yield and yield contributing traits. Results obtained revealed significant relationship exists between 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.

Shanko *et al.* (2014) reported that seed yield exhibited positive and significant environmental correlation with number of primary branches per plant, number of secondary branches per plant, days to 50 per cent flowering, number of pods per plant, number of seeds per pod and plant height.

2.2.5 Path Coefficient Analysis

Path coefficient analysis is used to separate the correlation coefficients into components of direct and indirect effects (Dewey and Lu, 1959).

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 (Misra *et al*., 1994). According to Sawant *et al.* (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. Path analysis showed that pod length was the main determinants of pod yield (Kar *et al.*, 1995). Chattopadhyay *et al.* (1997) reported 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.

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 (Harshavardhan and Savithramma, 1998b). Based on path coefficient analysis, pods per plant was the most important component character (Singh *et al*. 1998). Resmi (1998) reported 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. In cowpea, Vardhan and Savithramma (1998) reported that 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. Path analysis showed positive direct effects of branches per plant, plant height, pod length and 100 seed weight on seed yield (Kalaiyarasi and Palanisamy, 1999). Rangaiah and Mahadevu (2000) noted very high direct effect of pod weight on yield. Pods per plant exhibited high indirect effect via pod weight on total seed weight. Path analysis revealed that maximum direct effect on yield was shown by number of pods per plant (0.7613) followed by pod weight (0.5884) and number of pods per inflorescence (0.1105). Number of pods per inflorescence had high indirect effect via number of pods per plant (0.6706) (Vidya, 2000). Kalaiyarasi and Palanisamy (2000) reported that pod length, seeds per pod, 100 seed weight and crude protein content had strong positive correlation with seed yield.

Pods per plant (0.7297) and pod weight (0.4065) 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 (Ajith, 2001). High positive direct effect on seed yield was observed for pod length (Bastian *et al.,* 2001). 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 weight was also strongly correlated with seeds per plant. Pod length and 100 seed weight had positive indirect effects on seed yield through pods per plant and seeds per pod. Neema and Palanisamy (2003) reported that 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.

Path analysis in cowpea, Kutty *et al.* (2003) indicated that 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. 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 (Venkatesan *et al.*, 2003). Lovely (2005) reported that the characters pods per cluster (0.2306), pods per plant (0.7010), pod weight (0.4745), pod length (0.2267), pod breadth (0.0360), seeds per pod (0.1204) and main stem length (0.0667) had positive direct effects while length of harvest period (-0.0708) had negative direct effect.

Path coefficient analysis indicated that pods per plant (0.6709) exerted the highest positive direct effect on yield, while pod weight and vine length had high indirect effects on pod yield (Manju, 2006). Madhukumar (2006) reported that number of pods per plant and pod weight were the primary yield contributing characters due to their high direct effect on pod yield. 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). Jithesh (2009) reported that the highest direct effect was observed for pod weight (0.4669) followed by pods per plant (0.4393), 100- seed weight (0.1699) and seeds per pod (0.1625). The highest positive and direct effect on yield was exerted by pods per plant (1.0462), followed by pod weight (0.6496), pod length (0.1963) and vine length (0.1545) (Sivakumar, 2012)

Path coefficient analysis shows that number of pods per plant had the highest direct effect to cowpea yield (Udensi *et al*., 2012b). Shanko *et al.* (2014) reported that yield per plant exerted the maximum positive direct effect on seed yield followed by number of pods per plant, while number of secondary branches per plant, days to flowering, days to maturity and number of seed per pod exhibited negative direct effect phenotypically. It was also observed that number of pod per plant had positive direct effect on seed yield in cowpea. Days to maturity and number of seed per pod contributed to seed yield mainly via their high and positive indirect effect with yield per plant. The positive direct effect of yield per plant on seed yield was counter balanced by its indirect effect via days to flowering which finally resulted in positive and low phenotypic correlation with seed yield. The residual effect determines unaccounted variability of the dependent factor (seed yield). Its magnitude 0.219 indicated that the traits included in the path analysis explained 78.1 per cent of the variation in seed yield.

2.2.1.6 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 F1. 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). Selection index for cowpea was pod yield which was positively correlated with number of pods/m^2, pod length and width. Pod yield was highest in 2004 (11t/ha) than the other years while it was least in 2003 (4 t/ha) IT86F-2014-1 had the highest number of pods/m^2 among the cultivars (261 pods/m^2) while the least was observed in IT 92KD-263-4-1 (70 pods/m ^{2}), The longest pods were recorded in IT 92KD-263-4-1, IT 83S-899, IT 86F-2062-5, IT 81D- 1228-14 and IT 93K-915 while the shortest pods were recorded in IT 86F-2014-1 (Nwofia, 2012).

The selection index for the genotypes were computed on the basis of the following characters like vine length, days to first flowering, pod length, pod girth, pod weight, number of pods per plant and yield per plant. Based on the selection index values, top ranking accessions namely VS 34, VS4, VS 29, VS 1, VS 31 and VS 47 (Sivakumar, 2012). Yield per plant and number of pods per plant could be used as a selection index for cowpea improvement (Shanko *et al.*, 2014).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Identification of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) genotypes suitable for polyhouse cultivation" was taken up at the Department of Olericulture, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, during 2014 - 2015. The objective of field experiment was to identify yard long bean genotypes with high yield and quality suitable for cultivation in naturally ventilated polyhouse.

3.1 EXPERIMENTAL SITE

The experimental site was located at 8.5^0 North latitude and 76.9^0 East longitude, at an altitude of 29 m above mean sea level. Predominat soil type of the experimental site was red loam to Vellayani series, texturally classified as sandy clay loam. A composite soil sample was collected from the field selected for laying out the experiment. The sample was air dried, sieved, and weighed. Basic physico - chemical properties determined by standard analytical procedures (Jackson, 1973) were given in Appendix I.

3.1.1 Details of Polyhouse

The experiment was conducted in saw tooth type naturally ventilated polyhouse with a gutter height of 5m, gutter slope of 2 per cent and size 1000 m^2 (50 m x 20 m) located in Instructional Farm, Vellayani (Plate 1A). The framework is made of GI pipes of 76mm ID, 2-3 mm thickness. The roof is made of 200 micron UV stabilised polyethylene sheet. The polyhouse is provided with fogger unit to control temperature.

3.1.2 Season

The experiment was conducted during the rainy season from June 2014 to October 2014.

1A. Naturally ventilated saw tooth type polyhouse located in Instructional Farm,Vellayani

1B. Raised beds covered with mulch sheet punched with holes at 45 cm distance

Plate 1. Inside and outside view of polyhouse located in Instructional Farm Vellayani

3.2 MATERIALS

The experimental materials consisted of 30 yard long bean accessions of which eighteen were landraces maintained in the Department of Olericulture, College of Agriculture, Vellayani, three were KAU released varieties and nine hybrids/varieties collected from private sector. The details of the yard long bean accessions used for the experiment were given in table 1.

3.3 METHODS

3.3.1 Design and Layout

The experiment was laid out in the naturally ventilated polyhouse in a randomised block design with three replications during June 2014 to October 2014.

3.3.1.1 Main Field Preparation

The experimental area inside the polyhouse was ploughed thoroughly and the weeds and stubbles were removed. Raised beds of 23m long and 70cm width were prepared, so that the row to row spacing was 1.5 m. and Farmyard manure and rock phosphate was incorporated at the rate of 20 t/ha and 52.5 kg/ha respectively. Then COC at the rate of 3 g/l was drenched in the beds and covered with silver on black plastic mulch of 30 micron thickness (Plate 1B). Holes were punched at 45cm spacing. Thus 10 plants per accession were maintained in each plot with a plot size of 6.75 m^2.

Seedlings were raised in portrays. Seeds were sown on 26/6/2015 (Plate 2A). Seeds getminated in 3-5 days. Fifteen day old seedlings at 2-3 true leaf stage were transplanted into the main field (Plate 2B). Field view of the experiment conducted in polyhouse condition is given in plate 2D.

3.3.1.2 Crop Management

Drip system of irrigation was followed in the polyhouse. Fogging was carried out regularly at specific intervals to avoid excess temperature buildup in the polyhouse. NPK fertilizers were applied once in 3 days from planting till the end of the crop.

2A. Seedling in protrays

2B. Seedlings at transplanting stage

2C. Plants trailed using plastic rope

2 D. Field view of the experiment

Plate 2. Growth stages of yard long bean accessions

Fertilizer schedule at 3 days interval is given in table 2 and the detailed schedule for precision farming in yard long bean (KAU, 2011) is given in Appendix II. During the experiment period, it was found that vegetative growth was more. So based on the performance observed, the quantity of urea applied was reduced to half the recommended dose. Plants were trained to grow vertically upwards along a polythene twine which was tied at gutter height of 3 m and extended vertically downward upto a height of 30 cm above the ground (Plate 2C). Plant protection chemicals were sprayed as and when pest and disease incidence was noticed.

Table 1. Details of yard long bean accessions used for evaluation

Treatment No.	Accession Number	Accession Name	Source
T1	VS 34	Githika	College of Agriculture, Vellayani
T2	VS 35	Periya Local	Periya, Kasargode
T3	VS 31	Muttacadu Local	Muttacadu, Thiruvananthapuram
T4	VS 44	Kanakakary Local	Kanakakary, Kottayam
T5	VS 52	Anad Local	Anad, Thiruvananthapuram
T6	VS 38	Kuttichal Local	Kuttichal, Thiruvananthapuram
T7	VS 51	Balaramapuram Local	Balaramapuram, Thiruvananthapuram
T8	VS 43	Ettumanoor Local	Ettumanoor, Kottayam
T9	VS 17	Pilicode Local	Pilicode, Kasargode
T10	VS 16	Pattom Local	Pattom, Thiruvananthapuram
T11	VS 50	Kakamoola Local	Kakamoola, Thiruvananthapuram
T12	VS 5	Hosdurg Local	Hosdurg, Kasargode
T13	VS 13	Neyyattinkara Local	Neyyattinkara, Thiruvananthapuram
T14	VS 54	Thirupuram Local	Thirupuram, Thiruvananthapuram

T15	VS 63	Nemom Local	Nemom, Thiruvananthapuram
T16	VS 6	Kumarapuram, Local	Kumarapuram, Thiruvananthapuram
T17	VS 45	Super Green	F1, Tan Indo seeds, Karnataka
T18	VS 64	Hari Rani	Sakata seed India Pvt.Ltd, Gurgaon
T19	VS 65	Rani	Sakata seed India Pvt.Ltd, Gurgaon
T20	VS 67	Rocket -77	Pahuja seed Pvt. Ltd, Delhi
T21	VS 68	NS-620	F1, Namdhari seeds, Bangalore
T22	VS 69	NS-621	F1, Namdhari seeds, Bangalore
T23	VS 70	NS-634	F1, Namdhari seeds, Bangalore
T24	VS 66	Babli	Sakata seed India pvt.Ltd, Gurgaon
T25	VS 71	FH-30	Farmhouse, Thiruvananthapuram
T26	VS 72	Palapoor Local	Palapoor, Thiruvananthapuram
T27	VS 42	Vellayani Jyothika	College of Agriculture, Vellayani
T28	VS 11	Lola	College of Horticulture, Vellanikkara
T29	VS 4	Kanjikuzhipayar	Cherthala, Alappuzha
T30	VS 47	NKRA Local	ARS, Thiruvalla

Table 2. Fertilizer schedule at 3 days interval for 400 m^2 area

Period – (Days after planting)	Fertilizers to be used at each time, at 3 days interval(g)				Number of split applications
	19:19:19	13:0:45	Urea	12:61:0	
3 to 18	280	320	260	-	6
21- 54	20	640	60	40	12
57- 120	20	640	300	40	22

3.3.2 Biometric Observations

Three plants were selected randomly from the plots and tagged for recording the biometric observations.

3.3.2.1 Vegetative Characters

3.3.2.1.1 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.

3.3.2.1.2 Primary Branches per Plant

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

3.3.2.1.3 Petiole Length (cm)

Length of petiole of five leaves selected at random (45 days after planting) was measured in each observational plant.

3.3.2.1.4 Leaflet Length (cm)

The fifth leaf from top of the selected plants (45 days after planting) 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.

3.3.2.1.5 Leaflet Width (cm)

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

3.3.2.2 Flowering Characters

3.3.2.2.1 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.

3.3.2.2.2. Peduncle Length

Length of peduncle was measured from five randomly selected inflorescences from each observational plants at 45 days after planting.

3.3.2.2.3 Fruit Set (%)

Fruit set was determined by dividing the total number of fruits on a plant with the total number of flowers produced in the same plant marked from the observation plants in each treatment plot. The mean percentage obtained in each treatment was taken as the true fruit setting percentage of plants.

3.3.2.3 Yield Characters

3.3.2.3.1 Pod Length (cm)

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

3.3.2.3.2 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.

3.3.2.2.3 Pod Weight (cm)

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

3.3.2.2.4 Pods per Plant

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

3.3.2.2.5 Seeds per Pod

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

3.3.2.2.6 100 Seed Weight

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

3.3.2.2.7 Yield per Plant (g)

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

3.3.2.2.8 Yield per Plot (kg)

Weight of all pods harvested from each plot was recorded. Average was worked out and expressed in kilo grams per plot.

3.3.2.2.9 Days to Harvest

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

3.3.2.2.10 Crop Duration

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

3.3.2.4 Quality Characters

3.3.2.4.1 Protein

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

1. 2% sodium carbonate
2. 0.5% copper sulphate solution in 1% of sodium potassium tartarate.
3. Mix 50ml of reagent A with 1ml of reagent B just prior to use.
4. Folin- ciaocalteau reagent: FCR is commercially available and has to be diluted with equal volume of water just before use. (The reagent can be prepared in the laboratory. Into a 2 litre flask, measure out 100g sodium tungstate, 25g sodium molybdate, 500 ml distilled water, 50ml 85 per cent phosphoric acid and 100ml con. HCl. The mixture is refluxed gently for about 10 hrs with a condenser. After cooling 150g lithium sulphate, 50 ml of distilled water and a few drops of bromine are added and boiling continued for another 10 minutes without condenser. This helps to remove excess bromine. After cooling, the volume is made up to 100 ml and filtered if necessary. The filtrate should not have any greenish tint. If it has, it is boiled with bromine once again. This is the stock and is diluted with equal volume of water just before use.
5. Stock standard Protein Solution:

   50mg of bovine serum albumin / 50 ml of water

   Working standard solution – Dilute 10 ml of the stock solution to 50 ml with water to obtain 200 g protein/ml.

Procedure

Extraction of protein from the sample

1. Grind 0.50 g of the sample with a suitable solvent system (water or buffer) in a pestle and mortar.
2. Centrifuge and use the supernatant for protein estimation. (Extraction of protein is usually carried out with buffers for enzyme assay. In case of enzymes the entire process should be done in cold.)

Estimation of Protein

1. Pipette out 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard solution into series of test tubes.
2. Pipette out 0.1 and 0.2 ml of sample extract into two other test tubes.
3. Make up the volume to 1 ml with water in all the tubes. A tube with 1ml of water serves as the blank.
4. Add 5 ml of solution C, mix well and incubate at room temperature for 10 minutes.
5. Add 0.5ml FCR, mix well immediately and incubate at room temperature in dark for 30 minutes.
6. Read the absorbance at 660 nm against the blank.
7. Draw a standard graph, calculate the amount of protein in the sample and express the results as per cent.

3.3.2.4.2. Crude Fibre

Procedure

Take 5 g of dried and powered sample in a 400 ml beaker. Add 200 ml of 1.25 per cent of H_2SO_4 and boil for half an hour. Filter through a muslin cloth. Wash with water to render it free from acid. Transfer the residue to the beaker and add 200 ml of 1.25 per cent caustic soda and boil for half an hour. Filter and wash it free from alkali, using in turn hot water, 1 per cent HNO_3 and hot water respectively. Transfer the residue to a weighed dish (w1) and dry it to a constant weight at 100 ^{0}C. Cool the dish in a dessicators and weighed (W2). Ignite the residue to get ash and find the weight again (W3). The loss in weight due to ignition is equal to crude fibre. This is expressed as per cent (Sadasivam and Manickam, 1996)

$$\text{Percentage crude fibre in sample} = \frac{\text{Loss in weight on ignition (W2-W1)-(W3-W1)}}{\text{Weight of sample}} \times 100$$

3.3.2.4.3 Keeping Quality

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

3.3.2.5 Screening for Pest and Diseases

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

3.3.2.5.1 Web Blight (Rhizoctonia solani)

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.

Score	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 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)

3.3.2.5.2. 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 the formula:

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

3.3.2.5.3 Mite

Observations on mite attack were recorded from all the plants. Scoring of the attack was done using a scale. The extent of attack was estimated based on the parts of the plants affected. Curling, damage, malformation and complete destruction of leaves were taken into account for devising the scale. Based on this a 0-4 scale has been devised.

0 ---- No symptom
1 ---- 1-25% leaves/plant showing curling or damage
2 ---- 26-50% leaves/plant showing curling - moderately damaged
3 ---- 51-75% leaves/plant showing curling – heavily damaged
4 ---- 75% leaves/plant showing curling & complete destruction of growing points.

Damage intensity was calculated by using formula:

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

3.3.2.6 Anatomical Characters

3.3.2.6.1 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 impression was counted using a compound microscope (40X objectives) and the number of stomata per cm^2 was calculated by using the formula given below

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

3.3.2.6.2 Vascular Bundles

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

3.3.2.6.3 Cuticle Thickness

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

3.3. 2.7 Meteorological Parameters

Meteorolgical parameters like temperature, relative humidity, light intensity and CO_2 concentration during the cropping period were recorded, both inside and outside the polyhouse.

3.3.2.7.1 Temperature

Maximum and minimum air temperature inside the polyhouse was recorded daily by using a mercury thermometer (0-50ºC) at canopy height and averages were computed.

3.3.2.7.2 Relative Humidity

The relative humidity in polyhouse was recorded by using wet bulb and dry bulb thermometer (0-100%) in per cent and averages were computed.

3.3.2.7.3 Light Intensity

Light intensity inside the polyhouse was recorded with luxmeter at crop canopy level and recorded in kilo lux and averages were computed.

3.3.2.7.4 CO_2 Concentration

The CO_2 concentration inside and outside the polyhouse was recorded with CO_2 analyser at two times per day (7am & 4pm) and averages were computed.

3.3.3 Genetic Cataloguing

The accessions were described morphologically using modified descriptor developed from the standard descriptor for cowpea by IPGRI (Appendix III).
The cataloguing was done on appropriate scales ranging from 0-9.

3.3.4. Statistical Analysis

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

a) To test significant difference among the accessions and

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

From the table other genetic parameters were estimated as follows:

3.3.4.1 Variance

	X	Y
Environmental variance (σ^2e)	$\sigma^2ex = E\,xx$	$\sigma^2ey = E\,yy$
Genotypic variance (σ^2g)	$\sigma^2gx = \frac{Gxx - E_{xx}}{I}$	$\sigma^2gy = \frac{Gyy - Eyy}{I}$
Phenotypic variance (σ^2p)	$\sigma^2 px = \sigma^2gx + \sigma^2ex$	$\sigma^2py = \sigma^2py + \sigma^2ey$

3.3.4.2 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}	$\sigma 2_{exy}$	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

3.3.4.3 Heritability

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

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 $\longrightarrow$ Low

31 – 60 per cent $\longrightarrow$ Moderate

>60 per cent $\longrightarrow$ High

3.3.4.4 Genetic Advance as Percentage Mean

$$GA = \frac{k\ H^2 \sigma p}{\bar{X}}$$

Where, k is the standard selection differential. K = 2.06 at 5 per cent 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

3.3.4.5 Correlation

Genotypic correlation coefficient (r_{gxy}) = $\frac{\sigma gxy}{\sigma gx \times \sigma gy}$

Phenotypic correlation coefficient (r_{pxy}) = $\frac{\sigma pxy}{\sigma px \times \sigma py}$

Environmental correlation coefficient (r_{exy}) = $\frac{\sigma exy}{\sigma ex \times \sigma ey}$

3.3.4.6 Path Analysis

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

3.3.4.7 Selection Index

The selection index developed by Smith (1937) using discriminate function of Fisher (1936) was used to discriminate the accessions 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 $G_1, G_2 \ldots\ldots\ldots\ldots\ldots G_k$ 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.

RESULTS

4. RESULTS

The experiment entitled "Identification of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) genotypes suitable for polyhouse cultivation" was taken up at the Department of Olericulture, College of Agriculture, Vellayani, during 2014 -2015. The experimental data collected on growth characters, yield and yield attributes, quality characters and incidence of pest and diseases were statistically analyzed and the results are presented under the following heads:

4.1. METEOROLOGICAL PARAMETERS

The weather data during the cropping period from June 2014 to October 2014 inside the polyhouse was recorded and presented in Fig. 1 and Appendix IV and outside polyhouse in Fig. 2 and Appendix V. In the polyhouse, the maximum temperature ranged from 30.4 ^{0}C to 41.3 ^{0}C and the minimum temperature ranged from 21.5 to 24.5 ^{0}C. Relative humidity ranged from 81to 94 per cent. Light intensity ranged from 60.3 klux to 70.1 klux. In open field, the maximum temperature ranged from 29.8^{0}C to 34.5 ^{0}C and the minimum temperature ranged from 21.5 ^{0}C to 24.5 ^{0}C. Relative humidity ranged from 75.6 to 90 per cent. Light intensity ranged from 83.4 klux to 98.1 klux. CO_2 concentration was recorded both in polyhouse and open field and represented in Fig. 3 and 4 and Appendix VI. In polyhouse it ranged from 269.38 to 293.32 ppm at 7am and 261.23 to 288.75 ppm at 4 pm. In open field CO_2 concentration at 7am was 256.54 to 287.65 ppm and at 4 pm 254.43 to 283.30 ppm.

4.2 MEAN PERFORMANCE OF YARD LONG BEAN ACCESSIONS

Analysis of variance was conducted to test the significant difference among treatments studied. The mean sum of squares due to various sources for 26 characters under polyhouse condition is presented in table 4. The analysis of variance revealed that the 30 yard long bean accessions differed significantly for all the characters studied (Plate 3).

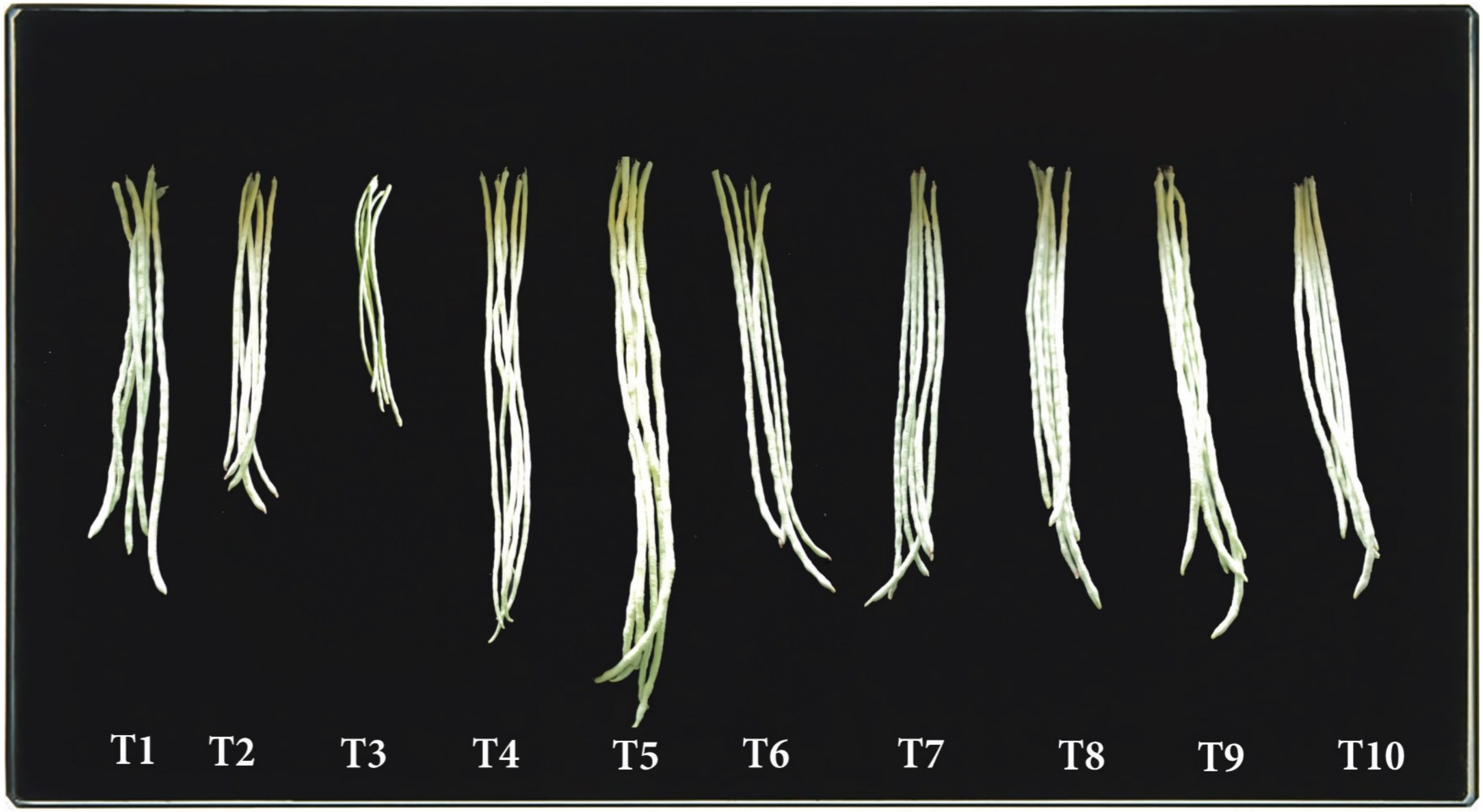

Plate 3. Variability in pod characters of yard long bean accessions T1 – T10

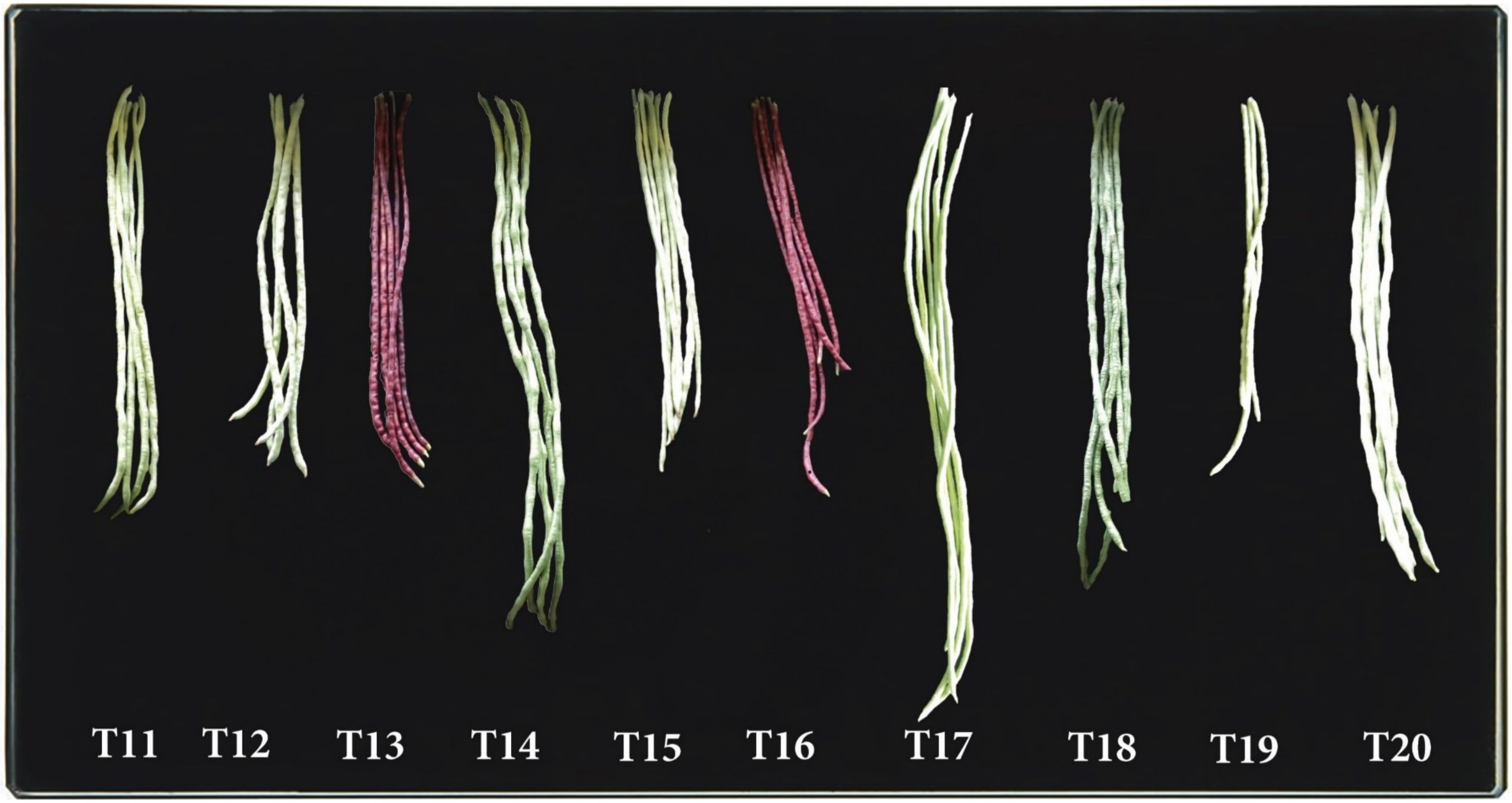

Plate 3. Variability in pod characters of yard long bean accessions T11- T20

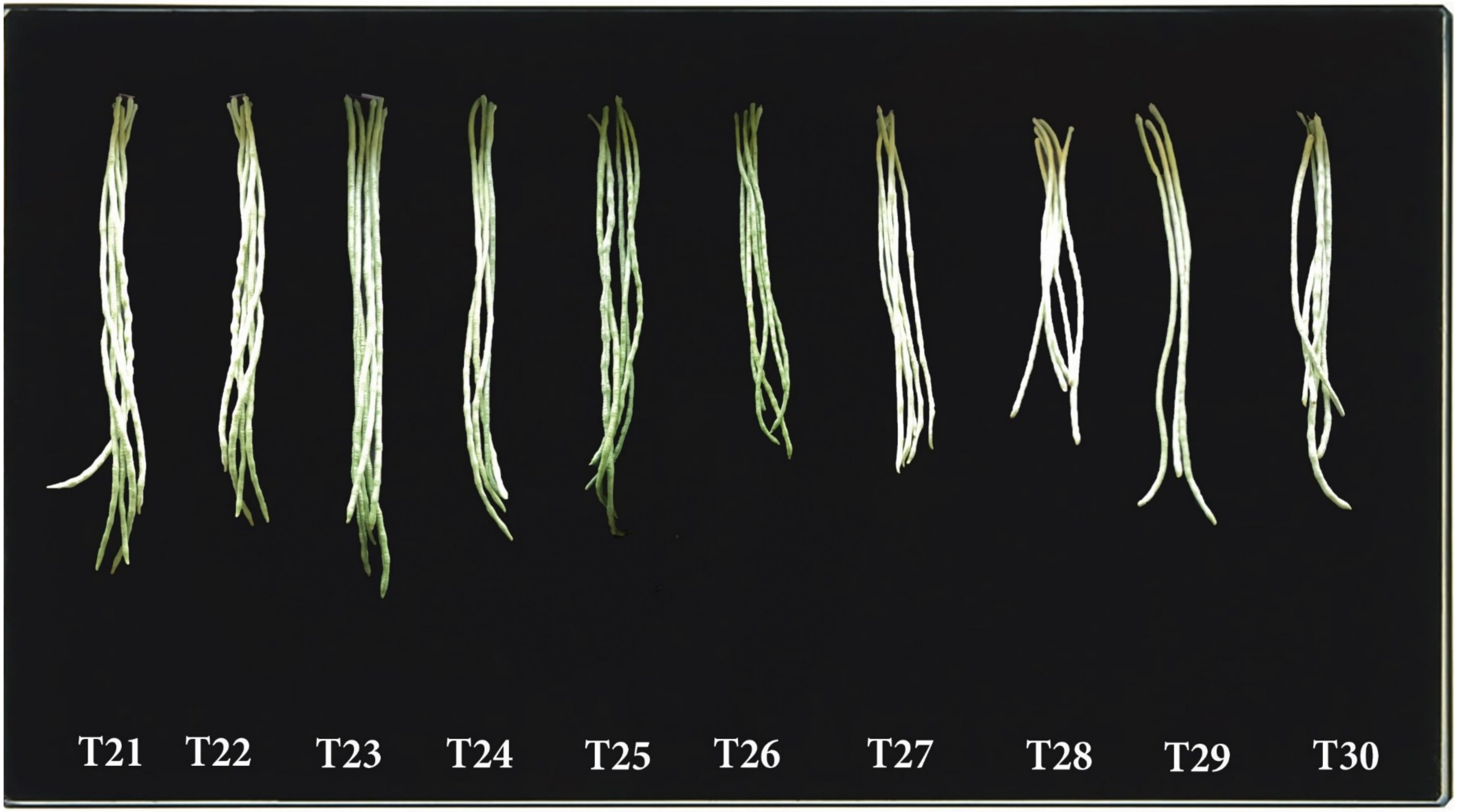

Plate 3. Variability in pod characters of yard long bean accessions T21-T30

Table 4. Analysis of variance for characters in yard long bean (mean squares are given)

Source	D.F	1	2	3	4	5	6	7
Replication	2	384.3964	0.0300	0.2173	0.9414	0.3202	0.2297	1.1121
Treatment	29	2513.234 **	1.1417 **	7.8992 **	1.2521 **	1.2844 **	2.1597**	1.3306 **
Error	58	418.8712	0.4626	0.7464	0.5310	0.3032	0.6990	0.4335

Source	D.F	8	9	10	11	12	13	14	15
Replication	2	0.3606	5.8633	4.0157	65.0903	0.3854	9.6248	7.8778	0.0185
Treatment	2	5.3300 **	70.554**	24.527**	289.427**	0.7029**	249.821**	727.988**	1.9846**
Error	9	0.8378	1.7327	7.7127	17.9332	0.1026	10.5861	50.4459	0.5740
	58								

Source	D.F	16	17	18	19	20	21
Replication	2	0.5373	7494.54	0.0111	0.5941	5.7621	0.1254
Treatment	29	40.778**	152309.95**	0.1490**	3.0133**	107.48**	2.351**
Error	58	1.7985	21432.48	0.0224	0.4353	8.6865	0.0903

Source	D.F	22	23	24	25	26
Replication	2	1.2690	0.0285	342904.8438	0.0380	0.2054
Treatment	29	4.6434**	0.3316**	894724.1250**	2.2045 **	18.9720**
Error	58	0.6794	0.1041	100028.4297	0.8227	0.2485

** significant at 1% level

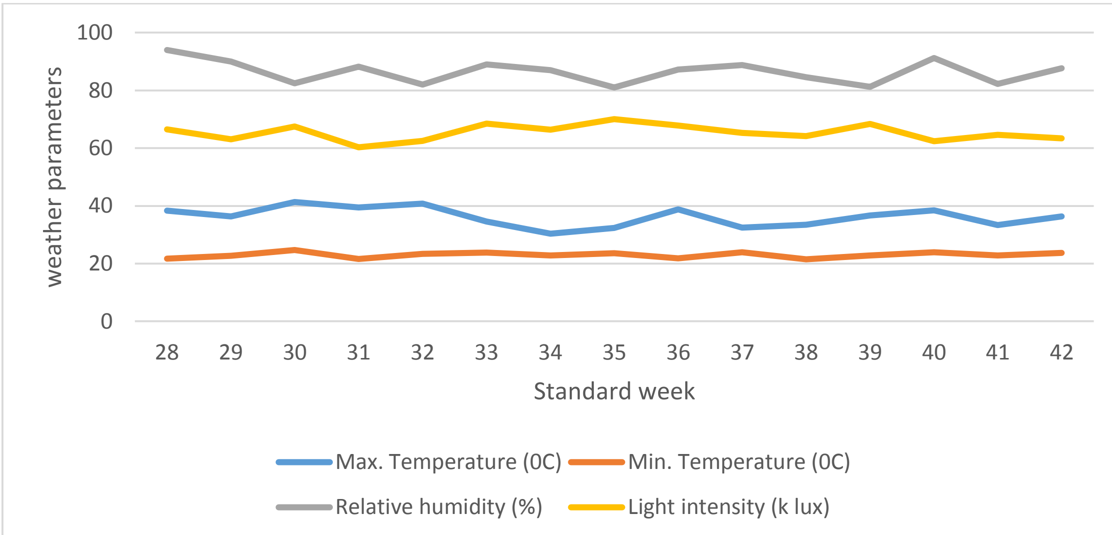

Fig 1. Weather parameters inside the polyhouse during the cropping period in June to October 2014

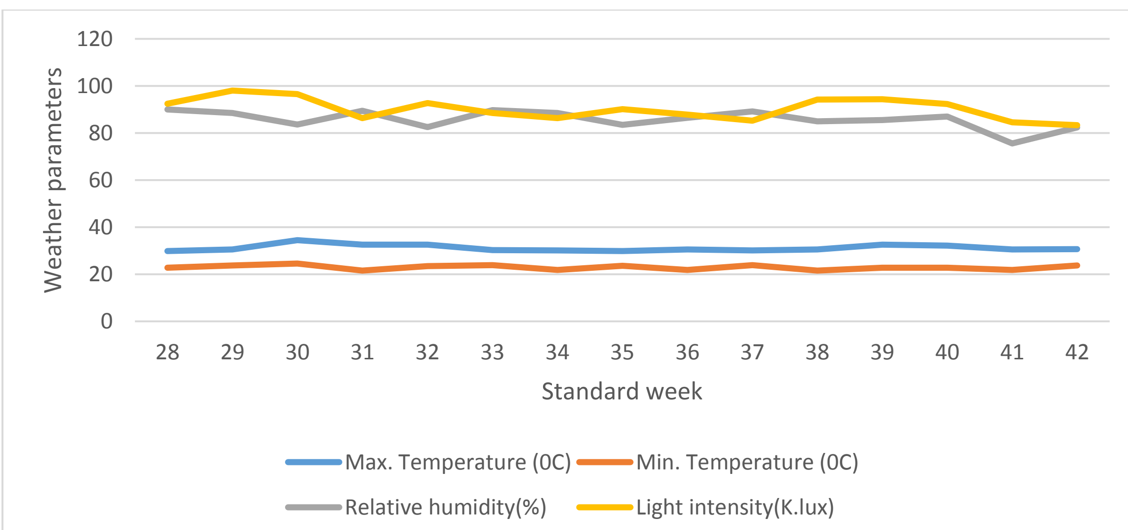

Fig 2. Weather parameters in open field during cropping period in June to October 2014

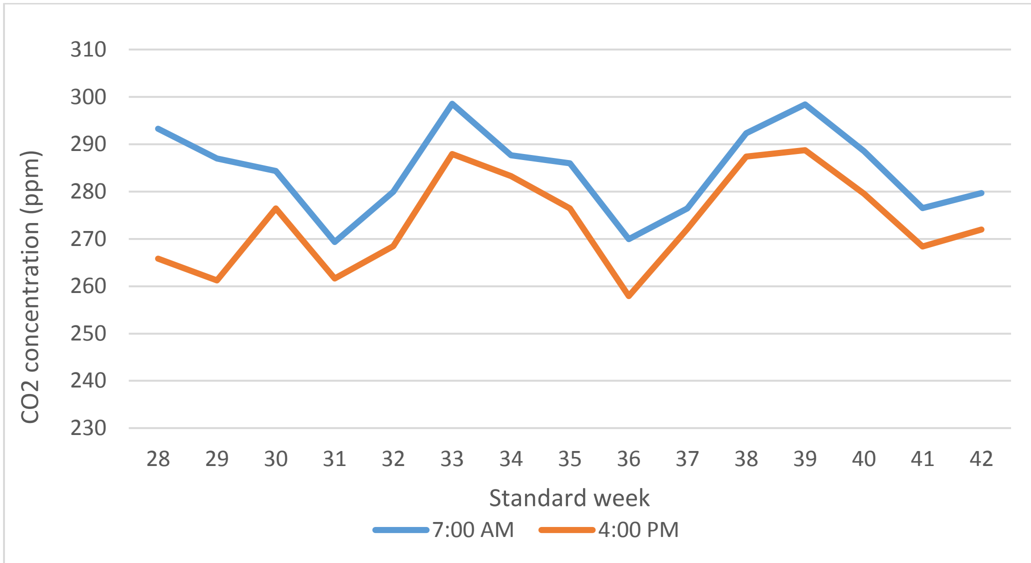

Fig 3. CO_2 concentration (ppm) in polyhouse during cropping period in June to October 2014

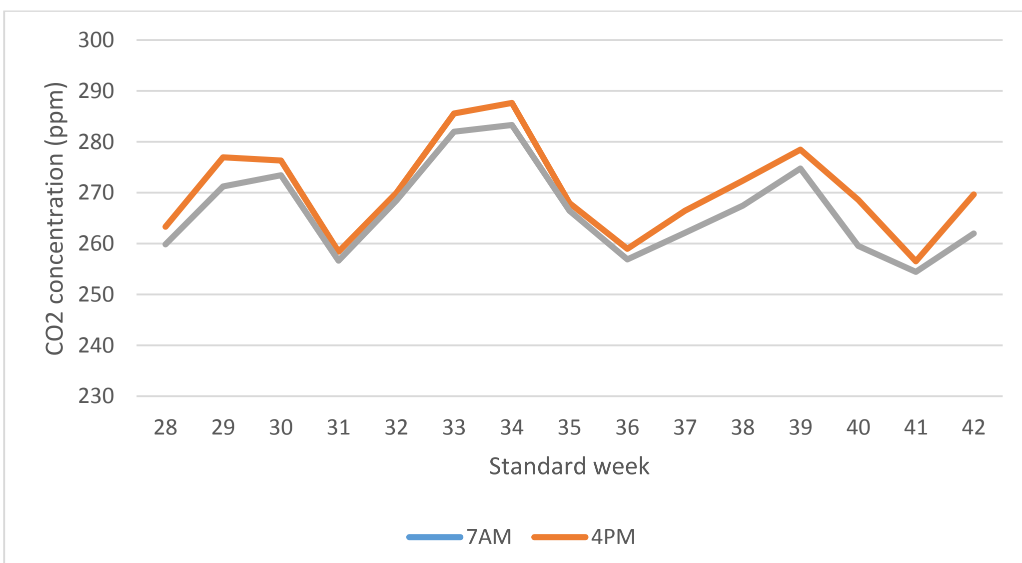

Fig.4. CO_2 concentration (ppm) in open field during cropping period in June to October 2014

The mean values of the accessions under polyhouse condition for growth, yield and quality characters are given below.

4.2.1 Growth Characters

The mean values for growth characters like vine length, primary branches per plant, petiole length and length and breadth of leaflets are furnished in table 5.

4.2.1.1 Vine Length

There was significant difference between treatments with respect to vine length. T 23 had the longest vine (510.89 cm) which was statistically on par with T 5 (506.61 cm), T 22 (502.44 cm), T 26 (499.00 cm), T 24 (498.94 cm), T 2 (489.22 cm), T 4 (485.28 cm) and T 27 (485.11 cm). T 19 had the shortest vine (412.94 cm).

4.2.1.2 Primary Branches per Plant

Primary branches per plant varied from 3.95 to 6.57 with an average of 5.19. The maximum number of primary branches was observed in T 16 (6.57) which was statistically on par with T 18 (5.96), T 15 (5.89), T 1 (5.85), T 24 and T 11 (5.71), T 4 (5.67) and T 12 (5.60). The minimum number of primary branches per plant was recorded by T 23.

4.2.1.3 Petiole Length

Wide variation among the treatments was observed for petiole length. It ranged from 14.27 cm to 21.27 cm T 10 recorded the highest petiole length (21.27 cm) followed by T 29 (20.45 cm), T 25 (19.65 cm) and T 20 (19.43 cm). The lowest petiole length was recorded for T 4.

4.2.1.4 Length and Breadth of Leaflets

Significant differences are observed for terminal leaflet length. T 17 had the longest (20.27 cm) leaflet followed by T 6 (19.49 cm), T14 (19.44 cm) and T18 (19.43 cm). T 9 had the shortest terminal leaflet (17.47 cm). Breadth of terminal leaflets varied

Table 5. Mean performance of 30 yard long bean accessions for vegetative characters

Treatments		Vine length (cm)	Primary branches/ plant	Petiole length (cm)	Terminal leaf length (cm)	Lateral leaf length (cm)	Terminal leaf width (cm)	Lateral leaf width (cm)
T1	Githika	463.27	5.85	16.43	17.93	17.33	9.64	9.26
T2	Periya Local	489.22	4.56	16.22	17.95	16.42	8.75	8.80
T3	Muttacadu Local	469.39	4.89	17.67	18.11	17.32	9.43	8.57
T4	Kanakakary Local	485.28	5.67	14.27	17.72	17.10	10.64	10.02
T5	Anad Local	506.61	5.07	14.28	17.63	17.23	10.60	9.57
T6	Kuttichal Local	478.67	5.37	15.53	19.49	17.84	10.60	11.52
T7	Balaramapuram Local	444.28	5.19	18.42	18.80	17.95	10.96	8.83
T8	Ettumanoor Local	474.00	4.89	18.39	18.94	17.24	9.75	9.37
T9	Pilicode Local	467.22	4.52	17.60	17.47	17.50	9.46	9.19
T10	Pattom Local	414.61	4.46	21.27	18.54	16.47	10.34	8.63
T11	Kakamoola Local	413.67	5.71	18.25	18.98	17.13	8.87	8.65
T12	Hosdurg Local	438.28	5.60	18.82	18.19	17.23	8.99	9.02
T13	Neyyattinkara Local	430.72	5.19	17.97	18.92	18.08	9.96	10.40
T14	Thirupuram Local	436.67	5.78	19.05	19.44	17.95	10.19	9.57
T15	Nemom Local	431.55	5.89	16.57	17.74	17.61	9.81	9.74
T16	Kumarapuram Local	447.00	6.57	19.23	18.66	18.05	9.21	9.28
T17	Super Green	444.72	4.52	18.21	20.27	18.24	9.25	8.39
T18	Hari Rani	429.11	5.96	16.87	19.43	19.05	9.54	9.65
T19	Rani	412.94	5.46	19.23	17.98	18.07	9.00	8.70
T20	Rocket -77	466.00	5.85	19.43	18.58	18.41	9.00	9.09
T21	NS-620	475.28	4.44	16.63	19.17	18.91	9.55	9.24
T22	NS-621	502.44	4.17	19.28	18.75	18.25	10.62	9.00
T23	NS-634	510.89	3.95	18.45	19.30	18.83	8.96	8.57
T24	Babli	498.94	5.71	18.04	18.43	17.95	8.74	8.76
T25	FH-30	492.61	4.99	19.65	18.83	18.33	8.70	8.45
T26	Palapoor Local	499.00	5.24	19.08	18.63	18.37	9.60	9.31
T27	Vellayani Jyothika	485.11	4.67	17.64	18.44	17.56	11.09	9.86
T28	Lola	469.83	5.22	17.83	18.69	18.34	12.28	8.69
T29	Kanjikuzhi payar	471.61	4.70	20.45	19.08	18.43	9.63	9.15
T30	NKRA Local	467.22	5.48	19.23	18.22	17.94	9.00	8.56
Mean		463.87	5.19	18.00	18.61	17.84	9.74	9.19
CD(0.05)		33.452	1.110	1.413	1.192	0.900	1.371	1.082

from 8.70 cm to 12.28 cm. Treatment T 28 recorded the highest terminal leaflet breadth (12.28 cm) followed by T 27 (11.09 cm), T 7 (10.96 cm) and T 4 (10.64 cm). The lowest terminal leaflet breadth was recorded in T 25 (8.70 cm).

The treatments varied considerably for lateral leaflet length also. T 18 had longest lateral leaflet length (19.05 cm) followed by T 21 (18.91 cm), T 23 (18.83 cm). T 2 had shortest lateral leaflet length (16.42 cm). Breadth of lateral leaflets varied from 8.39 cm to 11.52 cm with an average of 9.19 cm. T6 recorded the highest value of 11.52 cm followed by T 13 (10.4 cm) and T 4 (10.02 cm). T 17 had the lowest value of 8.39 cm.

4.2.2 Flowering Characters

The mean values for flowering characters like days to first flowering, peduncle length and fruit set (%) are furnished in table 6.

4.2.2.1 Days to First Flowering

There was significant difference among treatments with respect to days to first flowering. It exhibited a range of 30.41days to 37.11days. Earliest flowering was noticed in T 19 (30.41 days) which was statistically on par with T 8 (31.53), T 25 (31.55) and T 12 (31.65). T 17 flowered late (37.11 days) compared to other treatments.

4.2.2.2 Peduncle Length

Peduncle length varied from 20.72 cm to 40.51 cm with a mean of 29.11 cm. Maximum peduncle length was observed in T 6 (40.51 cm) followed by T 21 (36.72 cm) and T 7 (35.78 cm). The minimum value was recorded in T 4 (20.72 cm).

4.2.2.3 Fruit Set (%)

In the case of fruit set, the values ranged from 72.41 per cent to 83.1 per cent with a mean of 77.8 per cent. The highest fruit set per cent was obtained from T 12 (83.18) which was statistically on par with T 25 (80.81), T 15 (80.75), T 5 (80.17),

Table 6. Mean performance of 30 yard long bean accessions for flowering characters

Treatments		Days to first flowering	Peduncle length (cm)	Fruit set(%)
T1	Githika	33.89	23.88	79.92
T2	Periya Local	34.00	23.17	77.22
T3	Muttacadu Local	34.78	23.50	74.87
T4	Kanakakary Local	33.00	20.72	75.67
T5	Anad Local	32.97	24.47	80.17
T6	Kuttichal Local	34.76	40.51	74.02
T7	Balaramapuram Local	33.21	35.78	75.88
T8	Ettumanoor Local	31.53	28.22	80.75
T9	Pilicode Local	34.09	26.75	74.64
T10	Pattom Local	32.09	23.77	82.73
T11	Kakamoola Local	34.10	27.14	78.96
T12	Hosdurg Local	31.65	26.88	83.18
T13	Neyyattinkara Local	32.00	28.13	73.93
T14	Thirupuram Local	34.54	26.20	78.17
T15	Nemom Local	32.54	26.35	80.75
T16	Kumarapuram Local	33.98	26.23	82.01
T17	Super Green	37.11	29.68	75.68
T18	Hari Rani	34.31	24.07	75.10
T19	Rani	30.41	27.06	74.12
T20	Rocket -77	34.88	30.33	72.41
T21	NS-620	32.55	36.72	79.67
T22	NS-621	33.33	34.44	75.84
T23	NS-634	33.55	31.55	77.01
T24	Babli	32.33	34.22	79.52
T25	FH-30	31.55	33.32	80.81
T26	Palapoor Local	34.00	33.78	77.15
T27	Vellayani Jyothika	34.11	34.01	79.84
T28	Lola	34.33	26.26	78.15
T29	Kanjikuzhi payar	32.89	32.61	77.36
T30	NKRA Local	32.88	33.44	79.00
Mean		33.38	29.11	77.82
CD(0.05)		1.502	2.151	4.541

T 16 (82.01), T 1 (79.92) and T 27 (79.84). The lowest value was obtained from T 20 (72.41).

4.2.3 Yield Characters

Mean values for yield and yield attributing characters like pod length, pod girth, pod weight, pods per plant, seeds per pod, 100 seed weight, yield per plant, yield per plot, days to harvest and crop duration are furnished in table 7.

4.2.3.1 Pod Length

The highest pod length of 85.07 cm was observed in T 17 (Super Green) (Plate 4A) followed by T 18 (Hari Rani) (72.25 cm) and T 5 (VS 52) (68.44 cm). The lowest value of 35.17 cm was observed in T 3.

4.2.3.2 Pod Girth

In the case of pod girth, the values differed significantly and ranged from 2.50 cm to 4.00 cm with a mean of 3.15 cm. Maximum pod girth was observed in T 23 (4.00 cm) (Plate 4B) which was statistically on par with T 11 and T 14 (3.9 cm), T 25 (3.8 cm), T 9 (3.73 cm), T 8 (3.7 cm) and T 26 (3.6 cm). The minimum pod girth was observed in T 3 (2.50 cm).

4.2.3.3 Pod Weight

Wide variation was observed among the treatments for pod weight. Highest pod weight of 64.77 g was recorded by T 17 (Super green) (Plate 4A) followed by T 5 (VS 52) and T 21 (NS-620) (36.43 g) and lowest was for T 15 (16.57 g) followed by T 16 (17.3 g).

4.2.3.4 Pods per Plant

There was significant difference between treatments with respect to pods per plant. It exhibited a range of 24.83 to 112.14 with a mean of 71.16. Highest value was

Plate 4B- Neyyattinkara Local, NS-634- the accession with maximum pod girth

Plate 4C- T13- Neyyattinkara Local- the accession with highest number of pods per plant

Plate 4A- Super Green- the accession with maximum pod length and weight

Plate 4 .Accessions with good yield characters

Table 7. Mean performance of 30 yard long bean accessions for yield characters

Treatments		Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pods plant^{-1}	Seeds pod^{-1}	100 Seed weight (g)
T1	Githika	46.92	2.67	26.50	89.74	21.53	16.47
T2	Periya Local	40.82	2.73	17.63	69.50	20.91	14.69
T3	Muttacadu Local	35.17	2.50	18.63	62.79	21.01	14.37
T4	Kanakakary Local	52.76	3.07	20.90	72.33	20.13	16.38
T5	Anad Local	68.44	3.53	36.43	61.91	19.90	16.50
T6	Kuttichal Local	49.87	2.90	19.80	75.45	20.00	18.36
T7	Balaramapuram Local	56.80	2.80	22.63	85.45	20.23	17.98
T8	Ettumanoor Local	49.45	3.70	23.60	84.66	18.90	16.53
T9	Pilicode Local	57.53	3.73	26.67	82.25	19.60	13.67
T10	Pattom Local	58.50	2.53	19.30	69.79	19.30	20.46
T11	Kakamoola Local	62.43	3.90	25.13	64.46	19.70	16.40
T12	Hosdurg Local	50.10	2.77	22.03	57.65	19.57	17.37
T13	Neyyattinkara Local	54.27	2.80	19.57	112.14	19.90	12.23
T14	Thirupuram Local	66.77	3.90	32.93	56.12	19.07	20.51
T15	Nemom Local	39.97	3.00	16.57	74.92	18.21	17.63
T16	Kumarapuram Local	52.83	2.87	17.30	97.23	19.83	21.13
T17	Super Green	85.07	3.47	64.77	24.83	18.13	18.75
T18	Hari Rani	72.25	3.90	31.89	72.29	19.80	16.63
T19	Rani	56.30	2.93	23.07	59.17	19.57	14.66
T20	Rocket -77	56.01	3.17	30.90	71.79	19.13	21.92
T21	NS-620	64.03	2.97	36.43	64.98	20.27	15.32
T22	NS-621	60.91	2.73	26.80	71.83	20.77	17.54
T23	NS-634	60.33	4.00	31.07	80.83	20.37	12.12
T24	Babli	52.47	2.93	29.63	75.87	21.57	18.49
T25	FH-30	56.21	3.80	31.23	85.39	20.73	18.32
T26	Palapoor Local	58.34	3.60	26.57	64.20	19.53	10.62
T27	Vellayani Jyothika	57.13	3.00	24.47	67.62	20.13	23.56
T28	Lola	54.40	2.50	20.23	67.12	19.80	23.65
T29	Kanjikuzhi payar	49.70	2.70	24.20	55.33	20.50	16.68
T30	NKRA Local	48.47	3.53	28.65	57.04	19.90	16.54
Mean		55.81	3.15	26.52	71.16	19.93	16.85
CD(0.05)		6.922	0.520	5.321	11.612	1.241	2.192

Table. 7. Continued

Treatments		Yield plant^{-1} (g)	Yield plot^{-1} (kg)	Days to harvest	Crop duration (days)
T1	Githika	1543.58	15.43	44.66	138.57
T2	Periya Local	1029.69	10.29	44.11	124.03
T3	Muttacadu Local	915.48	9.15	45.89	130.03
T4	Kanakakary Local	1113.22	11.13	44.22	133.47
T5	Anad Local	1627.12	16.27	44.33	136.87
T6	Kuttichal Local	1111.04	11.11	44.44	133.73
T7	Balaramapuram Local	1310.48	13.10	43.55	132.23
T8	Ettumanoor Local	1440.85	14.40	43.55	133.53
T9	Pilicode Local	1367.37	13.67	43.78	139.53
T10	Pattom Local	1169.78	10.69	43.44	137.80
T11	Kakamoola Local	971.21	9.71	43.55	133.80
T12	Hosdurg Local	919.92	9.19	42.89	133.80
T13	Neyyattinkara Local	1487.41	14.87	43.33	140.73
T14	Thirupuram Local	1382.75	13.82	44.22	137.53
T15	Nemom Local	1041.39	10.41	42.33	133.60
T16	Kumarapuram Local	1266.71	12.66	44.77	137.57
T17	Super Green	1358.21	13.58	45.33	127.20
T18	Hari Rani	1528.75	15.28	44.11	143.27
T19	Rani	893.04	8.93	40.65	115.87
T20	Rocket -77	1481.20	14.81	42.88	139.90
T21	NS-620	1508.36	15.08	43.33	140.77
T22	NS-621	1511.72	15.11	42.77	139.77
T23	NS-634	1620.29	16.20	44.22	141.23
T24	Babli	1383.82	13.83	42.33	138.90
T25	FH-30	1400.03	14.00	43.78	128.50
T26	Palapoor Local	1147.35	11.474	44.11	126.13
T27	Vellayani Jyothika	1131.71	11.31	43.78	136.97
T28	Lola	1042.06	10.42	44.00	133.70
T29	Kanjikuzhi payar	1054.37	10.54	44.77	137.03
T30	NKRA Local	1244.27	12.44	44.55	140.07
Mean		1266.77	12.66	43.79	134.87
CD(0.05)		239.273	2.422	1.082	4.821

noted in T 13 (112.14) (Plate 4C) followed by T 16 (97.23) and lowest value in T 17 (24.83) followed by T 29 (55.33).

4.2.3.5 Seeds per Pod

Treatments varied significantly for seeds per pod. The highest value was recorded in T 24 (21.57) followed by T 1 (21.53), T 3 (21.01) and T 2 (20.91). The least number of seeds per pod was found in T 17 (18.13).

4.2.3.6 100 Seed Weight

Considerable variation among the treatments was observed for 100-seed weight. Maximum weight of 23.65 g was observed in T 28 which is statistically on par with T 27 (23.56 g) and T 20 (21.92 g). Lowest weight was recorded in T 26 (10.62 g) followed by T 23 (12.12 g) and T13 (12.23 g).

4.2.3.7 Yield per Plant

Highest average yield was obtained for T 5 (Anad Local) (1627.12 g) which was statistically on par with T 23 (NS-634) (1620.29 g), T 1 (Githika) (1543.58 g) and T 18 (Hari Rani) (1528.75 g) (Plate 5). The minimum yield was observed in T 19 (893.04 g).

4.2.3.8 Yield per Plot (kg)

Treatments varied significantly for yield per plot. Highest yield per plot was recorded in T 5 (1.627 kg) followed by T 23 (1.620 kg), T 1 (1.543 kg) and T 18 (1.528 kg). The lowest yield was recorded in T 19 (0.889 kg).

4.2.3.9 Days to Harvest

Significant differences were observed for days to harvest. T 19 was harvested earliest (40.65 days) followed by T 15 and T 24 (42.33 days), T 22 (42.77 days) and T20 (42.88 days). T 3 took 45.89 days to harvest.

T5- Anad Local T1- Githika T23- NS-634

Plate 5. Top yielding accessions

4.2.3.10 Crop Duration

There was significant difference between treatments for duration of the crop. The longest duration of 143.27 days was noted in T 18 which was on par with T 23 (141.23 days), T 21 (140.77 days), T 13 (140.73 days) and T 9 (139.53 days). The shortest duration of 115.87 days was recorded in T 19 followed by T 2 (124.03 days), T 26 (126.13 days), T 17 (127.20 days) and T 25 (128.50 days).

4.2.4 Quality Characters

The quality characters like, pod protein, crude fibre and keeping quality were also studied and presented in table 8 for yard long bean.

4.2.4.1 Pod Protein

There was significant difference between treatments for pod protein content. The value was ranged from 4.82 to 8.46 per cent with an average of 6.63 per cent. The maximum value obtained in T 11 (8.46 %) and minimum in T 1 (4.82 %).

4.2.4.2 Fibre

Fibre content differed significantly from 12.25 per cent to 16.43 per cent. Maximum fibre content was noticed in T 30 (16.43 %) which was statistically on par with T 23 (16.34 %), T 7 (16.07 %), T 17 (15.73 %), T 21 (15.56 %) and T 24 (15.09 %). The least fibre content was noted in T 13 (12.25 %).

4.2.4.3 Keeping Quality

The treatments varied significantly for keeping quality. The treatment T 27 had the highest keeping quality (4.77 days) which was on par with T 22 (4.62 days), T 28 (4.59 days) T 26 (4.53 days), T 20 (4.50 days), T 7 (4.29 days) and T 11 (4.25 days). T 4 had lowest (3.41 days) keeping quality.

4.2.5 Anatomical Characters

The anatomical characters like stomatal density, vascular bundles and cuticle thickness were also studied and presented in table 8.

4.2.5.1 Stomatal Density

The stomatal density was expressed as number of stomata/cm ^{2} and it varied from 2073.62 (T 9) to 4066.49 (T 4).

4.2.5.2 Vascular Bundles

In the case of vascular bundles highest number was recorded in T 7 (20.10) followed by T 25 (19.87), T 29 (19.77) and T 20 (19.73). The lowest number of vascular bundles was recorded in T 1 (16.90).

4.2.5.3 Cuticle Thickness

There was significant difference between treatments for cuticle thickness. Highest value for cuticle thickness was observed in T 8 (37.12 µm) followed by T 24 (35.46 µm), T 22 (35.41µm) and T 12 (35.40 µm). The lowest value was observed in T 7 (27.22 µm).

4.2.6 Screening for Pests and Diseases

The crop was monitored for the incidence of pests and diseases during the cropping period. Web blight (*Rhizoctonia solani*), fusarium wilt (*Fusarium oxysporum*) and mite (*Tetranychus* sp.) were the predominant ones exhibiting characteristic damage symptoms. Collar rot, pythium rot, viral diseases and pod borers were not observed.

4.2.6.1 Web Blight

The crop was monitored throughout the growing period for the incidence of web blight. Number of plants infected was counted and intensity of disease was calculated and presented in table 9 and plate 6A.

Plate 6A. Web blight

Plate 6 **Plate 6. Incidence of pests and diseases** ate 6C. Mite attack

Table. 8. Mean performance of 30 yard long bean accessions for quality and anatomical characters

Treatments		Pod protein (%)	Fibre (%)	Keeping quality (days)	Stomatal density (no./ cm²)	Vascular bundles (nos)	Cuticle thickness (µm)
T1	Githika	4.82	13.06	4.00	2266.77	16.90	33.12
T2	Periya Local	6.64	12.74	3.86	2895.11	17.43	32.07
T3	Muttacadu Local	7.43	12.51	3.65	3628.25	19.29	29.40
T4	Kanakakary Local	5.84	14.40	3.41	4066.49	19.50	31.96
T5	Anad Local	5.23	12.84	3.96	2933.08	17.53	30.30
T6	Kuttichal Local	5.74	13.00	3.85	2531.62	18.73	33.44
T7	Balaramapuram Local	7.08	16.07	4.29	3288.96	20.10	27.22
T8	Ettumanoor Local	7.78	13.58	4.23	2407.98	18.90	37.12
T9	Pilicode Local	6.67	14.80	3.85	2073.62	18.17	28.27
T10	Pattom Local	7.91	12.78	4.04	3272.38	17.00	30.64
T11	Kakamoola Local	8.46	13.70	4.25	2389.39	18.63	31.71
T12	Hosdurg Local	7.29	12.47	3.84	3729.49	17.93	35.40
T13	Neyyattinkara Local	7.19	12.25	3.51	2738.28	18.07	31.19
T14	Thirupuram Local	6.41	14.07	4.09	2451.27	18.33	29.38
T15	Nemom Local	5.67	12.46	3.87	3373.23	19.43	33.50
T16	Kumarapuram, Local	5.86	13.02	3.75	2335.92	18.80	28.98
T17	Super Green	6.72	15.73	4.12	2521.58	19.53	29.17
T18	Hari Rani	7.48	13.87	4.06	3478.63	19.13	29.85
T19	Rani	5.84	12.90	3.67	2241.11	18.50	28.92
T20	Rocket -77	6.76	12.91	4.50	2694.79	19.73	33.45
T21	NS-620	5.48	15.56	4.30	3244.88	19.70	33.78
T22	NS-621	7.20	14.42	4.62	2808.80	18.83	35.41
T23	NS-634	5.32	16.34	4.16	2523.77	19.30	29.33
T24	Babli	6.60	15.09	4.18	3765.32	18.47	35.46
T25	FH-30	7.31	13.83	4.40	3392.01	19.87	35.33
T26	Palapoor Local	6.21	14.81	4.53	3350.24	18.07	33.21
T27	Vellayani Jyothika	6.35	14.36	4.77	3583.98	18.90	30.99
T28	Lola	6.93	13.18	4.59	2348.38	19.60	33.59
T29	Kanjikuzhi payar	7.44	13.21	3.93	3055.76	19.77	32.80
T30	NKRA Local	7.27	16.43	4.14	3313.03	18.30	32.67
Mean		6.63	13.88	4.08	2956.80	18.75	31.92
CD(0.05)		0.490	1.351	0.531	516.911	1.480	0.810

Table 9. Intensity of web blight, fusarium wilt and mite in yard long bean, per cent

Treatments		Web blight intensity	Fusarium wilt intensity	Mite (Damage intensity)
T1	Githika	0.00	0.00	8.33
T2	Periya Local	0.00	0.00	8.33
T3	Muttacadu Local	0.00	0.00	25.00
T4	Kanakakary Local	0.00	0.00	8.33
T5	Anad Local	0.00	0.00	8.33
T6	Kuttichal Local	0.00	0.00	16.66
T7	Balaramapuram Local	32.63	0.00	8.33
T8	Ettumanoor Local	0.00	0.00	16.66
T9	Pilicode Local	0.00	0.00	25.00
T10	Pattom Local	25.40	0.00	16.66
T11	Kakamoola Local	0.00	0.00	8.33
T12	Hosdurg Local	0.00	0.00	25.00
T13	Neyyattinkara Local	0.00	0.00	16.66
T14	Thirupuram Local	0.00	8.33	25.00
T15	Nemom Local	25.92	0.00	16.66
T16	Kumarapuram Local	0.00	0.00	8.33
T17	Super Green	0.00	0.00	8.33
T18	Hari Rani	31.84	0.00	8.33
T19	Rani	0.00	16.66	16.66
T20	Rocket -77	0.00	0.00	8.33
T21	NS-620	0.00	0.00	8.33
T22	NS-621	0.00	10.66	8.33
T23	NS-634	0.00	0.00	8.33
T24	Babli	0.00	0.00	8.33
T25	FH-30	0.00	0.00	8.33
T26	Palapoor Local	0.00	29.16	8.33
T27	Vellayani Jyothika	0.00	0.00	8.33
T28	Lola	0.00	0.00	8.33
T29	Kanjikuzhi payar	0.00	0.00	8.33
T30	NKRA Local	27.15	41.66	8.33
CD (0.05)		-	-	1.09

Among 30 accessions, 25 were free from web blight incidence under polyhouse conditions. The remaining five accessions namely T 7, T 10, T 15, T 18 and T 30 had shown web blight symptoms at later stage of crop growth. Maximum diseases intensity was recorded in T 7 (32.63%) followed by T 18 (31.84%) and T 30 (27.15%).

4.2.6.2 Fusarium Wilt (*Fusarium oxysporum)*

The crop was monitored for fusarium wilt incidence and the percentage of disease intensity was calculated and given in table 9 (Plate 6B).

There was very low incidence of fusarium wilt in yard long bean under polyhouse condition. Only five accessions were infected with fusarium wilt. PDI ranged from 8.33 per cent (T 14) to 41.66 per cent (T 30).

4.2.6.3 Mite

Observations on mite attack were recorded from all the plants and damage intensity was calculated and given in table 9 (Plate 6C).

The damage intensity ranged from 8.33 – 25 per cent. Twenty treatments had least damage intensity of 8.33 per cent, four treatments (T 3, T 9, T 12 and T 14) had 25 per cent and the remaining six treatments (T 6, T 8, T 10, T 13, T 15, and T 19) had 16.66 per cent of damage intensity.

4.3. 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 26 characters under polyhouse condition were studied and are presented in table 10 (Fig. 5 and 6).

4.3.1 Growth Characters

Vine length ranged from 412.94 cm to 510.89 cm with a mean of 463.27 cm. The GCV was 5.70 and PCV was 7.20. Heritability was as high as 62.5 per cent while genetic advance as low as 9.28.

Primary branches showed a range of 3.95- 6.57 and the mean was 5.19. GCV was found to be 9.18 and PCV was 16.01. Heritability and genetic advance were moderate, 32.85 per cent and 10.83 respectively.

Petiole length ranged from 14.27- 21.27 cm and showed a mean value of 18.00 cm. The GCV and PCV were 8.58 and 9.83 respectively. Heritability was high (76.16) and genetic advance was moderate (15.42).

Length of terminal leaflets ranged from 17.47- 20.27 cm and showed a mean value of 18.61 cm. The GCV and PCV were 2.63 and 4.72 respectively. Heritability was moderate (31.16 per cent) and genetic advance was low (3.03). Length of lateral leaflets ranged from 16.42- 19.05 cm and showed a mean value of 17.84 cm. The GCV and PCV were 3.21 and 4.45 respectively. Heritability was moderate (51.9 per cent) and genetic advance was low (4.76).

Breadth of terminal leaflets ranged from 8.70- 12.28 cm with an overall mean of 9.74 cm. GCV was 7.17 and PCV was 11.18. Heritability was found to be moderate (41.06). Genetic advance was low (9.46). Breadth of lateral leaflets ranged from 8.39 to 11.52 cm with an overall mean of 9.19 cm. GCV was 5.95 and PCV was 9.31. Heritability was moderate (40.82 per cent). Genetic advance was low (7.83).

4.3.2 Flowering Characters

Mean of days to first flowering was 33.38 days and the range was 30.41- 37.11 days. GCV and PCV values were 3.67 and 5.09 respectively. Heritability was 64.12 per cent but genetic advance was low (6.05). Peduncle length ranged from 20.72- 40.51 cm with a mean of 29.11 cm. The GCV was 16.46 and PCV was 17.07, heritability was

Table 10. Estimates of genetic parameters for various characters in yard long bean

Character	Range	Mean	GCV	PCV	Heritability (%)	Genetic advance (GA) at 5%	Genetic advances as percentage of mean
Vine Length (cm)	412.94- 510.89	463.87	5.70	7.20	62.5	43.03	9.28
Primary branches/ plant	3.95- 6.57	5.19	9.18	16.01	32.85	0.56	10.83
Petiole length (cm)	14.27- 21.27	18.00	8.58	9.83	76.16	2.78	15.42
Terminal leaf length (cm)	17.47- 20.27	18.61	2.63	4.72	31.16	0.56	3.03
Lateral leaf length (cm)	16.42- 19.05	17.84	3.21	4.45	51.9	0.85	4.76
Terminal leaf width (cm)	8.70- 12.28	9.74	7.17	11.18	41.06	0.92	9.46
Lateral leaf width (cm)	8.39- 11.52	9.19	5.95	9.31	40.82	0.72	7.83
Days to first flowering	30.41- 37.11	33.38	3.67	4.58	64.12	2.02	6.05
Peduncle length (cm)	20.72- 40.51	29.11	16.46	17.07	92.98	9.51	32.69
Fruit set (%)	72.41- 83.18	77.82	3.04	4.69	42.09	3.16	4.07
Pod length (cm)	35.17 - 85.07	55.81	17.05	18.66	83.46	17.90	32.08
Pod girth (cm)	2.50- 4.00	3.15	14.18	17.44	66.11	0.75	23.75
Pod weight (g)	16.57- 64.77	26.52	33.68	35.84	88.28	17.28	65.18

Table 10. Continued…

Character	Range	Mean	GCV	PCV	Heritability (%)	Genetic advance (GA) at 5%	Genetic advances as percentage of mean
Pods/ plant	24.83- 112.14	71.16	21.12	23.36	81.74	27.99	39.34
Seeds/ pod	18.13- 21.57	19.93	3.44	5.13	45.03	0.95	4.76
100 Seed weight (g)	10.62- 23.65	16.85	21.39	22.83	87.84	6.96	41.31
Yield per plant (g)	893.04- 1627.12	1266.77	16.49	20.14	67.06	352.34	27.81
Yield/ plot (kg)	0.89- 1.62	1.27	16.23	20.07	65.38	0.34	27.03
Days to harvest	40.65- 45.89	43.79	2.12	2.60	66.38	1.56	3.55
Crop duration (days)	115.87- 143.27	134.87	4.26	4.78	79.13	10.52	7.80
Pod protein (%)	4.82- 8.46	6.63	13.09	13.86	89.3	1.69	25.49
Fiber (%)	12.25- 16.43	13.88	8.28	10.19	66.04	1.92	13.86
Keeping quality (days)	3.41- 4.77	4.08	6.75	10.39	42.16	0.37	9.02
Stomatal density (no./ cm^2)	2073.62- 4066.49	2956.80	17.41	20.43	72.59	903.32	30.55
Vascular bundles	16.90- 20.10	18.75	3.62	6.04	35.89	0.84	4.47
Cuticle thickness (μm)	27.22- 37.12	31.92	7.83	7.98	96.17	5.05	15.81

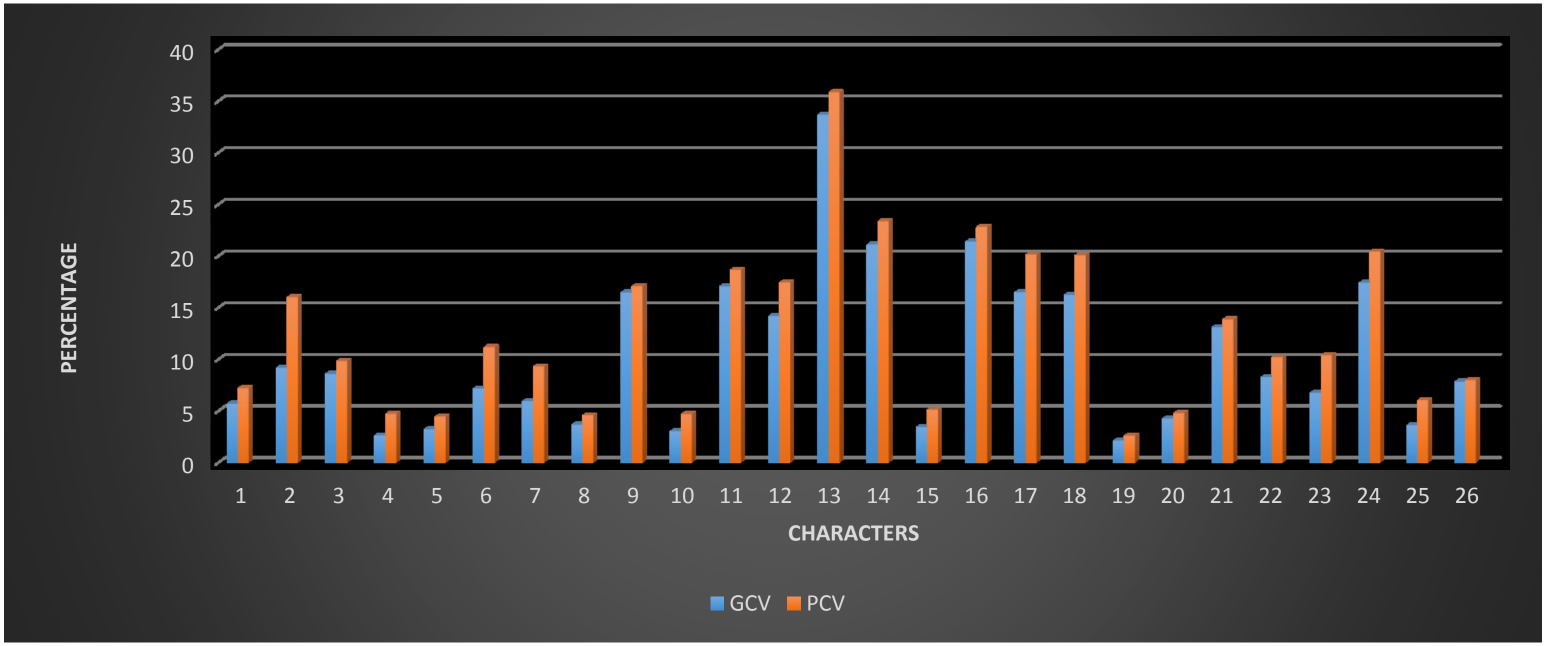

Figure.5. Genotypic and phenotypic coefficients of variation for different characters in yard long bea

X1. Vine Length (cm)	X8. Days to first flowering	X15. Seeds pod $^{-1}$	X22. Fiber (%
X2. Primary branches plant^{-1}	X9. Peduncle length (cm)	X16. 100 seed weight (g)	X23. Keeping quality (days)
X3. Petiole length (cm)	X10. Fruit set (%)	X17. Yield plant^{-1} (g)	X24. Stomatal density (no cm$^{2\ -1}$)
X4. Terminal leaf length (cm)	X11. Pod length (cm)	X18. Yield plot^{-1} (kg)	X 25. Vascular bundles
X5. Lateral leaf length (cm)	X12 .Pod girth (cm)	X19. Days to harvest	X26. Cuticle thickness (µm)
X6. Terminal leaf width (cm)	X13. Pod weight (g)	X20. Crop duration (days)	
X7. Lateral leaf width (cm)	X14. Pods plant $^{-1}$	X21. Pod protein (%)	

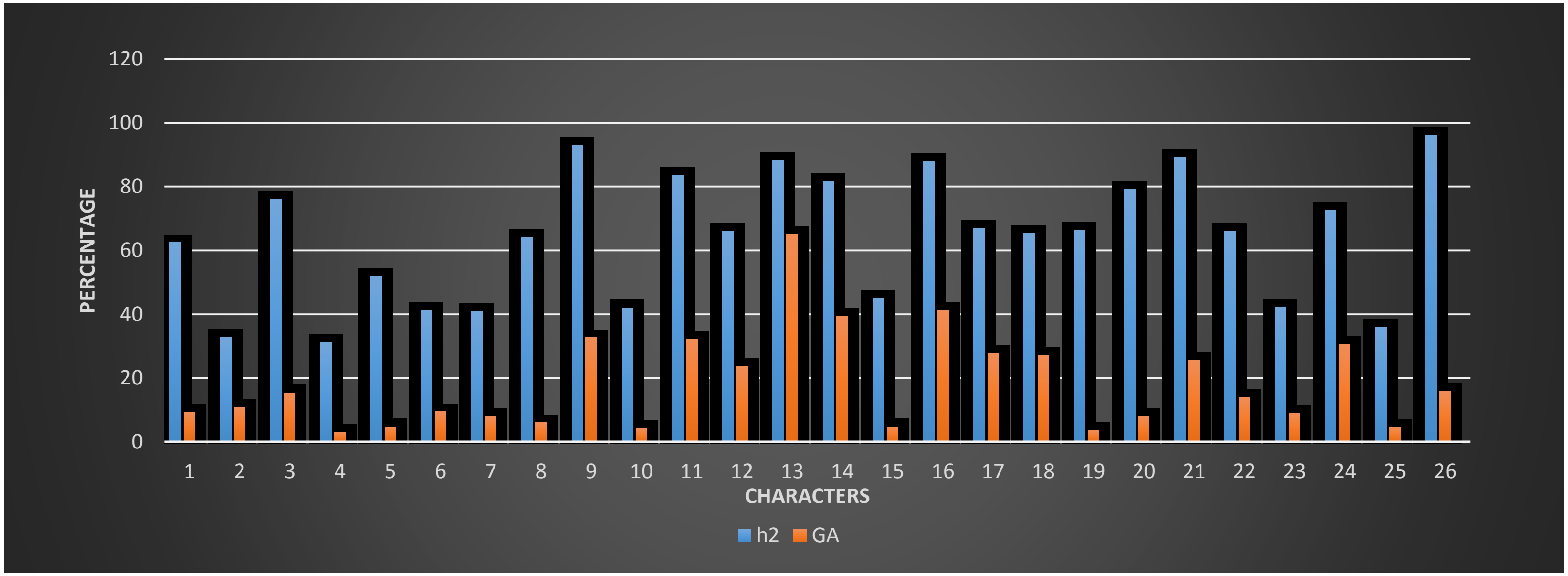

Fig. 6. Heritability and genetic advances for different characters in yard long bean

X1. Vine Length (cm)

X2. Primary branches plant^{-1}

X3. Petiole length (cm)

X4. Terminal leaf length (cm)

X5. Lateral leaf length (cm)

X6. Terminal leaf width (cm)

X7. Lateral leaf width (cm)

X8. Days to first flowering

X9. Peduncle length (cm)

X10. Fruit set (%)

X11. Pod length (cm)

X12 .Pod girth (cm)

X13. Pod weight (g)

X14. Pods plant $^{-1}$

X15. Seeds pod $^{-1}$

X16. 100 seed weight (g)

X17. Yield plant^{-1} (g)

X18. Yield plot^{-1} (kg)

X19. Days to harvest

X20. Crop duration (days)

X21. Pod protein (%)

X22. Fiber (%)

X23. Keeping quality (days)

X24. Stomatal density (no cm$^{2\ -1}$)

X 25. Vascular bundles

X26. Cuticle thickness (µm)

92.98 (high) and genetic advance was 32.69 (high). Fruit set per cent ranged from 72.41- 83.18 per cent with a mean of 77.82 per cent. The GCV was 3.04 and PCV was 4.69, heritability was found to be moderate (42.09) and genetic advances was low (4.07).

4.3.3 Yield Characters

Pod length ranged from 35.17 - 85.07 cm with an overall mean of 55.81 cm. GCV was17.05 and PCV was 18.66. Heritability and genetic advance was high 83.46 per cent and 32.08 respectively. Pod girth ranged from 2.50- 4.00 cm with an overall mean of 3.15 cm. GCV and PCV was 14.18 and 17.44 respectively. Heritability was 66.11 per cent (high). Genetic advance was 23.75 (high). Pod weight ranged from 16.57- 64.77 g with a mean of 26.52 g. The GCV was 33.68 and PCV was 35.84. Heritability was 88.28 and genetic advance was very high (65.18). Range of pods per plant was 24.83- 112.14 with a mean of 71.16. The GCV was 21.12 and PCV was 23.36. Heritability was high (81.74) and genetic advance was high (39.34).

Yield per plant showed a range of 893.04- 1627.12 g and the mean was 1266.77 g. GCV was found to be 16.49 and PCV was 20.14. Heritability was 67.06 and genetic advance was high (27.81). Seeds per pod ranged from 18.13- 21.57 with a mean of 19.93. The GCV was 3.44 and PCV was 5.13. Heritability was moderate as 45.03 and genetic advance was low 4.76. 100 seed weight showed a range of 10.62- 23.65 g and the mean was 16.85 g. GCV was found to be 21.39 and PCV was 22.83. Heritability and genetic advance was high, 87.84 and 41.31 respectively.

Days to harvest ranged from 40.65 to 45.89 days and the mean was 43.79 days. GCV was found to be 2.12 and PCV was 2.60. Heritability was 66.38 (high) and genetic advance was 3.55 (low). Crop duration ranged from 115.87 days to 143.27 days and the mean was 134.87 days. GCV was found to be 4.26 and PCV was 4.78. High heritability of 79.13 and low genetic advance of 7.80 was noticed.

4.3.4 Quality Characters

Protein content varied from 4.82 to 8.46 and the mean was 6.63. GCV was 13.09 and PCV was 13.86. Heritability was high (89.3) and genetic advance was very high *i.e*. 25.49. Fiber content showed a range of 12.25 to 16.43 per cent and the mean was 13.88. GCV was found to be 8.28 and PCV was 10.19. High heritability of 66.04 and moderate (13.86) genetic advance was noticed. Keeping quality showed a range of 3.41- 4.77 days and the mean was 4.08. GCV was found to be 6.75 and PCV was 10.39. Heritability was moderate as 42.16 and genetic advance was low as 9.02.

4.3.5 Anatomical Characters

Stomatal density varied from 2073.62- 4066.49 (no/cm^2) with a mean of 2956.80. GCV was found to be 17.41 and PCV was 20.43. Heritability was 72.59 and genetic advances was high as 30.55. Number of vascular bundles ranged from 16.90 to 20.10 with a mean of 18.75. GCV was found to be 3.62 and PCV was 6.04. Moderate heritability of 35.89 and low genetic advance of 4.47 was noticed. Cuticle thickness varied from 27.22- 37.12 with a mean of 31.92. GCV was found to be 7.83 and PCV was 7.98. High heritability of 96.17 and moderate genetic advance (15.81) was noticed.

4.4. CORRELATION STUDIES

The phenotypic, genotypic and environmental correlation among 14 characters in yard long bean under polyhouse condition are worked out and presented in tables 11, 12 and 13.

4.4.1 Phenotypic Correlation

Yield per plant showed positive correlation with pod length (0.4151), pod weight (0.4081), pod girth (0.3952), pods per plant (0.3544), lateral leaf length (0.3051) and vine length (0.2572).

Table 11.Phenotypic correlation coefficient for vegetative and yield characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.0000													
X2	**-0.2888**	1.0000												
X3	-0.1695	-0.0298	1.0000											
X4	0.0976	0.0784	***0.4207***	1.0000										
X5	0.0056	-0.0065	-0.0078	-0.0459	1.0000									
X6	0.0029	0.1849	0.0612	-0.0728	***0.3843***	1.0000								
X7	0.0763	-0.0239	**0.2734**	0.0171	0.1714	0.1214	1.0000							
X8	**0.2885**	-0.1565	***0.3443***	***0.4198***	0.0395	0.1651	0.0147	1.0000						
X9	-0.0280	-0.0692	-0.0617	***-0.3134***	-0.0283	-0.0507	**-0.2356**	-0.0772	1.0000					
X10	-0.1263	-0.0816	***0.4073***	***0.3551***	0.0652	-0.0816	**0.2234**	0.1063	-0.0875	1.0000				
X11	0.0476	0.0529	**0.2645**	0.1580	-0.1578	0.0395	0.1484	0.0540	-0.0378	***0.4326***	1.0000			
X12	0.0616	-0.1558	***0.3778***	**0.2898**	-0.1363	-0.1968	***0.3447***	0.1698	-0.0716	***0.7580***	***0.4083***	1.0000		
X13	0.0346	0.1276	-0.1590	-0.0545	0.0644	**0.2598**	**-0.2724**	-0.0235	0.0301	-0.3336	-0.0246	***-0.5048***	1.0000	
X14	**0.2572**	-0.0893	0.1821	***0.3051***	-0.0012	0.0279	0.0342	0.1292	-0.0408	***0.4151***	***0.3952***	***0.4081***	***0.3544***	1.0000

(Bold italics - significant at 1% level; Bold - significant at 5% level)

X1. Vine length (cm)
X2. Primary branches/ plant
X3. Terminal leaf length (cm)
X4. Lateral leaf length (cm)
X5.Terminal leaf width (cm)
X6. Lateral leaf width (cm)
X7. Days to first flowering
X8. Peduncle length (cm)
X9. Fruit set (%)
X10. Pod length (cm)
X11. Pod girth (cm)
X12. Pod weight (g)
X13. Pods plant^{-1}
X14. Yield plant^{-1} (g)

Table 12. Genotypic correlation coefficient for vegetative and yield characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.0000													
X2	***- 0.5459***	1.0000												
X3	-0.0707	***-0.3560***	1.0000											
X4	0.1691	-0.1042	***0.7211***	1.0000										
X5	0.1516	**-0.2577**	0.0104	-0.0410	1.0000									
X6	0.0617	***0.3452***	0.0101	0.0616	***0.3739***	1.0000								
X7	0.1050	0.0011	***0.5184***	0.2252	0.1032	-0.0227	1.0000							
X8	***0.3848***	***-0.3677***	***0.5561***	***0.5787***	0.0222	0.1452	-0.0140	1.0000						
X9	-0.0334	***0.3352***	**-0.2822**	***-0.3473***	-0.0669	***-0.4158***	***-0.4970***	-0.1540	1.0000					
X10	-0.0990	**-0.2437**	***0.7645***	***0.4574***	0.0938	-0.1006	***0.3938***	0.1140	-0.1408	1.0000				
X11	0.1080	-0.0364	**0.2935**	***0.3622***	***-0.5076***	-0.1593	0.1098	0.0340	-0.0319	***0.5556***	1.0000			
X12	0.1369	**-0.3287**	***0.6755***	***0.4620***	**-0.2496**	***-0.3373***	***0.4911***	0.1862	-0.1569	***0.8144***	***0.4924***	1.0000		
X13	0.0614	**0.2656**	**-0.2948**	0.0119	0.0482	***0.3989***	***-0.4033***	-0.0079	0.0077	***-0.4039***	-0.1635	***-0.6038***	1.0000	
X14	***0.3967***	**-0.2371**	***0.3422***	***0.4868***	-0.0385	0.1045	0.1155	0.1829	-0.0798	***0.5113***	***0.4018***	***0.5150***	0.3003	1.0000

(Bold italics - significant at 1% level; Bold - significant at 5% level)

X1. Vine length (cm)
X2. Primary branches/ plant
X3. Terminal leaf length (cm)
X4. Lateral leaf length (cm)
X5.Terminal leaf width (cm)
X6.Lateral leaf width (cm)
X7. Days to first flowering
X8. Peduncle length (cm)
X9. Fruit set (%)
X10. Pod length (cm)
X11. Pod girth (cm)
X12. Pod weight (g)
X13. Pods plant^{-1}
X14. Yield plant^{-1} (g)

Table 13. Environmental correlation coefficient for vegetative and yield characters in yard long bean

Character	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1.0000													
X2	-0.0827	1.0000												
X3	**-0.2722**	0.1237	1.0000											
X4	0.0031	0.2136	0.2271	1.0000										
X5	-0.1514	0.1402	-0.0182	-0.0508	1.0000									
X6	-0.0600	0.0928	0.0903	-0.1896	***0.3915***	1.0000								
X7	0.0266	-0.0496	0.0838	**-0.2717**	**0.2576**	**0.2886**	1.0000							
X8	-0.0295	0.2150	0.2046	0.0967	0.1269	***0.3714***	0.1612	1.0000						
X9	-0.0234	**-0.3109**	0.0641	**-0.2863**	-0.0009	0.2077	0.0496	0.0947	1.0000					
X10	-0.2203	0.1381	0.0517	0.1915	0.0327	-0.0730	**-0.2656**	0.0546	-0.0131	1.0000				
X11	-0.0611	0.1464	**0.2718**	-0.1341	0.2387	**0.2729**	0.2206	0.1770	-0.0473	0.0841	1.0000			
X12	-0.1911	0.0754	0.0827	-0.0968	0.0530	0.0215	-0.1209	0.0117	0.0922	***0.4231***	0.1611	1.0000		
X13	0.0981	0.0156	-0.0102	0.0700	-0.1069	-0.0707	0.1139	**0.2493**	0.0676	0.1241	-0.0584	0.1180	1.0000	
X14	0.0010	0.0467	0.0540	0.0451	0.0430	-0.0607	-0.1208	-0.0999	0.0036	0.1395	***0.3822***	0.0604	0.0616	1.0000

(Bold italics - significant at 1% level; Bold - significant at 5% level)

X1. Vine length (cm)
X2. Primary branches/ plant
X3. Terminal leaf length (cm)
X4. Lateral leaf length (cm)
X5.Terminal leaf width (cm)
X6. Lateral leaf width (cm)
X7. Days to first flowering
X8. Peduncle length (cm)
X9. Fruit set (%)
X10. Pod length (cm)
X11. Pod girth (cm)
X12. Pod weight (g)
X13. Pods $plant^{-1}$
X14. Yield $plant^{-1}$ (g)

Vine length was positively correlated with peduncle length (0.2885). Terminal leaf length was positively correlated with lateral leaf length (0.4207), pod length (0.4073), pod weight (0.3778) and peduncle length (0.3443). Lateral leaf length was positively correlated with peduncle length (0.4198), pod length (0.3551) and yield (0.3051). Positive correlation was found between terminal leaf width and lateral leaf width (0.3843). Days to first flowering was positively correlated with pod weight (0.3447).

Positive correlation was found between pod length and pod weight (0.7580), pod girth (0.4326) and yield per plant (0.415). Pod girth was positively correlated with pod weight (0.4083).

4.4.2 Genotypic Correlation

High positive correlation was obtained between yield per plant and pod weight (0.515), pod length (0.5113), lateral leaf length (0.4868), pod girth (0.4018), terminal leaf length (0.3422), pods per plant (0.3003) and vine length (0.3967).

Vine length exhibited a positive correlation with peduncle length (0.3848) and yield (0.3967). It was highly negatively correlated with primary branches per plant (-0.5459). Primary branches per plant was positively correlated with terminal leaf width (0.3452), fruit set per cent (0.3352) and negatively correlated with terminal leaf length (-0.3560), peduncle length (-0.3677) and pod weight (-0.3287). Terminal leaf length exhibited a positive correlation with days to first flowering (0.5184), peduncle length (0.5561), pod length (0.7645) and pod weight (0.6755). Lateral leaf length was positively correlated with peduncle length (0.5787), pod length (0.4574), pod weight (0.4620) and yield (0.4868). Positive correlation was found between lateral leaf width and pods per plant (0.3989). Days to first flowering had positive correlation with pod length (0.3938) and pod weight (0.4911). Pod length exhibited positive correlation with pod girth (0.5556), pod weight (0.8144) and yield (0.5113). Pod girth and pod weight were positively correlated with yield 0.4018 and 0.5150 respectively.

4.4.3 Environmental Correlation

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.

4.5 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, number of primary branches, days to flowering, pod length, pod girth, pod weight and pods per plant were selected for path coefficient analysis in yard long bean. Direct effects and correlation of the yield components are presented in table 14 and Fig. 7.

All characters except days to first flowering and pod girth recorded positive direct effect. Highest positive direct effect was observed for pod weight (0.8724) followed by pods per plant (0.8569).

Vine length had direct effect of 0.2776. Major portion of indirect effects was through pod weight (0.1194). Indirect effect of vine length on yield was through number of primary branches (-0.0164), days to first flowering (-0.0090), pod length (-0.0235), pod girth (-0.0042), and pods per plant (0.0526).

Number of primary branches had a genotypic correlation of -0.2371 with yield. In this, the direct effect was 0.0300. Indirect effect on yield through days to first flowering was -0.0001, then to pod length (-0.0577), pod girth (0.0014), pod weight (-0.2867) and pods per plant (0.2276).

The direct effect of days to first flowering on yield was negative (-0.0855) but genotypic correlation with yield was 0.1155. Days to first flowering had indirect effect on yield mainly through vine length (0.0292), pod length (0.0933), pod girth (-0.0043), pod weight (0.4284) and pods per plant (-0.3456).

Table 14 . Direct and indirect effect of yield components on yield of yard long bean

Character	Vine length	Primary branches	Days to first flowering	Pod length	Pod girth	Pod weight	Pods per plant	Genotypic correlation with yield
Vine length	**0.2776**	-0.0164	-0.0090	-0.0235	-0.0042	0.1194	0.0526	0.3967
Primary branches	-0.1516	**0.0300**	-0.0001	-0.0577	0.0014	-0.2867	0.2276	-0.2371
Days to first flowering	0.0292	0.0000	**-0.0855**	0.0933	-0.0043	0.4284	-0.3456	0.1155
Pod length	-0.0275	-0.0073	-0.0337	**0.2370**	-0.0216	0.7105	-0.3461	0.5113
Pod girth	0.0300	-0.0011	-0.0094	0.1317	**-0.0388**	0.4296	-0.1401	0.4018
Pod weight	0.0380	-0.0099	-0.0420	0.1930	-0.0191	**0.8724**	-0.5174	0.5150
Pods per plant	0.0171	0.0080	0.0345	-0.0957	0.0063	-0.5267	**0.8569**	0.3003

Residue (R) = 0.3076 (Underlined figures are direct effects)

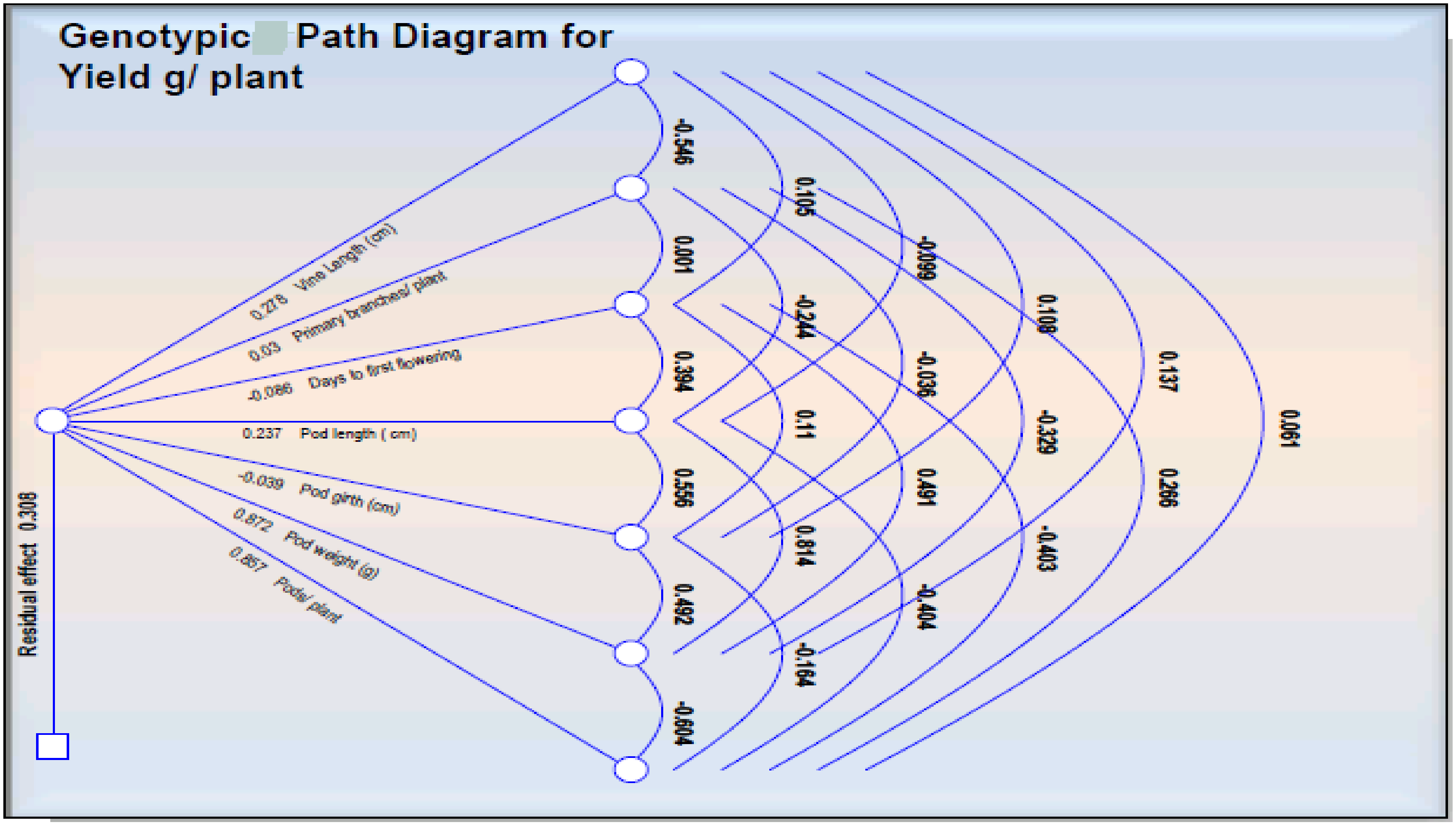

Fig. 7. Path diagram showing direct and indirect effect of yield components on total yield of yard long bean

The total genotypic correlation of pod length on yield was 0.5113. The direct effect was 0.2370. The rest of its effect on yield was contributed by indirect effect through vine length, number of primary branches, days to first flowering, pod girth, pod weight and pods per plant.

Pod girth had negative direct effect (-0.0388) on yield but genotypic correlation on yield was 0.4018. Pod girth had indirect effect on yield mainly through vine length (0.0300), number of primary branches (-0.0011), days to first flowering (-0.0094), pod length (0.1317), pod weight (0.4296) and pods per plant (-0.1401).

The direct effect of pod weight on yield was high (0.8724) and genotypic correlation was 0.5150. The rest of its effect on yield was contributed by indirect effect through vine length (0.0380), number of primary branches (-0.0099), days to first flowering (-0.0420), pod length (0.1930), pod girth (-0.0191) and pods per plant (-0.5174).

The total genotypic correlation of pods per plant on yield was 0.3003. The direct effect was 0.8569. Pods per plant had indirect effect on yield through vine length (0.0171), number of primary branches (0.0080), days to first flowering (0.0345), pod length (-0.0957), pod girth (0.0063) and pod weight (-0.5267).

4.6 SELECTION INDEX

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

Selection index was computed based on eight characters *viz*., vine length (X_1), number of primary branches (X_2), days to first flowering (X_3), pod length (X_4), pod girth (X_5), pod weight (X_6) pods per plant (X_7) and yield per plant (X_8).

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

$$I = 1.704\ X_1 - 5.7\ X_2 + 2.335\ X_3 + 3.965\ X_4 - 28.493\ X_5 + 8.235\ X_6 + 4.701\ X_7 + 0.414\ X_8$$

The index value for each treatment was determined and they were ranked. The values obtained for the treatments based on the selection index are given in Table 15.

Based on selection index, T1 was ranked first with a value of 2411.62, followed by T13 (2410.448). T18, T5 and T20 obtained next three positions with indices of 2373.98, 2346.539 and 2339.504 respectively. The minimum value was obtained for T19 followed by T3 with an index of 1881.481 and 1889.13 respectively.

4.7 CATALOGING OF GERMPLASM

All the 30 accessions used in the study were described morphologically using the modified descriptor developed from the standard descriptor for cowpea by IPGRI. The cataloguing was done on appropriate scales ranging from 0-9 (Table 16).

All the accessions had climbing habit with indeterminate growth pattern. Intermediate type of leafiness was noticed in T10, T17 and T29. T26, T28 and T13 was leafy. Rest of the accessions had vigorous growth. Plant pigmentation varied among the accessions. T16, T28, T30 and T2 had very slight pigmentation on stem and T13 had intermediate pigmentation on stem, leaf and petiole while T1 and T16 had moderate pigmentation on petiole. The rest of the accessions had no pigmentation.

All the accessions were glabrous and showed synchronous flowering. Flower pigment pattern showed marked variation. T 2, T 13, T 16 and T 17 had mauve pink colour, while T 3 and T 27 had creamy white flower. All other accessions had violet pigmentation on the flower. Calyx pigment pattern also showed variation. T 13 and T 16 had deeply pigmented calyx while T 2, T 12 and T 28 had light pigmented calyx and the rest had green calyx.

For all the accessions, pods were pendent. Pod colour is the important character used for the identification of a variety. Eighteen accessions had light green pods. Four accessions namely T 14, T18, T25 and T 26 had dark green pods. Green pods with red tip was noticed in six accessions *viz*. T 2, T 6, T 7, T 12, T 28 and T 30. Dark red

Table 15. Yard long bean acceessions ranked according to selection index
(Based on discriminant function analysis)

Treatments	Index	Ranks in ascending order
T1	2411.625	1
T13	2410.448	2
T18	2373.98	3
T5	2346.539	4
T20	2339.504	5
T23	2339.26	6
T16	2331.647	7
T25	2307.12	8
T24	2289.159	9
T17	2262.117	10
T21	2260.933	11
T9	2237.841	12
T22	2235.084	13
T7	2232.495	14
T8	2231.01	15
T14	2212.687	16
T6	2108.183	17
T26	2105.414	18
T4	2100.072	19
T30	2075.955	20
T27	2070.851	21
T28	2030.478	22
T11	2022.583	23
T15	2009.424	24
T10	1993.633	25
T2	1954.604	26
T29	1931.456	27
T12	1899.584	28
T3	1889.13	29
T19	1881.481	30

Table 16. Genetic cataloguing of genotypes of yard long bean used for the study

Treatments		Growth habit	Growth pattern	Twining tendency	Leafiness	Plant pigmentation		
						Stem	Branch	Petiole
T1	Githika	7	2	7	1	0	1	3
T2	Periya Local	7	2	7	1	1	0	1
T3	Muttacadu Local	7	2	7	1	0	0	0
T4	Kanakakary Local	7	2	7	1	0	0	0
T5	Anad Local	7	2	7	1	0	0	0
T6	Kuttichal Local	7	2	7	1	0	0	0
T7	Balaramapuram Local	7	2	7	1	0	0	0
T8	Ettumanoor Local	7	2	7	1	0	0	1
T9	Pilicode Local	7	2	7	1	0	0	0
T10	Pattom Local	7	2	7	3	0	0	0
T11	Kakamoola Local	7	2	7	1	0	0	0
T12	Hosdurg Local	7	2	7	1	0	0	1
T13	Neyyattinkara Local	7	2	7	2	5	5	5
T14	Thirupuram Local	7	2	7	1	0	0	0
T15	Nemom Local	7	2	7	1	0	0	0
T16	Kumarapuram Local	7	2	7	1	1	1	3
T17	Super Green	7	2	7	3	0	0	0
T18	Hari Rani	7	2	7	1	0	0	0
T19	Rani	7	2	7	1	0	0	0
T20	Rocket -77	7	2	7	1	0	0	0
T21	NS-620	7	2	7	1	0	0	0
T22	NS-621	7	2	7	1	0	0	0
T23	NS-634	7	2	7	1	0	0	0
T24	Babli	7	2	7	1	0	0	0
T25	FH-30	7	2	7	1	0	0	0
T26	Palapoor Local	7	2	7	2	0	0	0
T27	Vellayani Jyothika	7	2	7	1	0	0	0
T28	Lola	7	2	7	2	1	1	1
T29	Kanjikuzhi payar	7	2	7	3	0	0	0
T30	NKRA Local	7	2	7	1	1	1	0

Table 16. Continued

Treatments		Duration of flowering	Raceme position	Flower colour	Calyx colour	Pod attachment to peduncle	Pod pigmentation	Pod Curvature	Seed colour
T1	Githika	3	3	2	0	3	1	3	7
T2	Periya Local	3	3	3	3	3	5	3	9
T3	Muttacadu Local	3	3	1	0	3	1	3	6
T4	Kanakakary Local	3	3	2	0	3	1	0	1
T5	Anad Local	3	3	2	0	3	1	3	7
T6	Kuttichal Local	3	3	2	0	3	5	0	9
T7	Balaramapuram Local	3	3	2	0	3	5	3	9
T8	Ettumanoor Local	3	3	2	0	3	1	3	7
T9	Pilicode Local	3	3	2	0	3	1	3	2
T10	Pattom Local	3	3	2	0	3	1	0	1
T11	Kakamoola Local	3	3	2	0	3	1	0	5
T12	Hosdurg Local	3	3	2	3	3	5	3	9
T13	Neyyattinkara Local	3	3	3	5	3	7	0	3
T14	Thirupuram Local	3	3	2	0	3	3	3	7
T15	Nemom Local	3	3	2	0	3	1	0	10
T16	Kumarapuram Local	3	3	3	5	3	9	3	9
T17	Super Green	3	3	3	0	3	1	3	3
T18	Hari Rani	3	3	2	0	3	3	0	3
T19	Rani	3	3	2	0	3	1	3	3
T20	Rocket -77	3	3	2	0	3	1	3	7
T21	NS-620	3	3	2	0	3	1	0	3
T22	NS-621	3	3	2	0	3	1	3	3
T23	NS-634	3	3	2	0	3	1	3	3
T24	Babli	3	3	2	0	3	1	3	3
T25	FH-30	3	3	2	0	3	3	3	7
T26	Palapoor Local	3	3	2	0	3	3	3	1
T27	Vellayani Jyothika	3	3	1	0	3	1	3	6
T28	Lola	3	3	2	3	3	5	3	9
T29	Kanjikuzhi payar	3	3	2	0	3	1	3	2
T30	NKRA Local	3	3	2	0	3	5	3	9

pigmented pods with green tip were the peculiarity of T 13 whereas T 16 had red pigmented pods with red tip.

Seed colour is also used for the varietal identification. There was wide variation in seed colour among the accessions. Black seed colour was observed in seven treatments *viz.*, T 2, T 6, T 7 T 12, T 16, T 28 and T 30. Light brown seeds were noticed in T 4, T 10 and T 26. Dual seed colour (brown and white) was observed in T 3, T 9, T17, T 27 and T 29. Dark brown seed colour was observed in T 1, T 5, T 8, T 11, T 14, T 20 and T 25. T15 had black and white seed colour. Rest of the treatments had brown seed colour (Plate 7).

Plate 7. Variation in seed colour in yard long bean accession, T1-T15

Plate 7. Variation in seed colour in yard long bean accession, T16-T30

DISCUSSION

5. DISCUSSION

Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) is one of the most popular and cosmopolitan vegetable crop grown in Kerala. But the productivity and quality of the produce is low during the monsoon periods due to heavy rainfall and incidence of pests and diseases. To overcome this situation, protected cultivation is the best alternative. Protected cultivation is a unique and specialized form of agriculture which offers protection from adverse climate and weather, which ultimately influences the overall productivity and quality of the produce.

The improvement of any crop depends on the available variability, heritability and genetic advance of the character under selection. Knowledge on nature and extent of genetic variation and diversity available in the germplasm helps the breeder for planning sound breeding programmes. Thus, germplasm collection from diverse eco-geographical sources and evaluation under uniform conditions is a pre-requisite for any breeding programme.

The present investigation was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during 2014- 2015 to identify yard long bean genotypes suitable for polyhouse cultivation. The experiment was conducted in the naturally ventilated saw tooth type polyhouse in the Instructional Farm, Vellayani. The experiment was laid out in RBD with thirty accessions with three replications. In this chapter, attempt is being made to discuss salient experimental findings and to offer possible explanations and evidences with a view to determine the cause and effect relationships with regard to different characters.

5.1 MEAN PERFORMANCE OF YARD LONG BEAN ACCESSIONS UNDER POLYHOUSE

Analysis of variance revealed significant difference among the 30 accessions of yard long bean under polyhouse condition for all the characters studied *viz.,* vine length, number of primary branches, petiole length, length and breadth of terminal and lateral leaflets, days to first flowering, peduncle length, fruit set percent, pod length, pod girth, pod weight, pods per plant, yield per plant, seeds per pod, 100-seed weight, days to harvest, duration of crop, pod protein content, fibre content, keeping quality, stomatal density, vascular bundles and cuticle thickness.

5.1.1 Vegetative Characters

In the present study remarkable variation in mean performance was observed for vegetative characters like vine length, primary branches per plant, petiole length and length and breadth of leaflets under polyhouse condition. The longest vines were observed in NS-634 (T 23) followed by Anad Local (T 5) which were the top yielders. High temperature and increased CO_2 concentration might have contributed to the increased leaf size and vine length. The mean maximum and minimum temperature inside the polyhouse during the cropping period were 38.47 ^{0} C and 22.96^{0} C and in open field 31.11^{0} C and 22.88 ^{0} C. High temperature inside the polyhouse might have contributed to increase in vine length and other vegetative characters. This agrees with the results of Kumar and Arumugam (2010) and Rajasekar *et al*. (2013). CO_2 concentration in polyhouse and open field were 284.34 ppm and 269.25 ppm respectively. Increased CO_2 in polyhouse causes greater leaf expansion and larger canopy as reported by Suseela (2013). The plants in the polyhouse had higher values for vegetative characters like vine length, primary branches, petiole length, leaflet length and breadth than crops under field condition. Better performance for growth characters like plant height and number of primary branches under shade net as compared to open field condition was previously reported by Ganiger, 2010; Kavitha *et al*., 2009 and Rajasekar *et al.*, 2013 and in petiole length by Kumar and Arumugam (2010). High variability in yard long bean for vegetative character under field condition was earlier reported by Vidya (2000), Manju (2006), and Sivakumar (2012).

5.1.2. Flowering Characters

In the present study, the variety Rani (T19) was the earliest for flowering (30.41 days). Earliness may be due to the better and faster vegetative growth in polyhouse condition. This is in agreement with findings of Kumar and Arumugam (2010) in tomato and Thapa *et al.* (2013) in sprouting broccoli who reported earliness in flowering under protected cultivation.

5.1.3 Yield Characters

Yield is the most important economic character considered for selection. Significant variability among accessions for yield and yield attributes were observed. The highest yield per plant of 1627.12 g was recorded in Anad Local (T 5) which was on par with NS-634 (T23), Githika (T 1) and Hari Rani (T 64). The overall mean for the 30 accessions used in the study was 1266.77 g under polyhouse condition. Sivakumar (2012) reported a mean yield of 774.06 g per plant in a study consisting of 44 yard long bean accessions at College of Agriculture, Vellayani, indicating that higher yields could be realised under protected condition as compared with open field. Suseela and Rangaswami (2011) and Tapa *et al.* (2013) opined that higher yield under protected condition was due to suitable micro climate. Increased leaf area in the present study might have increased the carbohydrate accumulation and therefore increased yield. High relative humidity under protected condition also might have contributed to higher yield (Rajasekar *et al*., 2013).

Among the accessions, Super Green (T 17) recorded the highest pod length (85.07 cm) and pod weight (64.77 g) whereas highest pod girth was noticed in NS -634 (T 23) and Neyyattinkara Local (T 13) recorded highest number of pods per plant. The pods of Babli (T 24) had the maximum number of seeds (21.57) and maximum 100 seed weight of 23.65 g was recorded in Lola (T 28). In general, performance of accessions for pod characters was superior under polyhouse as compared to the results obtained in previous works under field condition (Resmi, 1998, Vidya, 2000, Lovely, 2005 and Sivakumar, 2012). This is in agreement with the finding that the number of fruits, fruit volume, fruit weight, fruit circumference and yield was higher in polyhouse condition than open field as reported by Kumar and Arumugam (2010) in tomato and Rajasekar *et al* (2013) in tomato, brinjal, chilli, bhindi and cluster bean, and Pintu (2014) in chilli.

Crop duration is another character which is altered favorably under protected cultivation. In the present study, the crop duration of 143.27 days was noticed for Hari Rani (T18). Increased crop duration under polyhouse may be due to better micro climate and less pest and disease incidence. The results are in agreement with findings of Suseela (2013).

5.1.4. Quality Characters

Quality characters are very important in any crop especially in vegetables because they impart nutritional quality of the produce. In the present study, different accessions showed variation in quality characters like protein content, fiber content and keeping quality. Highest protein content of 8.46 per cent was recorded by T11 and lowest by T1 (4.82 percent). A range of 4.61 to 5.94 per cent 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). In the present study the mean values for keeping quality in yard long bean grown under polyhouse was 4.08 days. There was not much difference with open condition (4.09 days) as was reported by Sivakumar (2012).

In the case of anatomical characters like vascular bundles and stomatal density, the variability under polyhouse condition was higher than that of open field. But cuticle thickness was higher in open condition (Sivakumar, 2012).

5.1.5 Screening for Pests and Diseases

The major constraints in yard long bean production were cowpea mosaic disease and pod borers, which were absent in the present study under polyhouse condition. Web blight, fusarium wilt and mites were noticed during the cropping period. However, there was no pronounced yield reduction due to pest and disease infestation.

Web blight caused by *Rhizoctonia solani* is an important disease causing severe economic losses in India (Shahina *et al*., 2003). Vegetable cowpeas are susceptible to diseases when planted in, moist soils coupled with high temperature and humid conditions (Thies *et al*., 2006). In the present study twenty five accessions were free from this disease, whereas five accessions namely T 7, T 10, T 15, T 18 and T 30 had shown web blight symptoms at later stage of crop growth. Among these, T7 had shown highest percentage of disease intensity followed by T18.

Fusarium wilt caused by *Fusarium oxysporum,* a systemic disease leading to collapse of the entire plant, affects the cowpea all over the world and it caused 2.2 to 98.1 per cent of yield loss (Eloy and Michereff, 2003). In this study among 30 accessions of yard long bean, only five accessions (T 14, T 19, T 22, T 26 and T 30) had incidence of fusarium wilt. The rest of the accessions were free from this disease. Less incidence of disease under protected condition was reported by Singh *et al.* (2005) in okra and cucumber and Kittas *et al*. (2009) in tomato. Low incidence may be due to high temperature and low humidity that prevailed in the polyhouse.

Among the insect pests, red spider mite *(Tetranychus* spp.) was noted in the present study. All the accessions recorded low damage intensity to a tune of 8.33 – 25 per cent. Sudden outbreak of mite was observed in the polyhouse which could be attributed to high temperature and low relative humidity resulting in dry condition. Weather parameters contributed for 78.24 to 84.65 per-cent of total variation in the population of mite (Mandal *et al*., 2006). Nadini (2010) and Monica *et al*. (2014) reported that the mite population showed high positive correlation with maximum temperature and negative correlation with relative humidity. On the other hand, Shah and Shukla (2014) reported that mite population had negative correlation with temperature and positive correlation with relative humidity.

In the present study, under polyhouse condition, it was noted that none of the accessions were affected by pod borer, aphids and mosaic diseases which are the limiting factors in yard long bean production.

5.2 COEFFICIENT OF VARIATION

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. PCV and GCV are the components used to measure the variability present in a population. The GCV provides a valid basis for comparing and assessing the range of genetic variability for quantitative characters and PCV measures the extent of total variation.

In the present study, high values of PCV and GCV were observed for pod weight, pods per plant and 100 seed weight. Moderate PCV and GCV were recorded for peduncle length, pod length, pod girth, yield per plant, pod protein and stomatal density.

Low GCV and PCV were recorded for vine length, fruit set per cent, seeds per pod, days to harvest, number of primary branches, petiole length, terminal and lateral leaflet length and breadth, days to first flowering, crop duration, fiber content, vascular bundles and cuticle thickness indicating low variability which limits the scope for further improvement through selection. The study revealed high estimates of GCV for pod weight which was in agreement with earlier reports by Lovely (2005), Girish *et al* (2006), Manju (2006), Jithesh (2009) and Sivakumar (2012).

In the present study, pods per plant also had high estimates of GCV and PCV. Similar results were reported in cowpea by Rangaiah (1997), Harshavardhan and Savithramma (1998b), Panicker (2000), Selvam *et al.* (2000), Jyothi (2001), Kutty *et al.* (2003), Madhukumar (2006) and Jithesh (2009) Sivakumar and Celine (2014).

A perusal of the data revealed that the GCV was very near to PCV for most of the characters, indicating a highly significant effect of genotype on phenotypic expression, with very little effect of environment. So the selection can be effective based on the phenotypic values. Such a closer PCV and GCV for different characters were earlier reported by Manju (2006), Madhukumar (2006) and Sivakumar (2012) in yard long bean.

From the foregoing discussions, it is clear that the characters *viz.,* pod weight and pods per plant offer good scope for selection in yard long bean.

5.3 HERITABILITY AND GENETIC ADVANCE

The variability existing in a population is the sum total of heritable and non-heritable components. Heritability provides information on the degree of inheritance of characters from the parents to the progeny. A high value of heritability (>60 per cent) indicates that the phenotype of that trait strongly reflects its genotype. A good knowledge of heritability is a pre-requisite for effective execution of plant breeding programmes, as it is a measure of success in separating genotypes by selection. Heritability on broad sense (V_G/V_P) expresses the extent to which individual's phenotypes are determined by genotypes. Characters possessing high heritability can be improved directly through selection as they are less affected by environment. 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 vine length, petiole length, days to first flowering, peduncle length, pod length, pod girth, pod weight, pods per plant, yield per plant, 100 seed weight, days to harvest, crop duration, pod protein, fiber content, stomatal density and cuticle thickness. Moderate heritability was observed for number of primary branches, terminal & lateral leaflet length, terminal & lateral leaflet breadth, seeds per pod, keeping quality and number of vascular bundles. High heritability can be attributed to the greater role of additive and additive x additive gene action, which can be exploited by following simple selection. Similar reports have also been put forward by Vidya (2000), Philip (2004), Resmi *et al*. (2004) Mary and Gopalan (2006), Nwosu *et al*. (2013) and Sivakumar and Celine (2014). Pod protein content showed high heritability in yard long bean by Madhukumar (2006) and Jithesh (2009).

High heritability estimates indicate the effectiveness of selection based on good phenotypic performance but does not necessarily mean high genetic gain for the particular character. High values of genetic advance as percentage of mean (> 20%) were observed for peduncle length, pod length, pod girth, pod weigh, pods per plant, yield per plant, 100 seed weight, protein content and stomatal density. The results are in line with the findings of Panicker (2000), Philip (2004), Mary and Gopalan (2006) and Sivakumar and Celine (2014) in cowpea. Vine length, terminal and lateral leaflet length, terminal and lateral leaflet breadth, seeds per pod, days to harvest, crop duration, keeping quality and number of vascular bundles had least genetic advance.

In the present study peduncle length, pod length, pod girth, pod weight, pods per plant, yield per plant, 100 seed weight, protein content and stomatal density recorded high heritability coupled with high genetic advance which indicate the presence of flexible additive gene effects and will be a useful criterion for selection for these characters. These results are in accordance with reports from Tikka *et al.* (1997), Panicker (2000), Pal *et al.* (2003), Philip (2004), Suganthi and Murugan (2007), Jithesh (2009), Kumar and Devi (2009), Sivakumar (2012) and Nwosu *et al*. (2013) in cowpea.

High heritability coupled with low to moderate genetic advance was observed for vine length, primary branches, petiole length, terminal and lateral leaflet length, terminal and lateral leaflet breadth, days to first flowering, fruit set percent, seeds per pod, days to harvest, crop duration, fiber content, keeping quality, number of vascular bundles and cuticle thickness suggesting improvement in these traits would be more effective by selecting specific combinations followed by intermating of lines. These results are in line with earlier workers Sreekumar *et al*. (1996), Resmi (1998) Panicker (2000) and Resmi *et al.* (2004) in yard long bean.

5.4 CORRELATION STUDIES

Yield is a complex character and is associated with a number of component characters. The relationship of yield with other characters is of great importance while formulating selection programmes for improvement of yield. 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 it improves, not only 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 pod length, pod girth, pod weight, pods per plant and days to first flowering. Sobha (1994) reported positive and significant correlation of pod yield with pod weight and pod length in bush cowpea. Resmi (1998), Vidya (2000), Kutty *et al.* (2003), Lovely (2005), Madhukumar (2006) and Jithesh (2009) also reported similar results in yard long bean.

Pod length exhibited a positive correlation with pod weight and pod girth. These results are in accordance with those of Singh and Verma (2002). It was negatively correlated with pods per plant and number of primary branches. Pod weight was positively correlated with pod yield per plant. These results are in agreement with the findings of Misra *et al.* (1994).

Pod girth was positively correlated with pod weight and days to first flowering. It was negatively correlated with pods per plant. Pods per plant was negatively correlated with pod length, pod girth, pod weight indicating that selection for increased pod length, pod girth or pod weight will result in reduction in number of pods per plant.

5.5 PATH COEFFICIENT ANALYSIS

Correlation coefficients reveal only the relation between yield and yield components and not the actual direct and indirect effects of the components on yield. Rate of crop improvement will be rapid if differential emphasis is given to the component characters during selection. The differential emphasis is to be given based on the degree of direct and indirect influence of the component characters on the economic character of interest as revealed by path coefficient analysis. Path analysis splits the genotypic coefficients into direct and indirect effects of the component characters on yield based on which crop improvement can be done more effectively.

If the correlation between yield and any of its components is due to the direct effect, it reflects a true relation between them and selection can be practiced for such character in order to improve yield. But if the correlation is mainly due to indirect effect of the character via another component trait, the breeder has to select the later trait through which the indirect effect is exerted.

In the present investigation, path coefficient analysis was used to separate the genotypic correlation coefficients of pod yield per plant with vine length, number of primary branches, days to first flowering, pod length, pod girth, pod weight and pods per plant. Pods weight (0.8724) exhibited the highest positive direct effect on pod yield followed by pods per plant (0.8569) indicating the importance of these characters in yield improvement programme. Vine length, number of primary branches and pod length also exerted positive direct effect on yield. Days to first flowering and pod girth exhibited negative direct effect on pod yield per plant. But its indirect effect *via* pod length, pod weight and vine length was positive and all other characters were negative, genotypic correlation with yield was positive.

The high direct effect of pod weight on yield is in accordance with earlier findings of Chattopadhyay *et al.* (1997), Rangaiah and Mahadevu (2000) and Madhukumar (2006). 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 Udensi *et al.* (2012b) in bush cowpea.

The positive direct effect of vine length, number of primary branches and pod length on yield observed in the study was in agreement with the findings of Kalaiyarasi and Palanisamy (1999), Lovely (2005) and Manju (2006). From the study it is evident that selection of genotypes based pod weight is most effective for improving yield of yard long bean.

The residue was 0.3076 indicating that selected seven characters contributed to the remaining 70 percent.

5.6 SELECTION INDEX

Selection of accessions based on suitable index is highly efficient in any breeding programme. 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 same character selected for path analysis like vine length, number of primary branches, days to first flowering, pod length, pod girth, pod weight, pods per plant and yield per plant were used for constructing selection index. Based on the selection index values, top ranking accessions namely Githika (T1) (2411.625), Neyyattinkara Local (T13) (2410.448), Hari Rani (T18) (2373.98), Anad Local (T5) (2346.539), Rocket-77 (T20) (2339.504) and NS-634 (T23) (2339.26) were identified as superior ones in yard long bean suitable for polyhouse cultivation.

Identification of superior accessions of vegetable cowpea based on discriminant function analysis was also done by Resmi (1998), Manju (2006), Jithesh (2009), Sivakumar (2012) and Shanko *et al.* (2014).

5.7 GENETIC CATALOGUING

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

The 30 yard long bean accessions, upon cataloguing showed distinct variation among each other with respect to vegetative, inflorescence, pod and seed characters. All the genotypes had climbing habit with indeterminate growth pattern. During vegetative stage most of the accessions were vigorous and leafy. Five accessions had purple or red pigmentation on stem, branches, and petioles. Among the accessions eighteen were light green poded, four dark green pods, six were green pods with red tip and remaining were red poded. There was wide variation in seed colour among the genotypes. Sees colour of all the accessions with red tip was black. Cataloguing of yard long bean was also attempted by Resmi (1998), Gopalakrishnan (2004) Manju (2006) and Sivakumar (2012).

SUMMARY

6. SUMMARY

The study entitled "Identification of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) genotypes suitable for polyhouse cultivation" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2014-2015 to identify yard long bean accessions with high yield and quality suitable for cultivation in naturally ventilated polyhouse.

The experiment was conducted in saw tooth type naturally ventilated polyhouse of size 1000 m^2 (50 m x 20 m), gutter height of 5 m and slope of 2 per cent, located at Instructional Farm, Vellayani. The framework is made of GI pipes of 76mm ID, 2-3 mm thickness. The roof was made of 200 micron UV stabilised polyethylene sheet. The polyhouse was provided with fogger unit to control temperature.

The experimental materials consisted of 30 yard long bean accessions including eighteen landraces maintained in Department of Olericulture, College of Agriculture, Vellayani, three KAU varieties and nine hybrids/varieties collected from private sector. They were evaluated in randomised block design with three replications. The accessions were assessed for the extent of variability, heritability and genetic advance. The relationship among the yield and associated traits was also worked out. The population was analyzed for the degree and direction of association between various economic traits and the direct and indirect effects of various components on yield. The salient results of the investigation are summarized below.

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 addition to the quality characters, anatomical characters, meteriological parameters and pest and disease scoring was also carried out.

The weather data during the cropping period from June 2014 to October 2014 inside and outside the polyhouse was recorded. In the polyhouse the maximum and minimum temperature ranged from 30.4 ^{0}C to 41.3 ^{0}C and 21.5 to 24.5 ^{0}C respectively. Relative humidity ranged from 81 to 94 per cent. Light intensity ranged from 60.3 klux to 70.1 klux. In open field the respective figures were 29.8^{0}C to 34.5 ^{0}C and 21.5 ^{0}C to 24.5 ^{0}C for temperature, 75.6 to 90 per cent relative humidity and 83.4 klux to 98.1 klux light intensity. CO_2 concentration was recorded both in polyhouse and open field. In polyhouse, it ranged from 269.38 to 293.32 ppm at 7am and 261.23 to 288.75 ppm at 4 pm. In open field, CO_2 concentration at 7am was 256.54 to 287.65 ppm and at 4 pm 254.43 to 283.30 ppm.

Analysis of variance revealed that the 30 accessions under study differed significantly for all the characters studied. The longest vines were observed in T 23 (NS-634) followed by T 5 (Anad Local). Primary branches per plant varied from 3.95 (T 23) to 6.57 (T16) and petiole length ranged from 14.27 (T4) cm to 21.27 (T10) cm. The variety T19 (Rani) was the earliest for flowering (30.41 days) and harvest (40.65 days) under polyhouse.

Among the treatments T 5 (Anad Local) had the highest yield (1627.12 g) which was on par with T 23 (NS-634) (1620.29 g), T1 (Githika) (1543.58 g) and T 18 (Hari Rani) (1528.75g), while T 17 (Super Green) recorded highest pod length (85.07 cm) and pod weight (64.77 g). Highest pod girth was noticed in T 23 (NS 634) (4.00 cm). Highest number of pods per plant (112.14) was recorded in T13 (Neyyattinkara Local). The highest fruit set per cent was obtained from T12 (83.18). Maximum 100 seed weight of 23.65 g was observed in T 28 which was statistically on par with T 27 (23.56 g) and T 20 (21.92 g).

Highest protein content of 8.46 per cent was recorded by T11 and lowest by T1 (4.82 %). Fibre content ranged from 12.25 per cent (T 13) to 16.43 per cent (T 30). Mean values for keeping quality of pods was 4.08 days. Highest number of vascular bundles was recorded in T 7 (20.10) while stomatal density was recorded in T 1 (16.90). Cuticle thickness was maximum in T 8 (37.12 μm) and the lowest in T 7 (27.22 μm).

The crop was monitored for the incidence of soil borne diseases, foliar diseases and pests during the cropping period. Crop was free from collar rot, pythium rot, viral diseases and pod borers. Web blight (*Rhizoctonia solani*), fusarium wilt (*Fusarium oxysporum*) and mite (*Tetranychus sp*.) were the predominant ones exhibiting characteristic damage. Twenty five accessions were free from web blight, whereas five accessions had shown the symptoms at later stages of crop growth. Among these, T7 had highest percentage of disease intensity (32.63%). Five accessions recorded fusarium wilt. Rest of the accessions were free from this disease. Among the insect pests, only red spider mite to a tune of 8.33 – 25 per cent intensity was noticed.

Phenotypic and genotypic coefficients of variation were high for pod weight, pods per plant and 100 seed weight and moderate PCV and GCV were recorded for peduncle length, pod length, pod girth, yield/plant, pod protein and stomatal density indicating good scope for further improvement through selection. GCV was very near to PCV for most of the characters, indicating a highly significant effect of genotype on phenotypic expression, with very little effect of environment.

In the present study, peduncle length, pod length, pod girth, pod weight, pods per plant, yield per plant, 100 seed weight, protein content and stomatal density recorded high heritability coupled with high genetic advance indicating the presence of flexible additive gene effects and will be a useful in selection for these characters.

The positive phenotypic and genotypic correlation with yield was observed for pod length, pod weight, pod girth, pods per plant and days to first flowering. Pod length exhibited a positive correlation with pod weight and pod girth. Pod girth was positively correlated with pod weight and days to first flowering. It was negatively correlated with pods per plant.

Path analysis revealed that pod weight exhibited the highest positive direct effect on pod yield (0.8724) followed by pods per plant and vine length. Number of primary branches and pod length also exerted positive direct effect on yield. Days to first flowering and pod girth exhibited negative direct effect on pod yield per plant. But its indirect effect through pod length, pod weight and vine length was positive.

Selection indices were worked out based on seven characters namely, vine length, number of primary branches, days to first flowering pod length, pod weight, pod girth and number of pods per plant. T 1 (Githika) was ranked first followed by T 13 (Neyyattinkara Local), T 18 (Hari Rani) and T 5 (Anad Local).

The accessions were genetically catalogued based on the descriptor for vegetable cowpea. The 30 yard long bean accessions, upon cataloguing, showed distinct morphological variation among each other with respect to vegetative, inflorescence, pod and seed characters.

REFERENCES

7. REFERENCES

Aberkain, K., Gosselin, A., Vineberg, S., and Dorais, M. 2006. Effects of insulating foams between double polyethylene films on light transmission, growth and productivity of greenhouse tomato plants grown under supplemental lighting. *Acta Hortic.* 711: 449-454.

Adewale, B. D., Okonji, C., Oyekanmi, A. A., Akintobi, D. A. C., and Aremu, C. O. 2010. Genotypic variability and stability of some grain yield components of cowpea. *Afr. J. Agric. Res.* 5(9): 874-880.

Aghora, T. S., Mohan, N., and Somkumar, R. G. 1994. Evaluation of vegetable cowpea (*Vigna unguiculata* (L.) Walp.) for earliness, protein content and green pod yield. *Leg. Res.* 17: 138-140.

Ahluwalia, M. S., Singh, B., and Singh, B. 1996. Effect of raising nursery in plastic greenhouse on yield, water use efficiency and quality of tomato crop. *Indian J. Ecol*. 23(2): 93-98.

Ajith, P.M. 2001. Variability and path analysis in bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 64p.

Alege, G. O. and Mustapha, O. T. 2007. Characterization studies and yield attributes of some varieties of cowpea (*Vigna unguiculata* L.). *Ethnobot. Leafl. 11: 113-121.*

Anbumalarmathi, J., Sheeba, A., and Deepasankar, P. 2005. Genetic variability and interrelationship studies in cowpea [*Vigna unguiculata* (L.) Walp.]. *Res. Crops* 6: 517-519.

Anbuselvam, Y., Manivannan, N., Saravanan, K., and Ganesan, J. 2001. Studies on genetic divergence in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J.* 87: 343-345.

Aremu, C.O. 2011. Trait response to early- generation selection using a common parent in two crosses of cowpea (*Vigna unguiculata*) for humid environment performance. *Adv. Appl. Sci. Res*. 2(6): 155-160.

Aruna, P. and Sudagar, I. P. 2009. Evaluation of capsicum varieties under polyhouse conditions. *Asian. J. Hortic.* 4(2): 336-337.

Awopetu, J. A. and Aliyu, O. M. 2006. Evaluation of cowpea accessions for the Southern Guinea savannah. *Trop. Sci.* 46: 227-232.

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

Backiyarani, S. and Natarajan, N. 1996. Variability studies in cowpea. *Leg. Res.* 19: 59-61.

Bastian, D., Das, L. D., Kandasamy, G., and Sakila, M. 2001. Path analysis in cowpea (*Vigna unguiculata* (L.) Walp*.). Madras Agric. J.* 88: 526-527.

Bhatnagar, P. R., Vedprakash, R. C., and Srivastav, R. C. 1990. Production of vegetables in poly house greenhouse during winters in mid hills of Uttar Pradesh. *Prog. Hortic*. 22: 97-100.

Bhatt, R. M. and Rao, N. K. S. 1993. Response of bell pepper to photo- synthesis, growth flower and fruit setting to night temperature. *Photosynthetica* 28: 127-132.

Biradar, M.S., Patil, C. R., and Mantur, S.M. 2015. Productivity and quality of color Capsicum as influenced by protected environment, planting geometry and pruning of stems. *J. Environ. Ecol*. 33(1B): 549-553.

Bowen, P. and Frey, B. 2002. Response of plasticultured bell pepper to staking, irrigation frequency and fertigated nitrogen rate. *HortScience*, 37: 95-100.

Buczkowska, H. 1990. Evaluation of yield of six sweet pepper cultivars grown in an unheated foil tunnel and in the open field. *Folia Hortic.* 2: 29-39.

Burt, J. 2005. Growing capsicums and chillies [on-line]. Available: http:/archive.agric.wa.gov.au/objtwr/importedassets/content/hort/veg/cp/capsicum/f6499.pdf. [16 Nov. 2014].

Chaturvedi, A. K., Prasad, P., and Nautiyal, M. C. 2010. Lesser chamber effect inside Open Top Chambers provides near natural microenvironment for CO_2 enrichment studies in an Alpine region of India. *J. Am. Sci.* 6(3): 109-117.

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

Cheema, D. S., Kaur, P., and Kaur, S. 2004. Off-season cultivation of tomato under net house conditions. *Acta Hortic.* 659: 177-181.

Chen, C. Y., Hu, Z. H., and Zhang, F.Y. 2001. Comparative experiment of protected ground cultivation patterns of asparagus bean (*Vigna unguiculata* subsp *sesquipedalis*) in early spring. *J. China Veg.* 6: 15-16.

Chowdhury, A. R. and Bhuyan, M. A. J. 1992. Effect of shading and 'atonik'-A plant stimulant on growth and yield of tomato in summer. *Punjab Veg. Grow.* 27:1-5.

Cobbinah, A. A., Quaye, A., and Asante, I. K. 2011. Characterization, evaluation and selection of cowpea (*Vigna unguiculata* (l.) Walp) accessions with desirable traits from eight regions of Ghana. *J. Agric Biol. Sci.* 6(7): 21-32.

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

De, N., Rajkumar, L., and Kalloo, G. 2001. Diet versatility in cowpea (*Vigna unguiculata* (L.) Walp.). *Indian J. Agric. Sci.* 71: 598-601.

Dixit, A. 2007. Performance of leafy vegetables under protected environment and open field condition. *Asian J. Hortic.* 2 (1): 197-200.

Dwivedi, N. K., Bhandari, D.C., Bhatnagar, N., Dabas, B.S., and Chandel, K.P.S. 1999. Conservation of genetic diversity in arid Legume. In: Faroda, A.S., Joshi, N.L, Kathju, S., and Kar, A. (eds), *Recent advances in Management of Arid Ecosystem.* Proceedings of the National Symposium on Recent Advances in Management of Arid Ecosystem, pp. 49-56.

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

Eloy, A. P. and Michereff, S. J. 2003. Yield reduction of cowpea cultivated in two planting dates by Fusarium wilt. *Summa Phytopathologica* 29: 330-333.

Eswaran, R. S., Kumar, T., and Venkatesan, M. 2007. Genetic variability and association of component characters for earliness in cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 30(1): 17-23.

Fisher, R.H. 1936. The use of multiple measurements in taxonomic problems. *Ann. Eugenics.* 7: 179-188.

Ganesan, M. 2002. Effect of poly-greenhouse models on plant growth and yield of tomato (*Lycopersicon esculentum*). *Indian J. Agric. Sci.* 72(10): 586-588.

Ganesan, M. and Subhasini. 2001. Study on Biometric characteristics of tomato grown in poly green house and open field conditions. *Madras Agric. J.* 89: 72-76.

Ganiger, V.M. 2010. Response of bell pepper to organic nutrition under different environments. *Karnataka J. Agric. Sci.* 23 (5): 840-845.

Gent, M. P. N. 1990. Factors affecting harvest date of tomato grown under floating row cover. *Appl. Agric. Res.* 5: 112-118.

Gimenes, E. S., Streck, N. A., Buriol, G. A., Garcia, D. C., and Rico, J. C. 1994. Effect of reduction in incident solar radiation on lettuce growth. *Ciencia Rural* 24: 241-246.

Girish, G., Viswanatha, K. P., Manjunath, A., and Yogeesh, L. N. 2006. Genetic variability, heritability and genetic advance analysis in cowpea [*Vigna unguiculata* (L.) Walp]. *J. Environ. Ecol.* 24: 1172-1174.

Gokulapalan, C., Girija, V. K., and Divya, S. 2006. *Fusarium pallidoroseum* causes fasciation and yield loss in vegetable cowpea (*Vigna unguiculata* var. *sesquipedalis*). *J. Mycol. Plant Pathol*. 36(1): 44-46.

Gopalakrishnan, T. R. 2004. *Three decades of vegetable research in Kerala Agricultural University*. Kerala Agricultural University, Vellanikkara, Thrissur, 152p.

Harshavardhan, P. N. and Savithramma, D. L. 1998a. Evaluation of cowpea genotypes for vegetable purpose (*Vigna unguiculata* (L.) Walp.). *ACIAR Food Leg. Newsl.* 28: 5-6.

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

Hazel, L.N. 1943. The genetic basis for constructing selection index. *Genetics*, 28: 476-490.

Hazra, P., Chattopadhyay, A., and Pandit, M. K. 1999. Genetic variability in three cultigroups of cowpea. *J. Interacademicia* 3: 263-268.

Hazra, P. and Som, M. G. 1999. *Technology for Vegetable Production and Improvement.* Nayaprokash, Calcutta (India). pp. 168-169.

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

Hazarika, T. K. and Phookan, D, B. 2005. Performance of tomato cultivars for poly house cultivation during spring summer in Assam. *Indian J. Hortic*. 62(3): 268-271.

Idahosa, D. O., Alika, J. E., and Omoregie, A. U. 2010. Genetic variability, heritability and expected genetic advance as indices for yield and yield components selection in cowpea (*Vigna unguiculata* (L.) Walp.). *Academia Arena* 2(5): 22-26.

Jackai, L. E. N. and Adalla, C. B. 1997. Pest management practices in cowpea: a review. In: Singh, B.B., Mohanraj, D.R., Dashiell, K.E. and Jackai, L.E.N. (eds), *Advances Cowpea Research* IITA, Nigeria, pp. 240-258.

Jackson, M.L. 1973. *Soil Chemical Analysis* (2nd Ed.). Prentice Hall of India (Pvt.Ltd.), New Delhi, 498p.

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

Jeevansab, 2000. Effect of nutrient sources on growth, yield and quality of capsicum grown under different environments. M.Sc. (Ag) thesis, University of Agricultural Sciences, Dharwad, Karnataka, India, 73p.

Jithesh, V.G. 2009. Genetic analysis of resistance to pod borers and yield in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 187p.

Johnson, H. W., Robinson, H. E., and Comstock, R. F. 1955. Genotypic and Phenotypic correlations in soya bean and their implications in selection. *Agron. J.* 47: 447-483.

Jyothi, C. 2001. Genetics of bruchid (*Callosobruchus* sp.) resistance and yield in cowpea. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 91p.

Kaddi, G., Tomar, B. S., Singh, B., and Kumar, S. 2014. Effect of growing conditions on seed yield and quality of cucumber (*Cucumis sativus*) hybrid. *Indian J. Agric. Sci.* 84(5): 624-627.

Kalaiyarasi, R. and Palanisamy, G. A. 1999. Correlation and path analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J.* 86: 216-220.

Kalaiyarasi, R. and Palanisamy, G. A. 2000. A study on character association and path analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res*. 24: 36-39.

Kalaiyarasi, R. and Palanisamy, G. A. 2001. A study on character association and path analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res*. 24: 36-39.

Kalaiyarasi, R. and Palanisamy, G. A. 2002. Path analysis of F_3 populations in cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 25: 47-49.

Kamaruddin, R. 2007. Design and development of naturally ventilated tropical crop protection structures and hydroponics systems. *Acta Hortic*. 742**:** 139-153.

Kamaruddin, R., Shahid, M., and Abdullah, F. 2006. Response of fertigation on capsicum growth under naturally ventilated tropical greenhouse. *Acta Hortic*. 710:275-280.

Kanthaswamy, V., Narendra, S., Veeraragavathatham, D., Srinivasan, K., and Thiruvudainambi, S. 2000. Studies on growth and yield of cucumber and sprouting broccoli under poly house condition. *S. Indian Hort*. 48: 47-52.

Kanwar, M.S. 2011. Performance of tomato under greenhouse and open field conditions in the trans-Himalayan region of India. *Adv. Hortic. Sci.* 25(1): 65-68.

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

Kapoor, A., Sohoo, M. S., Beri, S. M., and Bhardwaj, B. L. 2000. Correlation and path analysis in cowpea. *Crop Improv.* 27: 250-251.

Kavita, R., Khatri, K. S., and Hooda, J. S. 2003. Stability analysis for flowering and maturity in cowpea (*Vigna unguiculata* (L.) Walp.). *Ann. Agric. Bio Res.* 8: 33-36.

Kavitha, M., Natarajan, S., Pugalendhi, L., and Meenakshi, N. 2009. Protected cultivation of tomato (*Solanum lycopersicon* L.) under shade net. In: *Proceedings on National Workshop Cum Seminar on Status and Future Strategies of Horticulture Development in A& N islands*, 23-25 January 2009, Port Blair, Andaman, 170 p.

KAU [Kerala Agricultural University] 2011. *Package of Practices Recommendations for precision farming in vegetables: Crops,* (14th Ed.). Kerala Agricultural University, Thrissur, 334p.

KAU [Kerala Agricultural University]. 2013. *Annu. Rep. 2012-2013.* Kerala Agricultural University, Thrissur, 136 p.

Kittas, C., Rigakis, N., Katsoulas, N., and Bartzanas, T. 2009. Influence of shading screens on microclimate, growth and productivity of tomato. *Acta Hortic*. 807: 97-102.

Kumar, K. M. and Devi, D. S. R. 2009. Variability studies in yard long bean (*Vigna unguiculata* sub sp. *Sesquipedalis* (L.)). *J. Res. ANGRAU* 37: 58-61.

Kumar, R. and Sangwan, R. S. 2000. Genetic variability and heritability in cowpea *Vigna unguiculata* (L.) Walp.). *Ann. Biol.* 16: 181-183.

Kumar, S. R. and Arumugam, T. 2010. Performance of vegetables under naturally ventilated poly house condition. *Mysore J. Agric. Sc*i. 44 (4): 770-776.

Kumar, U. Singh, A.K., and Chandra, G. 2014. Perfomance of capsicum hybrids under naturally ventilated polyhouse in north Bihar condition. *J. Environ. Ecol.* 32(3): 972-974.

Kumari, P., Ojha, R. K., Abhivyakti, W. A., and Rajesh, R. P. 2014. Microclimatic alteration through protective cultivation and its effect on tomato yield. *J. Agrometeorol.* 16(2): 172-177.

Kutty, C. N., Mili, R., and Jaikumaran, U. 2003. Correlation and path coefficient analysis in vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *Indian J. Hortic*. 60: 257-261.

Kutty, C.N., Mili, R., and Jaikumaran, U. 2003. Variability and genetic divergence in vegetable cowpea. *J. Maharashtra Agric. Univ*. 28: 26-29.

Kutty, C.N., Sreelatha, U., Jyothi, M.L., and Gopalakrishnan, T.R. 2014. Advances in protected cultivation of vegetables in Kerala. In: Singh, B., Sabir,N. and Hasan, M.

(eds), *Advances in protected cultivation*. New India Publishing Agency, New Delhi, 133p.

Lange, A. J. and Combark, N. J. J. 1997. Microclimate and yield of seedless watermelon as affected by plant covers and soil mulches. *Appl. Plant Sci.* 11: 1- 6.

Lovely, B. 2005. Genetic analysis of yield and mosaic resistance in yard long bean [*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt). Ph.D. thesis, Kerala Agricultural University, Thrissur, 147p.

Madhukumar, K. 2006. Genetic variability for yield and fusarium wilt resistance in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 121p.

Mahajan, G. and Singh, K. G. 2006. Response of greenhouse tomato to irrigation and fertigation. *Agric. Water Manag.* 84(2): 202-206.

Malarvizhi, D. 2002. Genetic variability, heritability and genetic advance for leaf, pod and seed protein content in cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 25: 196-198.

Malu, K. 2011. Perfomance analysis of tropical cabbage (*Brassica oleraceae* var. *capitata*) hybrids under open and protected conditions. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 196 p.

Mandal, S. K., Sattar, A., and Banerjee, S. 2006. Impact of meteorlogical parameters on population buildup of red spider mite in okra (*Abelmoschus esculentus* (L.)) under North Bihar condition. *J. Agric. Physics* 6(1): 35-38.

Manggoel, W., Uguru, M. I., Ndam, O. N., and Dasbak, M. A. 2012. Genetic variability, correlation and path coefficient analysis of some yield components of ten cowpea [*Vigna unguiculata* (L.) Walp] accessions. *J. Plant Breed. Crop Sci*. 4: 80-86.

Manju, P. R. 2006. Characterization of vegetable cowpea (*Vigna unguiculata* (L.) Walp.). Ph.D. thesis, Kerala Agricultural University, Thrissur, 147p.

Manthur, S. M. and Patil, S. R. 2008. Influence of spacing and pruning on yield of tomato grown under shade house. *Karnataka J. Agric. Sci.* 21(1): 97-98.

Marsin, N. and Osvald, J. 1997. The influence of different cover materials of green houses on growth and development of pepper (*Capsicum annuum* L.). *Zbornic- Biotehniske-Fakultete-Univerze-v-Ljubljani,-Kmetijstvo.* 69: 141-46.

Mary, S. S. and Gopalan, A. 2006. Dissection of Genetic Attributes among Yield Traits of Fodder Cowpea in F_3 and F_4. *J. Appl Sci Res. 2(10)*: 805-808.

Mashego, D. C. 2001. The production of vegetable crops under protection for small scale farming situations. [on-line]. Available: http://www.alldissertations.com/full. [08 January 2015].

Mayee, C. D. and Dattar, V. V. 1986. *Phytopathometry.* Technical Bulletin – 1, Marathwada Agricultural University, Akola. 146p.

Megharaja, K.M. 2000. Studies on the effect of growing conditions and growth regulators on growth and productivity of hybrid capsicum cv. Indira. M.Sc. (Ag) thesis, University of Agricultural Sciences, Bangalore, Karnataka, 67p.

Mehta, D. R. and Zaveri, P. P. 1998. Genetic variability and association analysis in F_5 generation resulted from three selection schemes in cowpea. *J. Maharashtra Agric. Univ.* 23: 238-240.

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

Mishra, G. P., Singh, N., Kumar, H., and Singh, S. B. 2010. Protected cultivation for food and nutritional security at Ladakh. *Def. Sci*. *J.* 61(2): 219-225.

Mishra, S. and Dubey, S. C. 1991. Studies on web blight of groundnut, field bean, soy bean and yard long bean caused by *R. solani*. *J. Mycol. Pl. Path*. 21: 18-19.

Mishra, S. K., Singh, B. B., Chand, D., and Meena, K. N. 2003. Diversity for economic traits in cowpea. In: *Proceedings of the National Symposium on Arid Legumes for Food, Nutrition Security and Promotion of Trade,* Hisar, India, 15-16 May 2002. Advances in arid Legume research. 2003, pp. 54-58.

Misra, H. P., Ram, G., and Jha, P. B. 1994. Correlation and path coefficient studies for yield and yield attributing characters in cowpea (*Vigna unguiculata* (L.)). *Rec. Hortic.* 1: 61-67.

Monica., L., Kumar, A. Chand, H., Paswan, S., and Sanjeev, K.2014. Population dynamics of *Tetranychus urticae* Koch on brinjal crop under North Bihar conditions. *Pest Manage. Hortic. Ecosyst.* 20(1): 47-49.

Murthy, D. S., Prabhakar, B. S., Hebbar, S. S., Srinivas, V., and Prabhakar, M. 2009. Economic feasibility of vegetable production under polyhouse: a case study of capsicum and tomato. *J. Hortic. Sci*. 4(2): 148-150.

Nagalakshmi, S., Nandakumar, N., Palaniswamy, D., and Sreenarayana, V. V. 2001. Naturally ventilated polyhouse for vegetable cultivation. *S. Indian Hortic.* 49: 345-346.

Nagoata, M., Takahashi, K., Arai, K., Hanada, T., and Yoshioka, H. 1979. Effects of light intensity, night temperature and CO_2 concentration on the growth and yield of glass house tomato. *Bull. Veg. Ornamental. Crops Res. Stn.* 6: 105-122.

Naidu, N. V., Satyanarayana, A., and Seenaiah, P. 1996. Interrelationship between yield and yield attributes in cowpea (*Vigna unguiculata* (L.) Walp.). *S. Indian Hortic.* 50: 98-104.

Naik, R.K. 2005. Influence of N-substitution levels through organic and inorganic sources on growth, yield and post-harvest quality of capsicum under protected condition. Ph.D. thesis, University of Agricultural Sciences, Dharwad, Karnataka, India, 65p.

Nandini, 2010. Survey and management of pests of capsicum under protected cultivation. M.Sc. thesis, University of Agricultural Sciences, Dharwad, Karnataka, India, 81p.

Neema, V. P. and Palanisamy, G. A. 2003. Character association in F_2 population of cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 26: 146-148.

Nehru. S. D. and Manjunath, A. 2001. Genetic variability for yield and accessory characters in cowpea (*Vigna unguiculata* (Walp). *Indian Agric*. 45: 99-101.

Nehru, S. D., Suvarna, H., and Manjunath, A. 2009. Genetic Variability and Character Association Studies in Cowpea in Early and Late Kharif Seasons. *Leg. Res*. 32: 4- 8.

Nimje, P. M. and Shyam, N. 1991. Greenhouse as an alternative technology for commercial vegetable crop production. *Indian J. Agric. Sci.* 61: 185-189.

Nwofia, G.E. 2012. Yield and yield components in vegetable cowpea on an ultisol. *Afr.J. Agric. Res*. 7(28): 4097-4103.

Nwosu, D. J., Olatunbosun, B. D. and Adetiloye, I. S. 2013**.** Genetic variability, heritability and genetic advance in cowpea genotypes in two agro-ecological environments. *Greener J. Biol. Sci*. 3(5): 202-207.

Ofori, I. and Djagbletey, D. 1995. Analysis of yield and components of yield in some early maturity varieties of cowpea (*Vigna unguiculata* (L.) Walp.). *Trop. Sci.* 35: 236-239.

Omoigui, L.O. Ishiyaku, M.F., Kamara, A.Y. Alabi, S.O., and Mohammed, S.G. 2006. Genetic variability and heritability studies of some reproductive traits in cowpea (*Vigna unguiculate* (L.)Walp.). *Afr. J. Biotechnol*. 5(13): 1191-1195.

Padi, F.A. 2003. Genetic analysis of pigmentation in cowpea. *Pakist. J. Biol. Sci.* 6: 1655-1659.

Pal, A. K., Maurya, A. N., Singh, B., Ram, D., and Kumar, S. 2003. Genetic variability, heritability and genetic advance in cowpea (*Vigna unguiculata* (L.) Walp.). *Orissa J. Hort.* 31: 94-97.

Panicker, P.R. 2000. Evaluation of vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.) for legume pod borer, *Maruca vitrata* (Fab.) resistance and yield. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 92p.

Parmar, L. D., Chauhan, R. M., and Tikka, S. B. S. 2003. Association analysis for grain yield and contributing characters in cowpea. In: Henry, A., Kumar, D., Singh, N. B. (eds), *Proceedings of the national symposium on arid Legumes, for food nutrition security and promotion of trade; 15-16 May, 2002; Hisar, India,* Advances in arid Legumes research, pp. 50-53.

Parvej, M. R., Khan, M. A. H., and Awal, M. A. 2010. Phenological development and production potentials of tomato under polyhouse climate. *J. Agric. Sci.* 5: 19-31.

Papadopoulos, A. P. and Ormorod, D. P. 1991. Plant spacing effect on growth and development of greenhouse tomato. *Can*. *J. Plant Sci*. 71: 297-304.

Peksen, A., Peksen, E., and Bozoglu, H. 2002. Effects of sowing dates on yield and quality of cowpea (*Vigna unguiculata* L. Walp.) genotypes grown in greenhouse. *Acta Hortic*. 579: 351-354.

Perrino, P., Laghetti, G., Zeuli, P. L. S., Monti, L. M., and Spagnoletti-zeuli, P. L. 1993. Diversification of cowpea in the Mediterranean and other centers of cultivation. *Gen. Resour. Crop Evol.* 40: 121-132.

Philip, M.C.A. 2004. Genetic analysis of legume pod borer *Maruca vitrata* (Fab.) resistance and yield in cowpea (*Vigna unguiculata* (L.) Walp.). PhD thesis, Kerala Agricultural University, Thirssur, 171p.

Prabhu, M., Kumar, A. R., Balasubramanian, V., Jagadeesan, R., and Ponnuswami, V. 2009. Protected cultivation of vegetables. *Asian J. Hortic*. 4(2): 529-533.

Prabhu, M., Remeshkumar, A., Balasubramanian, B., Jagadeesan, R. and Ponnuswami, V.2010. Protected cultivation of vegetables. *Asian J. Hort.* 4: 529-533.

Pradhan, S., Chatterjee, R., and Thapa, U. 2008. Studies on the year round Cauliflower production in open and under cover conditions in the hill of Darjeeling District. *J. Interacademicia* 12(1): 16-26.

Pravin, K.K., Nathish, K.R., Nagajothi, T., Rajesh, L., and Usha, K.R. 2013.Morphological and genetic variation studies in cowpea genotypes [*Vigna unguiculata* (L.)Walp]. *Leg. Res*. 36(4): 351-354.

Pintu, R. V. 2014. Production technology of chilli (*Capsicum annuum* L.) under protected cultivation. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 127 p.

Purushotham, S., Narayanaswamy, G. V., Siddaraju, R., and Girejesh, G. K. 2001. Production potential of fodder cowpea genotypes under rainfed conditions. *Karnataka J. Agric. Sci.* 14: 446-448.

Rahman, M. J. and Inden, H. 2012. Effect of nutrient solution and temperature on capsaicin content and yield contributing characteristics in six sweet pepper (*Capsicum annuum* L.) cultivars. *Food Agric. Environ*. 10(1): 524-529.

Rajasekar, M., Arumugam, T., and Kumar, S. R. 2013. Influence of weather and growing environment on vegetable growth and yield. *J. Hortic For*. 5(10): 160-167.

Rangaiah, S. 1997. Variability studies in two F_2 populations of cowpea (*Vigna unguiculata* (L.) Walp.). *Karnataka J. Agric. Sci.* 10: 1026-1029.

Rangaiah, S. and Mahadevu, P. 2000. Genetic variability, correlation and path coefficient analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Madras Agric. J. 86*: 381-384.

Rejatha, V. 1992. Combining ability in vegetable cowpea [*Vigna unguiculata* var. *sesquipedalis*]. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 113p.

Resmi, P.S. 1998. Genetic variability in yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Verdcourt). M.Sc. (Ag) Thesis, Kerala Agricultural University, Thrissur. 94p.

Resmi, P. S., Celine, V. A., and Vahab, M. A. 2004. Genetic variability in yard long bean {*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt}. *Leg. Res.* 27: 296-298.

Robinson, H. F., Comstock, R. E., and Harvey, P. H. 1949. Estimates of heritability and the degree of dominance in corn. *Agron. J.* 14: 352-359.

Rylski, I. and Spigelman, M. 1986. Effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation. *Scientia Hortic*. 29(2): 31-35.

Sadasivam, S. and Mainckam, A. 1996. *Biochemical methods for agricultural sciences*. Wiley Eastern Ltd., New Delhi, 246p.

Satparthy, S., Rai, S., and Kapoor, K. S. 1998. Integrated management of vegetable pest. In: *National Symposium on Emerging Scenarios in Vegetable Research and Development*, 1998. Indian Institute of Vegetable Research, Varanasi, pp. 123-130.

Sawant, D. S., Birar, S. P., and Yadhav, B. B. 1994. Heterosis in cowpea. *J. Maharashtra Agric. Univ.* 19: 89-91.

Selvam, Y.A., Manivannan, N., Murugan, S., Thangavelu, P., and Ganesan, J. 2000. Variability studies in cowpea [*Vigna unguiculata* L. (Walp.)]. *Leg. Res*. 23(4): 279-280.

Shah, D.R. and Shukla, A. 2014. Seasonal incidence of spider mite, *Tetranychus urticae* (Koch) (*Tetranychidae*: Acari) on gerbera (*Gerbera jamesonii*) under polyhouse conditions. *Pest Manage. Hortic. Ecosyst.* 20(1): 26-29.

Shahina, K., Luthra, Y. P., and Gandhi, S. K. 2003. Role of zinc and manganese in resistance of cowpea root rot. *J. Plant Dis. Prot.* 110: 235-243.

Shanko, D., Andargie, M., and Zelleke, H. 2014. Interrelationship and path coefficient analysis of some growth and yield characteristics in cowpea (*Vigna unguiculata* L. Walp) genotypes. *J. Plant Sci*. 2(2): 97-101.

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

Sharma, M. K., Kumar, R. and Kumari, S. 2011. Identifying superior quality F_1 tomato hybrids for year round production under low cost plastic green houses in North-West Himalayas. *Veg. Sci.* 38: 30-34.

Sharma, N. K. and Tiwari, R. S. 1993. Effect of shade on growth contributing characters and factors in relation to yield of tomato cv. Pusa Ruby. *Prog. Hortic*. 25:180-184.

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

Singh, A. K., Singh, B., and Gupta, R. 2011. Performance of sweet pepper (*Capsicum annuum*) varieties and economics under protected and open field conditions in Uttarakhand. *Indian J. Agric. Sci.* 81(10): 973–975.

Singh, A. K., Singh, B., Sindhu, S. S., Singh, J. P., and Savir, N. 2012. Study of protected v/s open field conditions on insect-pest incidence to minimize insecticide application for quality production of high value horticultural crops. *Int. J. Plant. Prot.* 5(1): 75-80.

Singh, A. K., Shrivastava, R., Gupta, M. J., and Chandra, P. 2005. Effect of protected and unprotected condition on biotic stress, yield and economics of spring summer vegetables. *Indian J. Agric. Sci*. 75: 485-487.

Singh, B. 1998. Vegetable production under protected condition: Problems and prospects. In: *National Symposium on Emerging Scenarios in Vegetable Research and Development*, 1998. Indian Institute of Vegetable Research, Varanasi, pp. 90-95.

Singh, K., Singh, R., Khurana, D. S., and Singh, J. 2013. Effect of low- tunnel on the growth, yield and harvesting span of sweet pepper. *HortFlora. Res. Spectrum* 2(1): 45-49.

Singh, M. K. and Verma, J. S. 2002. Variation and character association for certain quantitative traits in cowpea germplasm. *Forage Res.* 27: 251-253.

Singh, N., Singh, V. P., and Singh, J. V. 1998. Correlation and path coefficient analysis in cowpea *Vigna unguiculata* (L) Walp.) *Trop. Grain Leg. Bull.* 26: 3-5.

Singh, R., Asrey, R., and Nangare, D. D. 2003. Studies on the performance of tomato and capsicum under medium cost greenhouse. In: *Proceedings of All India Sem. on Potential and Propsects for Protected Cultivation,* 12-13 December 2003. Institute of Engineers, Ahmednagar, pp. 158-161.

Singh, S. K., Tiwari, P. S., Singh, G. R., Singh, B. R., and Singh, D. 2009. Economics of naturally ventilated greenhouse for tomato production in northern plain of india. *Prog. Agric*. 9(1): 130-133.

Sivakumar, V. 2012. Screening of vegetable cowpea (*Vigna unguiculata* (L) Walp) germplasm for yield quality and resistance to collar rot and web blight. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 175 p.

Sivakumar, V. and Celine, V.A. 2014. Genetic variability, heritability and genetic advance for yield and rield attributes in yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt). *Bioinfolet* 11(2A): 415-417.

Smith, F. H. 1937. A discriminant function for plant selection. *Ann. Eugenics.* 7: 240-250.

Smith, I.E., Savage, M.J., and Mills, P. 1984. Shading effects on greenhouse tomatoes and cucumbers. *Acta Hortic.* 148: 229-237.

Sobha, P. P. 1994. Variability and heterosis in bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 120 p.

Sobha, P. P. and Vahab, M. A. 1998. Genetic variability, heritability and genetic advance in cowpea (*Vigna unguiculata* (L.) Walp*). J. Trop. Agric*. 36: 21-23.

Sreekumar, K. 1995. Genetic analysis of biological nitrogen fixation traits and yield components in cowpea (*Vigna unguiculata* (L.) Walp.). Ph.D. thesis, Kerala Agricultural University, Thrissur, 175p.

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

Srichandran, S., Panda, S.C., Sahu, G. S., Mahapatra, P., and Mishra, R. C. 2006. Effect of shade net on growth and yield of cauliflower. *Orissa J. Hortic*. 34(1): 28-31.

Stoilova, T. and Lozanov, I. 2001. Correlative dependences between some quantitative indices in *Vigna unguiculata*. *Plant Sci*. 38: 213-217.

Subbiah, A., Anbu, S., Selvi, S., and Rajankam, J. 2003. Studies on the cause and effect relationship among the quantitative traits of vegetable cowpea. (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 26: 32-35.

Sudhakumari, J.S. 1993. Screening of cowpea (*Vigna unguiculata* (L.) Walp.) types for resistance to cowpea aphid borne mosaic disease. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 104p.

Sudhakumari, J. S. and Gopimony, R. 1994. Genetic divergence in cowpea. In: Das, M. R. (ed.), *Proceedings of the sixth Kerala Science Congress, January 29-31, 1994;* Thiruvananthapuram. Kerala State Committee on Science, Technology and Environment, Government of Kerala, pp. 164-167.

Suganthi, S and Murugan, S. 2007. Variability studies in cowpea [*Vigna unguiculata* (L.) Walp.]. *Crop Res. Hissar.* 33 (1/3): 195-197.

Suganthi, S. and Murugan, S. 2008. Association analysis in cowpea (*Vigna unguiculata* (L.) Walp). *Leg. Res.* 31 (2): 130-132.

Suseela, P. 2013. Design and management of protected cultivation in Kerala- A practical Guide-Communication centre, KAU. 366p.

Suseela, P. and Rangaswami, M.V. 2011. Influence of temperature inside the greenhouse on growth attributes and yield of cauliflower. *Karnataka J. Agric. Sci.* 24(5): 706-708.

Suseela, P. and Rangaswami, M.V. 2012. Variation of relative humidity inside the greenhouse with height, ventilation and ambient climatic parameters. *Karnataka J. Agric. Sci*. 25(1). 100-103.

Tamgadge, S., Dod, V.N., Mahorkar, V.K., and Peshattiwar, P.D. 2008. Genetic variability, heritability and genetic advance in cowpea [*Vigna unguiculata* (L.) Walp]. *Asian J. Hortic.* 3(1): 30-32.

Thangam, M. and Thamburaj, S. 2008. Comparative performance of tomato varieties and hybrids under shade and open conditions. *Indian J. Hortic*. 65(4):429-433.

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

Thapa, U., Rai, R., Lyngdoh, Y.A., Chattopadhyay, S. B., and Prasad, P. H. 2013. Assessment of producing quality sprouting broccoli (*Brassica oleracea* var. *italica*) under cover and open condition. *Afr. J. Agric. Res. 8*(15): 1315-1318.

Thies, J. A., Berland, P. A., and Fery, R. L. 2006. Response of cowpea cultivars to *Rhizoctonia solani* in field tests. *Hortic Sci.* 40: 876-879.

Tikka, S. B. S., Jaimini, S. N., Asawa, B. M., and Mathur, J. R. 1997. Genetic variability, interrelationship and discriminant function analysis in cowpea (*Vigna unguiculata* (L.) Walp). *Indian J. Heredity* 9: 1-9.

Tyagi, P. C., Kumar, N. M. C., and Kumar, N. 2000. Genetic variability and association of component characters for seed yield in cowpea. (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 23: 92-96.

Udensi, O. U. and Edu, N. E. 2015. Evaluation and identification of genetic variation pattern in cowpea [*Vigna unguiculata* (L.) Walp] accessions using multivariate analyses. *J. Basic & Appl. Sci.* 11: 149-158.

Udensi, O. U., Edu, N. E., Ikpeme, E.V., Ebiwgai, J.K., and Ekpe, D.E. 2012a. Biometrical evaluation and yield performance assessment of cowpea (*Vigna unguiculata* (L.) Walp) landraces grown under lowland tropical conditions. *Int.J. Plant Breeding Genet*. 6(1): 47-53.

Udensi, O., Edu, E. A., Ikpeme, E. A., Ebiwgai, J. K., and Ekpe, D. E. 2012b. Relationship studies in Cowpea (*Vigna unguiculata* (L.) Walp.) landraces grown under humid lowland conditions. *Int. J. Agric. Res.* 7: 33-45.

Uguru, M.I. 1995. Heritable relationship and variability of yield and yield components in vegetable cowpea. *Afr. Crop Sci. J.* 3(1):23-28.

Umaharan, P., Ariyanayagam, R. P., and Haque, S. Q. 1997. Genetic analysis of yield and its components in vegetable cowpea (*Vigna unguiculata* (L.) Walp.). *Euphytica*. 96: 207-213.

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

Vidya, C. 2000. Legumeume pod borer resistance and genetic divergence in domestic germplasm of yard long bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt.). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 121p.

Venkatesan, M., Prakash, M., and Ganesan, J. 2003. Genetic variability, heritability and genetic advance analysis in cowpea (*Vigna unguiculata* (L.) Walp.). *Leg. Res.* 26(2): 155-156.

Venthamoni, P.I. and Natarajan, S. 2008. Cultivation of sweet pepper cultivars (*Capsicum annuum* var *grossum* L.) under shade net in tropical plains of Tamil Nadu. *Asian. J. Hortic*. 3(2): 372-376.

Wani, K. P. Singh, P. K. Amin, A. Mushtaq, F., and Dar Z.A. 2011. Protected cultivation of tomato, capsicum and cucumber under kashmir valley conditions. *Asian J. Sci. Technol. 1(4): 56-61.*

Wright, S. 1954. The interpretation of multivariate systems, In: Kempthrone, O., Bancroft, T. A., Gawen, J. W. and Lush, J. L (eds.), *Statistics and Mathematics in Biology*. State University Press., Iowa, pp. 11-13.

Yadav, J., Singh, N., and Kumar, N. 1999. Nutritional values of off-season leafy vegetables grown in trench under cold arid conditions of Leh. *Agric. Sci. Digest*. 19(2): 103-04.

Yadav, R. K., Kalia, P., Choudhary, H., Husainand, Z., and Dev, B. 2014. Low-Cost Polyhouse Technologies for Higher Income and Nutritional Security. *Int. J. Agric. Food Sci. Technol.* 5(3): 191-196.

Yellavva, K. 2008. Evaluation of capsicum hybrids under different protected structures, M.Sc. (Ag) thesis, University of Agricultural Sciences, Dharwad, 53 p.

IDENTIFICATION OF YARD LONG BEAN (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) GENOTYPES SUITABLE FOR POLYHOUSE CULTIVATION

by

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ABSTRACT

The present investigation entitled "Identification of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) genotypes suitable for polyhouse cultivation" was taken up at the Department of Olericulture, College of Agriculture, Vellayani, during 2014- 2015 with the objective of identifying yard long bean genotypes with high yield and quality suitable for cultivation in naturally ventilated polyhouse.

The experiment was conducted in the saw tooth type naturally ventilated polyhouse of size 1000 m^2 (50 m x20 m) located at Instructional Farm, Vellayani. The experimental materials consisted of 30 yard long bean accessions, including 18 landraces, three KAU varieties and nine hybrids/varieties collected from private seed firms. The experiment was laid out in RBD with three replications.

During the cropping period the maximum and minimum temperature in the polyhouse ranged from 30.4 ^{0}C to 41.3 ^{0}C and 21.5 to 24.5 ^{0}C respectively. The relative humidity ranged from 81 to 94 per cent and light intensity from 60.3 klux to 70.1 klux. CO_2 concentration varied between 269.38 to 293.32 ppm at 7am and 261.23 to 288.75 ppm at 4 pm.

Analysis of variance showed significant difference between the accessions for all the characters studied. The longest vines were observed in NS-634 (T 23) followed by Anad Local (T 5). Primary branches per plant varied from 3.95 (T 23) to 6.57 (T16) and petiole length ranged from 14.27 (T4) cm to 21.27 (T10) cm. The variety Rani (T19) was the earliest for flowering (30.41 days) and harvest (40.65 days) under poly house.

Among the accessions, Anad Local (T 5) had the highest yield (1627.12 g) which is on par with NS-634 (T 23), Githika (T 1) and Hari Rani (T 64), while Super Green (T 17) recorded the highest pod length (85.07 cm) and pod weight (64.77 g).

Highest pod girth was noticed in NS -634 (T 23) and Neyyattinkara Local (T 13) recorded highest number of pods per plant.

The crop was free from collar rot, pythium rot, viral diseases and pod borers. However mild incidence of web blight and fusarium wilt was noticed in few accessions while low incidence of mites was observed in most of the accessions at high temperature and low relative humidity.

High values of PCV and GCV were observed for pod weight, pods per plant and 100 seed weight. High heritability coupled with high genetic advance were recorded for peduncle length, pod length, pod girth, pod weight, pods per plant, yield per plant, 100 seed weight, protein content and stomatal density indicating that selection based on these characters would be effective.

Positive phenotypic and genotypic correlation with yield was observed for pod length, pod weight, pod girth, pods per plant and days to first flowering. The path analysis revealed that pod weight had the highest positive direct effect on pod yield (0.8724) followed by pods per plant.

The selection indices were worked out based on seven characters namely vine length, number of primary branches, days to first flowering, pod length, pod weight, pod girth and number of pods per plant. Githika (T 1) was ranked first followed by Neyyattinkara Local (T 13), Hari Rani (T 18) and Anad Local (T 5).

On the basis of *per se* performance and selection index values, the top yielders Anad Local (T 5), NS 643 (T 23) and Githika (T1) were identified as the most suitable for cultivation in naturally ventilated polyhouse.

APPENDICES

APPENDIX- I

PHYSICO-CHEMICAL PROPERTIES OF SOIL

Parameter	value	Rating
P^H	5.60	Moderately acid
Electrical conductivity ($dSm^{-1)}$	0.074	Normal
Organic carbon (%)	1.10	Medium
Available P (Kg ha^{-1})	43.20	High
Available K (Kg ha^{-1})	405.00	High
Exchangeable Ca (ppm)	250.00	Deficient
Exchangeable Mg (ppm)	60.00	Deficient
Available S (ppm)	25.20	Sufficient
Available Fe (ppm)	26.60	Sufficient
Available Mn (ppm)	39.30	Sufficient
Available Zn (ppm)	6.50	Sufficient
Available Cu (ppm)	1.00	Sufficient
Available B (ppm)	0.52	Sufficient

APPENDIX II
FERTIGATION SCHEDULE FOR PRECISION FARMING IN YARD LONG BEAN
40 Split – 120 Days

Sl No	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha)	200 sqm (g)
	Basal Dose P (kg/ha)		52.50	1.050
1	3rd Day after planting	19:19:19	52.50	1.050
		13:0:45	6.90	0.140
		Urea	7.80	0.160
		12:61:0	6.40	0.130
2	6th Day after planting	19:19:19	0.00	0.00
		13:0:45	6.90	0.140
		Urea	7.80	0.160
		12:61:0	6.40	0.130
3	9th Day after planting	19:19:19	0.00	0.00
		13:0:45	6.90	0.140
		Urea	7.80	0.160
		12:61:0	6.40	0.130
4	12th Day after planting	19:19:19	0.00	0.00
		13:0:45	6.90	0.140
		Urea	7.80	0.160
		12:61:0	6.40	0.130
5	15th Day after planting	19:19:19	0.00	0.00
		13:0:45	6.90	0.140
		Urea	7.80	0.160
		12:61:0	6.40	0.130
6	18 th Day after planting	19:19:19	6.90	0.140
		13:0:45	7.80	0.160
		Urea	6.40	0.130
		12:61:0	0.00	0.00
7	21st Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
8	24th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
9	27th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
10	30st Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020

APPENDIX II Continued

Sl No	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha)	200 sqm (g)
11	33rd Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
12	36th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
13	39th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
14	42nd Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
15	45th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
16	48th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
17	51st Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
18	54th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	1.25	0.030
		12:61:0	1.080	0.020
19	57th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
20	60th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020

APPENDIX II Continued

Sl No	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha)	200 sqm (g)
21	63th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
22	66st Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
23	69th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
24	72th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
25	75th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
26	78th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
27	81st Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
28	84th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
29	87th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
30	90th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020

APPENDIX II Continued

Sl No	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity (kg/ha)	200 sqm (g)
31	93rd Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
32	96th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
33	99th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
34	102 rd Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
35	105th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
36	108rd Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
37	111th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
38	114th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
39	117th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020
40	120th Day after planting	19:19:19	3.50	0.010
		13:0:45	15.80	0.320
		Urea	7.30	0.150
		12:61:0	1.080	0.020

Appendix- III

MODIFIED DESCRIPTOR FOR COWPEA BY IPGRI

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. 6 Plant 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/ 5.30-90o down from erect/ 7.erect

Appendix- III continued

2.6 Pod pigmentation	- 1.Light green/ 3.Dark green/ 5. Green with red tips /7.Red pod with green tip / 9. Red pod with red tip
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.Blac. 10. Black and white

APPENDIX IV

Weather data in poly house during the cropping period

(10th July – 19th October, 2014) Weekly average

Standard week	Temperature (^{0}C)		Relative humidity (%)	Light intensity (K. lux)
	Max. temp	Min. temp		
28	38.4	21.7	94.00	66.5
29	36.4	22.7	90.00	63.1
30	41.3	24.5	82.25	67.5
31	39.5	21.6	88.20	60.3
32	40.8	23.4	82.00	62.8
33	34.6	23.8	89.00	68.5
34	30.4	22.8	87.00	66.4
35	32.4	23.6	81.00	70.1
36	38.8	21.8	87.25	67.8
37	32.5	23.9	88.75	65.3
38	33.5	21.5	84.55	64.2
39	36.7	22.8	81.25	68.4
40	38.5	23.9	91.25	62.4
41	33.4	22.8	82.25	64.6
42	36.4	23.7	87.65	63.4

APPENDIX V

Weather data in open field during the cropping period

(10th July – 19th October, 2014) Weekly average

Standard week	Temperature (^{0}C)		Relative humidity (%)	Light intensity (K. lux)
	Max. temp	Min. temp		
28	29.8	22.7	90.0	92.5
29	30.5	23.7	88.5	98.1
30	34.5	24.5	83.6	96.5
31	32.6	21.6	89.5	86.3
32	32.5	23.4	82.5	92.8
33	30.2	23.8	89.7	88.5
34	30.1	21.8	88.5	86.4
35	29.9	23.6	83.5	90.1
36	30.5	21.8	86.5	87.8
37	30.1	23.9	89.2	85.3
38	30.5	21.5	85.0	94.2
39	32.5	22.8	85.5	94.4
40	32.2	22.7	87.0	92.4
41	30.5	21.8	75.6	84.6
42	30.6	23.7	82.4	83.4

APPENDIX VI

CO_2 concentration (ppm) inside and outside the polyhouse during cropping period

(10th July – 19th October, 2014) Weekly average

Standard week	CO_2 concentration in poly house		CO_2 concentration outside the polyhouse	
	7 am	4 pm	7 am	4 pm
28	293.32	265.85	263.32	259.85
29	286.98	261.23	276.98	271.23
30	284.34	276.45	276.34	273.45
31	269.38	261.65	258.38	256.65
32	279.98	268.45	269.98	268.45
33	298.56	287.98	285.56	281.98
34	287.65	283.30	287.65	283.30
35	285.98	276.45	267.98	266.45
36	269.95	257.89	258.95	256.89
37	276.45	272.11	266.45	262.11
38	292.35	287.43	272.35	267.43
39	298.45	288.75	278.45	274.75
40	288.56	279.56	268.56	259.56
41	276.54	268.43	256.54	254.43
42	279.67	271.98	269.67	261.98