IDENTIFICATION OF PHOTO INSENSITIVE GENOTYPE(S) OF WINGED BEAN (*Psophocarpus tetragonolobus* (L.) DC.)

by

PRASANTH, K.

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Identification of photo insensitive genotype(s) of winged bean (*Psophocarpus tetragonolobus* (L.) DC.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Date: 30-06-2014 (2012-12-101)

CERTIFICATE

Certified that this thesis entitled **"Identification of photo insensitive genotype(s) of winged bean (*Psophocarpus tetragonolobus* (L.) DC.)"** is a record of research work done independently by Mr. Prasanth, K. 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 him.

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LIST OF ABBREVIATIONS

%	Per cent
>	Greater than
<	Less than
µg	Microgram
CD	Critical difference
cm	Centimeter
et al.	And others
Fig.	Figure
g	Gram
GA	Genetic advance
GCV	Genotypic coefficient of variation
h	hour
h^2	Heritability
ha	Hectare
i.e.	That is
IPGRI	International Plant Genetic Resource Institute
KAU	Kerala Agricultural University
Kg	Kilogram
L	Litre
m	Metre
mg	Milligram
min	Minutes
ml	Milliliter
mm	Millimeter
Max.	Maximum
No. of	Number of
^0C	Degree Celsius
PCV	Phenotypic Coefficient of Variation
RH	Relative humidity
sec	Seconds
SE	Standard error
sp.	Species
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
var.	Variety

INTRODUCTION

1. INTRODUCTION

In the course of civilization, man has explored about 80,000 edible plants, out of which only a small fraction of about 3000 plant species has been used for food and only about 150 species have been cultivated commercially. Nevertheless, majority of the people in the world are fed with only 20 crops including cereals, pulses, roots and other food crops. Dependence of humans on plant species is inevitable, but continued dependence on few crops is risky in terms of evolution of virulence leading to large scale crop failures.

India is the second largest producer of vegetables in the world next only to China. Our country shares about 14 per cent of world's output of vegetables from about two per cent of cropped area in the country. Despite the contribution of vegetables as high as 48.37 per cent of the total horticultural produce, the present per capita availability is only about 230 g per day as against 300 g recommended for proper health (Vanitha *et al.*, 2011). As far as Kerala is concerned, we are producing only 25 percent of the required quantity and the rest is meeting from neighbouring states. Hence, concerted efforts are suggested for augmenting the vegetable production and their availability through well-planned strategies in several directions.

A large number of leguminous species, which have not yet been fully exploited, have a great potential for contributing to nutritive food, feed and forage needs in the tropical countries where almost half of the world's under and malnourished population lives. Hence, it is important to exploit such legume vegetables for better health and nutrition.

Among the under exploited legume vegetables, winged bean (*Psophocarpus tetragonolobus* (L.) DC.), also known as 'flying bean' or 'four angled bean' in English and as 'chathurapayar' or 'erachipayar' in Malayalam is the most important. Since nearly every portion of the plant is edible or can be profitably utilized, several superlatives like 'soya's rival', 'God-sent vegetable' and 'vegetable of twentieth century' (Peter, 1998) have often been used for winged bean. All parts of this plant, *viz.*, leaves, flowers, green pods, fresh and dry seeds and tubers are consumed as food in variety of preparations. Winged bean is also known as super market on a stalk because the plants combine the desirable characteristics of common bean, pea, spinach, mushroom, soya bean and potato (Gopalakrishnan, 2007). Presently it is cultivated only for its tender green pods and seeds.

Winged bean belongs to the genus *Psophocarpus* (from the Greek word 'noise' and 'fruit' as the fruit makes sound while opening). *Psophocarpus paulustris* Desv., *P. scandens* (Endl.) Verd., *P. lancifolius* (Horms.), *P. monophyllus* (Horms) and *P. tetragonolobus* (L.) DC. are some of the winged bean species grown. Among these, only *P. tetragonolobus* is commercially cultivated.

Winged bean is a herbaceous perennial legume grown as annual climber with green or purple stem, twining to a height of four meters or more if suitably supported. Thus, there is an added advantage of this crop to be included in the cropping system with the crops having long, sturdy and solitary stems (drumstick, curry leaf, etc.) and is a photosensitive crop and requires short days for normal flower induction. Winged bean requires day length shorter than 12 hours and a maximum and minimum temperature of 27^0C and 22^0C respectively for flowering (Hazra and Som, 1999). In this context, development of photo insensitive variety is a major breeding objective in the crop improvement programmes of winged bean.

Being a tropical vegetable, winged bean prefers a warm climate and is drought tolerant. The advantage of winged bean includes its easiness to grow, adaptation to drought and freedom from serious pest and diseases. Though it is a protein rich vegetable its flowering and fruiting are limited to the short day period of the year (November to January). But with the development of photo insensitive variety, it is possible to get fruits throughout the year.

Winged bean was introduced in India in 1979 at the Kew Garden, Sibpur, Kolkata. It has not spread or cultivated widely despite its tremendous nutrition and diversified utility due to lack of concerted effort on crop improvement programmes suiting to different agro ecological conditions coupled with lack of awareness among the growers and consumers about the potentiality of the crop. As a step towards to this direction, the present investigation on winged bean was undertaken with the following objectives to:

1. Study the genetic variability in winged bean germplasm
2. Identify superior genotypes(s) of winged bean based on yield and photo insensitivity
3. Estimate genotypic correlations among yield and its components
4. Estimate direct and indirect effect of different growth and yield parameters and
5. Estimate the genetic divergence and selection index in selected winged bean genotypes.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

A thorough understanding of the genetic variation available in the germplasm for different traits, their heritability and relationship with yield and extent of genetic diversity is important for any crop improvement programme to be successful. In winged bean also attempts were made to study the genetic variability for various productive traits, inheritance of these traits and correlation between yield and its components. The available literature pertaining to the investigation on winged bean and related crops has been presented in this chapter under appropriate headings.

2.1 Variability and heritability studies

2.2 Correlation and Path coefficient analysis

2.3 Genetic divergence and selection index

2.1 VARIABILITY AND HERITABILITY STUDIES

2.1.1 Growth and yield characters

In winged bean, variability has been noticed for various traits. A summary of literature available on this aspect is presented below. Khan (1976) recorded high variability for pod yield per plant in ten lines of winged bean. High phenotypic and genotypic variability was observed in the form of coefficient of variation for pod yield per plant along with high heritability coupled with high genetic advance as percentage over mean for this character (Erskine, 1981; Philip and Ramachandran, 1986; Seth *et al*., 1988 and Dahiya *et al.*, 1989; Dandannavar, 2000) in winged bean genotypes.

Thompson and Haryono (1980) reported variation for days to flowering in the range of 57 to 87 days in Papua New Guinea accessions of winged bean. Philip and Ramachandran (1986) studied with 32 genotypes of winged bean noted variation for this trait from 55.67 to 87.67 days. They also observed low GCV and PCV, high heritability and low GA for these traits. Solanki and Saxena (1989) also noted considerable variation for this trait in winged bean genotypes.

Wide range of genetic variability was reported for vine length, pods per plant, pod length and pod girth in winged bean by Chandel *et al.* (1979), Erskine and Kesavan (1982), Dutta and Gangwar (1983), Philip (1984), Abe *et al.* (1988), Solanki and Saxena (1989), Dandannavar (2000) and Mohamadali and Madalageri (2004).

Philip and Ramachandran (1986) observed low values for GCV, PCV, heritability and genetic advance for these traits. Seth *et al.* (1988) also observed low genotypic and phenotypic coefficient of variation in winged bean. Nandi *et al.* in 1995 also recorded high heritability but low genetic advance as percentage over mean in pole type french bean for the trait. Contrary to this, Dahiya *et al.* (1989) though reported high heritability, but it was also coupled with low genetic advance.

Philip and Ramachandran (1986) reported that pods per plant ranges from 34.00 to 98.47. This character showed high GCV and PCV. High heritability, genetic advance and maximum genetic gain were also recorded for number of pods per plant. In the studies of Seth *et al.* (1988) and Dahiya *et al.* (1989) also, this trait had high GCV and PCV with high heritability, genetic advance as percent of mean.

Philip and Ramachandran (1986) observed variation for days to 50 per cent flowering in the range of 89.67 to 149.00 days, while Dandannavar (2000) noted variation in the range of 91.16 to 104.50 days. Low PCV and GCV, high heritability and low genetic advance were reported for this trait by Philip and Ramachandran in 1986.

Singh *et al.* (1988) observed high heritability in broad sense for days to 50 per cent flowering coupled with low genetic advance as percentage over mean in broad bean genotypes.

Abe *et al.* (1988) reported variation in fruit setting in winged bean in the range of five per cent in Ishigase and 4 to 76.20 per cent in Urizan variety. Dandannavar (2000) also observed variation for this trait in the range of 6.21 to

82.05 per cent. Seth *et al.* (1988) reported low phenotypic (PCV) and genotypic (GCV) coefficient of variation for plant height.

Dahia *et al.* (1989) also observed significant difference among the lines of winged bean for vine length. They also noticed low coefficients of variation (genotypic and phenotypic), but high heritability coupled with moderate genetic advance over mean for this trait. Singh and Khanna (1995) reported high heritability coupled with high genetic advance and coefficient of variation was noticed for flowers per raceme, pods per raceme, seed yield and pods per plant in winged bean. Yield was positively correlated with all the traits except days to flower, though significant positive was only with pods per plant.

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).

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

In cowpea, high phenotypic and genotypic coefficients of variation were reported for main stem length, primary branches and pod weight by Ajith (2001). High PCV and GCV were reported for pods per plant by Malarvizhi (2002).

Pan *et al.* (2004) conducted a study on seven photo insensitive dolichos bean lines. They reported maximum extent of genetic variability, high heritability coupled with high genetic advance in pod yield, pod breadth and pod weight.

Basavarajappa and Byre Gowda (2004) reported that in 144 dolichos genotypes studied wide variability was present for pods per plant, pod yield per plant, seed yield per plant and these characters also exhibited high heritability with high genetic advance indicating additive gene effects. Similar results were also reported in dolichos bean by Ali *et al.* (2005) and Mohan and Aghora (2006).

Pod length, pod weight, pods per plant, pod clusters per plant and yield per plant had the highest PCV and GCV among different characters (Girish *et al.,* 2006; Manju, 2006; Suganthi and Murugan, 2008; Jithesh, 2009) in cowpea.

Nandan, *et al.* (2010) studied 21 diverse winged bean genotypes for phenotypic and genotypic variability, heritability and genetic advance in nine quantitative traits and reported considerable amount of genetic variability in days to 50 per cent flowering, pod length, dry pod weight, 100 seed weight and grain yield per plant. They also recorded, days to 50 per cent flowering, days to maturity, number of pod per plant, 100 seed weight and grain yield per plant gave high heritability estimates with moderate genetic advance.

Chattopadhyay and Dutta (2010) evaluated 12 genotypes of pole type dolichos bean (*Lablab purpureus* var. *typicus*) for their genetic variability and character association among nine quantitative traits. The study revealed significant variation in days to 50 per cent flowering, pod length, pod breadth, pod weight, 100 seed weight, number of pods per plant, protein content of pod and pod yield per plant.

Junaif *et al.* (2010) conducted a study using 26 genotypes of french bean (*Phaseolus vulgaris* L.) and reported that phenotypic and genotypic coefficients of variation for most of the traits were found moderate to high except for protein content. High heritability along with high genetic gain was observed for green pod yield per plot, followed by green pod yield per plant and pods per plant.

Pandey *et al.* (2011) studied variability among 18 exotic and indigenous french bean (*Phaseolus vulgaris* L.) genotypes and found that the variability was higher in adaptation, vegetative growth, floral and pod characteristics.

Thirty genotypes of dolichos bean (*Lablab purpureus*) were evaluated by Parmar *et al.* in 2013. Highest and lowest coefficient of variation was observed for single podded clusters per plant and protein content respectively. Little or no difference between the phenotypic and genotypic coefficients of variation in the expression of various horticultural traits studied.

2.1.2 Seed yield per plant

Joshi (1971) observed wide range of variability for seed yield per plant in *Dolichos lablab* var. *lignosus.* He also reported high heritability coupled with high genetic advance as percentage over mean.

Khan and Erskine (1978) reported considerable variation for seeds per pod, 100 seed weight and shelling percentage in winged bean. Several other workers also reported variation in the seeds per pod depending on the varieties (Thompson and Haryono 1980, Dutta and Gangwar, 1983; Singh and Paroda, 1983; De silva and Omran, 1986; Philip and Ramachandran, 1986; Abe *et al.*, 1988; Solanki and Saxena, 1989; Bhagmal, 1994, Dandannavar, 2000 and Mohamadali and Madalageri, 2007).

Low estimates of GCV, PCV and heritability along with low genetic advance as percentage over mean for the above traits in winged bean accessions were reported by Philip and Ramachandran (1986) and Mohamadali and Madalageri, (2007).

Saini *et al.* (1976) observed wide variability for shelling percentage in peas with low estimates of GCV and PCV. However, the heritability for the trait was high but genetic advance and genetic advance over mean were low.

Selvam *et al.* (2000) recorded high genotypic and phenotypic coefficient of variation with moderate heritability along with moderate genetic advance in cowpea.

2.1.3 Root tuber yield and yield components

Wide range of variation for root tubers per plant, tuber length and tuber girth was reported by Abe and Nakamura (1987); Dahia *et al.* (1989); Dandannavar (2000) and Mohamadali (2001) in winged bean.

Dahia *et al.* (1989), low GCV and PCV with high estimates of heritability (86.52 %) and genetic advance (43.72) was recorded by them for these traits in winged bean.

2.1.4 Quality characters

Jayaprakasam (1982) observed that crude protein content of 16 winged bean varieties ranged from 23.16 percent to 29.29 per cent in seeds.

Banerjee *et al.* (1984) reported protein content of whole plant, vegetable pods, seeds and tubers in the range of 22 to 34, 25 to 38, 32 to 38 and 16 to 19 per cent, respectively.

Philip and Ramachandran (1986) reported variation for seed protein content of 32 accessions of winged bean. The estimates of GCV and PCV were low. However, a high estimate of heritability but low genetic gain recorded for crude protein content of seeds.

Bharati (1997) also analysed protein content in seeds of 46 winged bean genotypes and it ranged from 28.76 per cent to 36.44 per cent.

In yard long bean, Jithesh (2009) reported low heritability for crude fiber content. He also reported that the protein content of pods showing high heritability along with high genetic advance.

2.1.5 Morphological characters

Khan (1976) reported two basic flower colours namely blue and purple with blue colouration being a little more prevalent. Considerable variation within the above colours was observed with respect to their intensity. A few plants had almost white flowers. Also he reported the pods of winged bean having pale yellow background had displayed green purple wing and he noticed variation in pod shape also. He classified pod shape as rectangular, semi flat, flat on sides and flat on suture. He reported two basic seed colours, *viz.*, brown and tan with variation in intensity from light brown to dark brown.

Martin and Delpin (1978) reported that leaves were trifoliate and they varied in shape from oval to ovate lanceolate with an entire margin, also noticed variation in tuber shape from irregular to spindle shaped tubers.

The inflorescence was a raceme bearing many flowers. Flowers were basically blue or purple ranging from almost white to deep reddish purple in some lines (Newell and Hymowitz, 1979).

Thompson and Haryono (1980) reported the mutants with reddish purple and other uncommon flower colours.

Bharati (1997) and Mohamadali (2001) also noticed variation in seed coat colour. It varied from cream, brown, grey and mixed colours to black.

2.2 CORRELATION AND PATH COEFFICIENT ANALYSIS

The interrelationship of different characters with yield determines the efficiency of selection in breeding programmes. It merely indicates the intensity of association. Phenotypic correlation reflects the observed relationship, while genotypic correlation underline the true relationship among characters. Selection procedures could be varied depending on the relative contribution of each. Assuming yield is a contribution of several characters which are correlated among themselves and to the yield, path coefficient analysis was developed (Wright, 1924, Dewey and Lu, 1957). Unlike the correlation coefficient which measures the extent of relationship, path coefficient measures the magnitude of direct and indirect contribution of a component characters to a complex character and it has been defined as a standardized regression coefficient which splits the correlation coefficient into direct and indirect effects.

Joshi (1971) reported that, number of pods, number of seeds and number of branches per plant showed strong positive association with seed yield in Indian beans. Aggarwal and Kang (1976) also noticed positive and highly significant correlation of seed yield in *Dolichos biflorus* with plant height, number of branches, pods per plant, pod length and seed size. Correlation of days to flowering and days to maturity had a high positive direct as well as an indirect effect on seed yield.

Khan (1976) observed significant correlation of the seed yield in winged bean with number of seeds per pod and the shelling percentage. Number of seeds per pod exhibited a positive correlation with seed weight. The strongest correlation was found between pod length and seed weight.

Khan and Erskine (1978) noticed a strong positive genetic correlation of pod number in winged bean with grain yield per plant. In turn, pods per plant was negatively correlated with seeds per pod, seed weight and pod length.

Singh *et al.* (1979) reported that seed yield per plant was positively and significantly associated with fruit length, fruit width and number of seeds per pod in lablab bean. Path analysis revealed highest direct path for number of seeds per pod followed by pod width. Indirect effects of fairly high magnitude were also exerted by number of seeds per pod in relation to other yield components.

Vijay *et al.* (1980) studied correlation and path coefficient analysis for seed yield and its components in seventeen cultivars of winged bean. Their study revealed that seed yield per plant showed positive significant correlation with number of dry pods per plant, 100 seed weight and days to flowering.

Path analysis studies in winged bean revealed that the dry pods per plant, weight of dry pod per plant, 100 seed weight and days to 95 per cent dry pod maturity exhibited positive direct effect on seed yield, while the pod length showed negative direct effect. Days to 50 per cent germination and days to flowering had negative direct effect on seed yield (Satyanarayana *et al.* 1978; Vijay *et al.* 1980).

In a study involving 32 lines of winged bean, Pandita *et al*. (1989) observed positive and significant association of vine length, total number of pods, pod weight, pod length and number of roots with pod and root yield. They also reported strong positive association of pods per plant with yield.

In Dolichos bean, Dahiya *et al.* (1991) observed that among eight characters studied, pods per plant showed highest direct contribution towards pod yield per plant. Singh and Khanna (1995) reported significant positive genotypic correlations among component traits between days to maturity and flowers per raceme, days to maturity and pods per raceme, flowers per raceme and pods per raceme and pod width and test weight in winged bean. Correlated response was maximum in seed yield through pods per plant, test weight, days to maturity, pod length and pods per raceme.

Motior *et al.* (1997) reported significant and positive correlation of seed yield with pods per plant, 100 seed weight, leaf dry matter, pod dry matter and total dry matter in winged bean.

Dandannavar (2000) observed that tuber yield per plant had positive and highly significant correlation with leaf area, vine length, dry matter accumulation, pod length, pods per plant, early green pod yield, late green pod yield, total green pod yield, seeds per pod, tubers per plant, tuber length, 100 seed weight, dry pods per plant, seed yield per plant, number of roots and tuber girth. However, the tuber yield per plant had negative and significant correlation with days taken for first flowering.

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

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

Ajith (2001) reported high positive genotypic correlation for pods per plant, pod weight, pods per cluster, pod clusters per plant and pod girth with pod yield per plant in cowpea. Pods per plant and pod weight had high direct effect on pod yield. Similar results were recorded by Patel *et al.* (2002) in cluster bean.

In a study with 43 genotypes of cluster bean, Singh *et al.* (2002) found positive and significant correlation of grain yield with branches per plant, pod clusters per plant and pods per plant. Pods per plant were positively correlated with days to 50 percent flowering, plant height, branches per plant and clusters per plant. They also reported positive correlation of pod clusters per plant with primary branches per plant and days to 50 percent flowering with plant height.

In a study conducted by Vidya and Sunny (2002) revealed that genotypic correlation of pod yield per plant was found to be significant and positive with pods per plant, pods per inflorescence, pod weight, length of harvesting period, pod girth, pod length and primary branches in yardlong bean.

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.

Singh *et al.* (2002) revealed that days to 50 percent flowering followed by clusters per plant, 100 seed weight and pods per plant had positive direct effect on seed yield in cluster bean while negative direct effect was observed for plant height.

Singh *et al.* (2003) conducted path analysis in cluster bean and revealed the importance of biological yield and primary branches on seed yield as these two traits had appreciable direct effects and negligible negative indirect effects on seed yield per plant.
Seed yield found to be positively correlated with number of clusters per plant, biological yield and harvest index and negatively correlated with plant height (Chaudhary *et al.*, 2003) in cluster bean genotypes.

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

Mohamadali and Madalageri (2004) conducted Correlation and path analysis studies on 20 green pod yield and yield attributing traits in 36 accessions of winged bean revealed that green pod yield per plant had highly significant and positive association with the number of early and late pods per plant, total green pods per plant, early and late pod yield per plant and total dry weight of plant. Path analysis for green pod yield revealed that traits like late pod yield, early pod yield and number of late pods per plant exhibited high positive direct effects on green pod yield. Late pod yield being chief contributing character for green pod yield with indirect effects through early pod yield and number of early pods per plant.

In dolichos bean, Basavarajappa and Byre Gowda (2004) reported significant and positive association of seed yield with pod yield per plant, pods per plant, branches per plant, days to 50 per cent flowering, days to maturity, plant height, inflorescence per plant and 100 seed weight.

Lovely (2005) reported that yield per plant showed strong positive genotypic correlation with 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.

Saini *et al.* (2005) conducted path analysis in cluster bean and revealed that biological yield per plot, pod length, clusters per plant and branches per plant had positive direct as well as indirect effects on seed yield per plot.

Path analysis in cluster bean by Singh *et al*. (2005) revealed that biological yield per plot had direct positive effect on seed yield per plot followed by days to maturity, pod length, pods per plant, 100 seed weight and plant height.

Anandhi and Sunny (2006) found that in cluster bean, pods per plant and pod weight are the characters with high direct effect on pod yield. Pods per plant showed highest direct effect on seed yield followed by plant height and branches per plant in a study conducted by Mahla and Kumar (2006) in cluster bean.

Correlation studies in cowpea by Manju (2006) revealed that characters like pod length, pod girth, pod weight, pods per plant, seeds per pod and 100 seed weight had high positive correlation with yield. Path coefficient analysis indicated that pods per plant exerted the highest positive direct effect on yield while pod weight had indirect effect on yield.

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

Deepa and Balan (2006) studied 35 genotypes of cow pea and reported that pod yield per plant expressed significant positive correlation with branches per plant, pods per plant, pod length, seeds per pod, 100 seed weight, green pod weight, protein content and grain yield per plant.

Anandhi and Sunny (2007) reported that in cluster bean, pods per plant, seeds per pod, pod weight and pod clusters per plant showed high positive correlation with vegetable pod yield whereas plant height and days to 50 per cent flowering showed negative genotypic correlation.

Mishra *et al.* (2008) in a study with pole type french bean reported positive correlation of green pod yield with days to first flowering, number of pods per plant and pod length.

Path co-efficient analysis in cluster bean genotypes revealed that the seeds per pod and pods per plant had highest direct effect on seed yield per plant (Buttar *et al.,* 2008; Kastoori *et al.,* 2009).

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

An Investigation was done by Mohamadali and Madalageri (2012) in 36 accessions of winged bean revealed that the seed yield per plant had significant positive association with seed weight per pod, number of seeds, dry pod yield and dry pod number per plant and shelling percentage. However, strong negative association of seed yield with protein content of seeds was observed.

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

Correlation and path analysis were studied by Ahmed and Kamaluddin (2013) in 57 germplasm lines of rajmash beans for yield and yield contributing traits. Seed yield was found to be positively correlated with days to 50 per cent flowering, plant height, pod length, number of pods/plant and number of seeds/pod. Path coefficient analysis revealed that 50 per cent flowering, number of pods per plant, pod length and 100 seed weight showed positive direct effects on seed yield.

2.3 GENETIC DIVERGENCE AND SELECTION INDEX

2.3.1 Genetic divergence

The geographic diversity is not an indication of genetic diversity. Such information that genetic diversity is not necessarily correlated with eco-geographical distribution has been indicated in other crops as well (De and Rao. 1987; Mishra and Dash, 1997; Katiyar, *et al.*, 1998; Reddy, *et al.*, 2004; Katiyar, et.al., 2005). Arunachalam and Bandyopadhayay (1984) indicated that the genetic drift and selection in different environments could cause greater diversity than geographic distances. This emphasizes the significance and importance of studying genetic diversity in germplasm irrespective of their geographic diversity in indigenous as well as exotic material. A summary of literature available on this aspect is presented below.

Two hundred and thirteen germplasm lines of cluster bean were grouped into 12 clusters by Mitra *et al.* (2000) and observed maximum genetic divergence between clusters V and IX whereas clusters II and VIII were the closest ones. Pods per plant exhibited maximum contribution to divergence. Singh *et al*. (2003) studied the degree of divergence in 60 genotypes of guar and grouped them into three clusters.

Chaudhary *et al.* (2004) grouped 40 guar genotypes into 12 clusters, indicating the presence of appreciable amount of diversity among the material. In a divergence study by Singh *et al.* (2005) with 40 accessions of guar, genotypes were grouped into 10 different clusters indicating that genetic diversity was not parallel to geographic diversity. Cluster I consisted of the maximum number of genotypes (17), followed by cluster II (13) and IV (three).

Thirty genotypes of cluster bean were evaluated for genetic diversity by Arora *et al*. (2005), grouped the genotypes into 12 clusters. Inter-cluster distance was maximum between clusters VII and XI and minimum between clusters III and VI.

Twenty nine genotypes of cluster bean were grouped into four clusters by Anandhi and Sunny (2006). Cluster II found to be the largest group with 10 genotypes and maximum inter cluster distance was observed between cluster I and IV and minimum between clusters II and III. Yield per plant contributed maximum towards the genetic divergence followed by pods per plant and plant height.

Mahto and Dua (2009) studied genetic divergence in 30 indigenous and exotic collections of winged bean for days to flowering, days to maturity, plant height, pods per plant, pod length and seeds per pod. Significant variations were recorded among the genotypes for all the characters. The genotypes were grouped into nine different clusters. The clustering pattern of the genotypes indicated that genetic diversity was uncorrelated with geographic diversity.

Pathak *et al.* (2010) studied genetic divergence in 40 guar accessions and grouped them into seven clusters. The genotypes of common geographic origin or same location were grouped into different clusters. The average inter cluster D^2 values indicated maximum statistical divergence between cluster III and VI, followed by I and VI and II and VI.

Cluster analysis conducted by Morris (2010), separated guar accessions into three clusters based on low, intermediate or high seed numbers. Guar accessions clustered in groups II and III appear to be more genetically related than those in group I.

2.3.2 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).

Philip (2004) worked out selection indices for 50 genotypes of cowpea on the basis of pods per plant, inflorescence per plant, pods per inflorescence, pod length, seeds per pod and 100 seed weight. Five superior genotypes were selected for hybridization programme as female parents to develop $F_{1.}$

Selection index analysis done by Madhukumar (2006) in yard long bean revealed that genotype VS 86 attained the maximum selection index value. Manju (2006) worked out selection indices. Based on selection index, VS 27 was ranked first followed by VS 8 and VS 19.

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

2.3.3 Pest and disease incidence

Winged bean is free from major diseases and pest. Bose *et al.* (1993) mentioned a few diseases and pests in winged bean such as false rust, leaf spot, cowpea aphid, lady bird beetle and root knot nematode.

As many as 21 insect pests of different groups have been recorded damaging the cowpea crop from germination to maturity. The avoidable losses in yield due to insect pests have been recorded in the range of 66 to 100 per cent in cowpea (Pandey *et.al.*, 1991). The important insect species attacking cowpea crop include aphid (*Aphis craccivora* Koch), thrips (*Megaleurothrips* spp.), whitefly (*Bemisia tabaci*, Genn.), spotted pod borer (*Maruca vitrata* Fab.), tobacco leaf eating caterpillar (*Spodoptera litura* Fab.) and blue butterfly (*Euchrysops cnejus* Cnidus) (Patel *et al.*, 2010).

Wright and Hunt (2011) observed that stem borer in soy bean causes severe yield reduction and they also noticed wide host range of this pest.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Identification of photo insensitive genotype(s) of winged bean (*Psophocarpus tetragonolobus* (L.) DC.)" was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2013-14. The experimental site was located at $8^o 5^'$ N latitude and $77^o 1^'$ E longitude at an altitude of 29 m above mean sea level. Predominant soil type of the experimental site was red loam belonging to Vellayani series, texturally classified as sandy clay loam with a pH of 5.2. The area enjoys a warm humid tropical climate.

The study was conducted for identification of photo insensitive, high yielding and year round fruiting genotype(s) of winged bean suitable for cultivation in Kerala.

3.1 MATERIALS

The experimental material comprised of 21 winged bean genotypes collected from different parts of Kerala, state agricultural universities and available germplasm of the Department of Olericulture, College of Agriculture, Vellayani. The details of genotypes used for the experiment are given in Table 1.

3.2 METHODS

3.2.1 Design and layout

The experiment was laid out in randomised block design with three replications from April 2013 to March 2014. Seeds of each genotype were sown in rows at spacing of 125 cm between rows and 50 cm between plants. Treatments were allotted at random in rows of each replication. Thus 12 plants per genotype were maintained in each plot. The crop received timely management practices as per package of practices recommendations of Kerala Agricultural University (KAU, 2011).

Table 1. Winged bean genotypes used for evaluation

Sl. No.	Accession Number	Accession name	Source
1	PT 1	Local	Parassala, Thiruvananthapuram
2	PT 2	Local	Veliyam, Kollam
3	PT 3	Local	Anchal, Kollam
4	PT 4	Local	Mavelikkara, Alappuzha
5	PT 5	Local	Varkala, Thiruvanathapuram
6	PT 6	Local	Munnar, Idukki
7	PT 7	Local	Alathoor, Palakkad
8	PT 8	Revathi	College of Horticulture, Vellanikkara
9	PT 9	PT 3	College of Horticulture, Vellanikkara
10	PT 10	PT 35-1	College of Horticulture, Vellanikkara
11	PT 11	PT 47-2	College of Horticulture, Vellanikkara
12	PT 12	PT 50-1	College of Horticulture, Vellanikkara
13	PT 13	PGK 08/03	College of Horticulture, Vellanikkara
14	PT 14	PT 50-1-1	College of Horticulture, Vellanikkara
15	PT 15	PT 60-2	College of Horticulture, Vellanikkara
16	PT 16	PT 60-3	College of Horticulture, Vellanikkara
17	PT 17	PT 62	College of Horticulture, Vellanikkara
18	PT 18	PT 63	College of Horticulture, Vellanikkara
19	PT 19	Local	College of Horticulture, Vellanikkara
20	PT 20	Local	Neyyatinkara, Thiruvanthapuram
21	PT 21	Local	Nemom, Thiruvananthapuram

3.3 OBSERVATIONS

3.3.1 Biometric observations

The observations on the following characters were taken from five randomly selected plants in each genotype and the mean values were worked out for each trait and is used for further statistical analysis.

3.3.1.1 Vegetative characters

3.3.1.1.1 Days to germination

Number of days taken from sowing to the emergence of seedling was counted.

3.3.1.1.2 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.

3.3.1.1.3 Primary branches per plant

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

3.3.1.1.4 Petiole length (cm)

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

3.3.1.1.5 Leaflet length (cm)

The fifth leaf from top of the selected plants was used for making the above observation. The length of terminal and lateral leaflet was measured as the distance from the base of the leaf to the top of the leaf and average was worked out.

3.3.1.1.6 Leaflet width (cm)

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

3.3.1.1.7 Duration of the crop

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

3.3.1.2 Flowering characters

3.3.1.2.1 Days to first flowering

Number of days from the date of sowing to the bloom of the first flower of observational plants in each treatment was recorded and the average obtained.

3.3.1.2.2 Days to 50 per cent flowering

Number of days taken from the date of sowing to appearance of first flower in half of the plant population in each treatment plot was recorded as days taken for 50 percent flowering.

3.3.1.2.3 Days to first harvest

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

3.3.1.2.4 Days to final harvest

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

3.3.1.3 Pod and Yield characters

3.3.1.3.1 Pod length (cm)

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

3.3.1.3.2 Pod girth (cm) (including the wings)

Girth of the pods were taken at the broadest part including the wings from the sample pods used for recording the pod length and average was worked out.

3.3.1.3.3 Pod weight (g)

Weight of pods used for recording pod length was measured and average was worked out.

3.3.1.3.4 Pods per plant

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

3.3.1.3.5 Yield per plant (g)

Weight of all pods harvested from observational plants was recorded and average was worked out.

3.3.1.3.6 Seeds per pod

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

3.3.1.3.7 100 seed weight (g)

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

3.3.1.3.8 Shelling percentage

Shelling percentage was calculated by the formula

$$\text{Shelling percentage} = \frac{\text{Total seed yield per plant (g)}}{\text{Total dry pod yield per plant (g)}} \times 100$$

3.3.1.3.9 Yield per plot (kg)

It is the net pod weight obtained per plot (3.75 m x 2 m).

3.3.1.4 Tuber characters

The three uprooted plants on which growth parameters recorded were also used for the following observations on the root tubers.

3.3.1.4.1 Root tubers per plant

The number of tubers from the three uprooted plants from each treatment plots was counted and average was recorded.

3.3.1.4.2 Weight of root tubers (g)

Weight of root tubers per plant was measured and average was worked out.

3.3.1.4.3 Tuber length (cm)

The length of the tubers from proximal end to distal end was measured and the average was worked out.

3.3.1.4.4 Tuber girth (cm)

The girth at the broadest portion of the tuber was measured and the average was recorded as tuber girth.

3.3.2 Morphological characters

3.3.2.1 Pigmentation on stem and leaf

Pigmentation on stem and leaf of each variety was observed.

3.3.2.2 Flower colour

Colour on flowers of each variety was observed.

3.3.2.3 Pod colour

Colour on pods of each variety was observed.

3.3.2.4 Seed colour

Colour on seeds of each variety was observed.

3.3.3 Quality characters

3.3.3.1 Protein

Protein was estimated by Lowry's method (Sadasivam and Manickam, 1996).

Reagents:

1. 2% Sodium Carbonate in 0.1 N Sodium Hydroxide (Reagent A)
2. 0.5 % Copper Sulphate ($CuSO_4.5H_2O$) in 1 % potassium sodium tartrate (Reagent B)
3. Alkaline copper solution: Mix 50 ml of A and 1 ml of B prior to use (Reagent C)
4. Folin-ciocalteau reagent (reagent D): this is (FCR) commercially available and has to be diluted with equal volume of water just before use. (The reagent can be prepared in the laboratory. Reflux gently for 10 hours mixture consisting of 100 g sodium tungstate ($Na_2WoO_4.2H_2O$), 25 g sodium molybdate ($Na_2MoO_4.2H_2O$), 700 ml water, 500 ml of 85 % phosphoric acid, and 100 ml of concentrated hydrochloric acid in a 1.5 L flask. Add 150 g lithium sulphate, 50 ml water and a few drops of bromine water. Boil the mixture for 15 minutes without condenser to remove excess bromine. Cool, dilute to 1 L and filter. The reagent should have no greenish tint. If it has, it is boiled with bromine once more. This is the stock solution and is diluted with equal volume of water just before use).

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

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

Procedure:

500 mg of the sample was weighed and ground well with a pestle and mortar in 5-10 ml of the buffer. This was centrifuged and the supernatant was used for protein estimation. 0.2, 0.4, 0.6, 0.8, and 1 ml of the working standard was pipette out into a series of test tubes. 0.1 ml and 0.2 ml of the sample extract was pipette out into two other test tubes. The volume was made up to 1 ml in all the test tubes. A tube with 1 ml of water is used as blank and 5 ml of reagent C was added to each tube including the blank. This was mixed well and allows standing for ten minutes. Then add 0.5 ml of reagent D, mix well and incubate at room temperature in the dark for 30 minutes, blue color was developed. The absorbance was read at 660 nm. A standard curve was plotted using standard absorbance *vs* concentration. The protein in the sample was calculated using the standard curve.

3.3.3.2 Crude fibre

Procedure

Take 5 gram of dried and powered sample in a 400 ml beaker marked at 200 ml level. Add 200 ml of 1.25 % 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 % caustic soda and boil for half an hour. Filter and wash it free from alkali, using in turn, hot water, 1 % 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 desiccators and weigh (*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 percentage (Sadasivam and Manickam, 1996).

$$\text{\% crude fibre in sample} = \frac{\text{Loss in weight on ignition } (W_2\text{-}W_1) - (W_3\text{-}W_1)}{\text{Weight of sample}} \times 100$$

3.3.4 Incidence of pests and diseases

3.3.4.1 Pod borer (Spodoptera litura)

Number of pods showing infestations were recorded and from this percentage of plants infested was calculated.

$$\text{Percentage of plants infested} = \frac{\text{Number of pods showing infestation}}{\text{Total number of pods}} \times 100$$

3.3.4.2 Stem borer **(*Oberia* sp.)**

Number of pods showing infestations were recorded and from this percentage of plants infested was calculated.

3.3.5 Weather parameters

Following weather parameters during the course of investigation were recorded.

3.3.5.1 Maximum temperature (^oC)

3.3.5.2 Minimum temperature (^oC)

3.3.5.3 Rainfall (mm)

3.3.5.4 Relative humidity (%)

3.3.5.5 Sunshine hours (h)

3.3.6 Statistical Analysis

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

a) To test significant difference among the genotypes and

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

From the Table 2 other genetic parameters were estimated as follows:

3.3.6.1 Variance:

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

Table 2. 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}	$\sigma2_{exy}$	E_{xy}	σ^2_{xy}
Total	vr-1		T_{xx}			T_{yy}	

3.3.6.2 Coefficient of variation

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

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

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

Where,

σ_{gx} - Genotypic standard deviation

σ_{px} - Phenotypic standard deviation

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

3.3.6.3 Heritability

$$h^2 = \frac{\sigma^2_{gx}}{\sigma^2_{px}} \times 100$$

Where, h^2 is the heritability expressed in percentage. Heritability estimates were categorized as low (< 30 per cent), moderate (31 – 60 per cent) and high (> 60 per cent) as suggested by Johnson *et al*. (1955).

3.3.6.4 Genetic Advance as percentage mean

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

Where, k is the standard selection differential.

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

The range of genetic advance as per cent of mean was classified according to Johnson *et al.* (1955) as low (< 10 per cent), moderate (11- 20 per cent) and high (> 20 per cent).

3.3.6.5 Correlation

Genotypic correlation coefficient (r_{gxy}) $= \dfrac{\sigma g_{xy}}{\sigma g_x \times \sigma g_y}$

Phenotypic correlation coefficient (r_{pxy}) $= \dfrac{\sigma_{Pxy}}{\sigma_{Px} \times \sigma_{Py}}$

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

3.3.6.6 Path analysis

The direct and indirect effects of yield contributing factors were estimated through path analysis technique (Wright, 1924; Dewey and Lu, 1957).

3.3.6.7 Genetic divergence analysis

Genetic divergence was measured using the technique D^2 statistics developed by Mahalanobis in 1936. Grouping of genotypes in to clusters was done based on the relative distance (D^2 values) from each other (Rao, 1952).

3.3.6.8 Selection Index

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

The selection index is described by the function, $I = b_1 x_1 + b_2 x_2 + \ldots\ldots\ldots + b_k x_k$ and the merit of a plant is described by the function, $H = a_1 G_1 + a_2 G_2 + \ldots\ldots\ldots + a_k G_k$ where x_1, x_2………… x_k are the phenotypic values and G_1, G_2 ………….. G_k are the genotypic values of the plants with respect to characters, x_1, x_2 ………..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………..$a_k = 1$. The regression coefficients (b) are determined such that the correlation between H and I is maximum. The procedure will reduce to an equation of the form, $b = P^{-1}Ga$ where, P is the phenotypic variance-covariance matrix and G is the genotypic variance-covariance matrix x.

3.3.7 Genetic cataloguing of winged bean

The descriptor developed by IPGRI for winged bean was used for cataloguing (Appendix I).

RESULTS

4. RESULTS

The experiment titled "Identification of photoinsenitive genotype(s) of winged bean (*Psophocarpus tetragonolobus* (L.) DC.) was carried out in the Department of Olericulture, College of Agriculture, Vellayani during the period of 2013 – 2014. Field view of this experiment was given in Plate 1.

Twenty one diverse genotypes of winged bean were subjected to evaluate the biometric characters, quality characters and incidence of pest and diseases. The data were subjected to statistical analysis and variability, heritability, correlation, path analysis and genetic divergence were worked out. The results obtained were presented under the following heads.

4.1 VARIABILITY IN WINGED BEAN

4.1.1Analysis of variance

The analysis of variance was conducted to test the significance of difference among genotypes studied. The mean sum of squares due to various sources for 32 characters is presented in Table 3. Analysis of variance revealed that the genotypes differed significantly for most of the characters except quality characters like pod protein and seed protein.

4.1.2 Mean performance of genotypes

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

4.1.2.1 Vegetative and flowering characters

The mean values for growth characters were furnished in Table 4.

There was significant difference between genotypes with respect to days to germination. PT 14 was the earliest in germination (7.33 days) followed by PT 12 (8.00 days), PT 6 (8.00 days) and PT 21 (8.33 days). PT 20 was late in germination and took 12.66 days.

Plate 1. Field view of the experiment

Table 3. Analysis of variance for 32 characters in winged bean (Mean squares are given)

Source	D.F	Days to germination	Vine length (cm)	Primary branches / plant (cm)	Petiole length (cm)	Terminal leaflet length (cm)	Lateral leaflet length (cm)	Terminal leaflet width (cm)
Replication	2	2.111	6349.0	12.206	1.605	1.044	1.918	0.424
Treatment	20	5.253*	14152.8**	19.882**	6.194**	2.392**	2.248**	2.154**
Error	40	2.577	1297.4	1.589	2.203	0.797	0.310	0.265

Source	D.F	Lateral leaflet width (cm)	Days to first flowering	Days to 50 % flowering	Days to first harvest	Days to final harvest	Pod length (cm)	Pod girth (cm)
Replication	2	0.348	217.093	151.031	608.375	98.000	0.575	0.474
Treatment	20	1.384**	2453.884**	2896.731**	2101.975**	695.275**	12.333**	1.982**
Error	40	0.134	53.928	33.545	35.065	62.187	1.053	0.107

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

Table 3. Continued…

Source	D.F	Pod weight (g)	Pods / plant	Yield / plant (g)	Yield per plot (kg)	Seeds / pod	100 seed weight	Shelling %	Days to edible maturity
Replication	2	1.021	566.812	640.361	3.834	3.347	14.421	1.132	0.491
Treatment	20	28.975**	2660.800**	906210.000**	35.419**	13.543**	104.930**	48.167**	15.949**
Error	40	2.385	640.361	198487.600	4.579	0.908	14.775	2.014	0.892

Source	D.F	Pod protein (%)	Seed protein (%)	Pod fibre (%)	Tubers / plant	Tuber length (cm)	Tuber girth (cm)	Tuber weight (g)	Duration of crop
Replication	2	0.696	12.047	1.833	0.587	0.074	0.861	514.349	108.25
Treatment	20	0.254	4.392	4.657**	9.896**	96.525**	56.321**	7438.955**	880.475**
Error	40	0.265	4.594	1.361	0.387	2.324	0.461	206.015	190.420

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

Vine length ranged from 551.33 cm to 813.33 cm with overall mean of 677.07 cm. PT 18 had the longest vine (813.33 cm) and this was statistically on par with PT 21 (770.00 cm) and PT 7 (767.66 cm). The shortest vine length was recorded in PT 9 (551.33 cm).

The primary branches per plant varied from 6.33 to 15.66 with an average of 11.46. The maximum number of primary branches was observed in PT 18 and minimum in PT 21.

Significant differences were observed for petiole length. Treatment PT 13 recorded the highest petiole length of 15.02 cm followed by PT 18 with 14.68 cm and PT 12 with 13.74 cm. These treatments were statistically on par with PT 9 (13.24 cm), PT 21 (13.05 cm), PT 16 (12.99 cm) and PT 1 (12.90 cm). The lowest petiole length of 9.65 cm was recorded in PT 20.

Significant differences were observed for terminal leaflet length. PT 16 had the largest (11.94 cm) and PT 17 had the shortest terminal leaflet (8.13 cm). Breadth of terminal leaflet varied from 7.34 cm in PT 17 to 11.80 cm in PT 18. The genotypes varied considerably for lateral leaflet length also. PT 17 had the shortest lateral leaflet (8.28 cm) and PT 18 had longest lateral leaflet (12.01). Breadth of lateral leaflet varied from 5.74 cm in PT 17 to 9.31 cm in PT 18.

Days to first flowering showed significant differences between genotypes. PT 21 recorded the shortest days required for flowering (75.05 days) which is followed by PT 14 (77.77 days) and PT 19 (77.77 days). These genotypes were statistically on par with PT 1 (80.22 days) and PT 4 (86.55 days). Treatment PT 18 recorded the maximum days required for flowering (178.83 days) followed by PT 7 (175.22 days) and PT 9 (141.44 days). Days to 50 per cent flowering also showed significant difference which range from 84.71 days (PT 14) to 187.23 days (PT 18). The treatment PT 14 was statistically on par with PT 1 (85.78 days), PT 21 (87.34 days) and PT 4 (89.54 days).

Table 4. Mean performance of 21 winged bean genotypes for vegetative and flowering characters

Genotypes	Days to germi-nation	Vine length (cm)	Primary branches / plant (cm)	Petiole length (cm)	Length of leaflets (cm)		Breadth of leaflets (cm)		Days to first flowering	Days to 50 % flowering
					Terminal	Lateral	Terminal	Lateral		
PT 1	9.33	696.66	9.00	12.90	10.73	10.68	9.01	7.49	80.22	85.78
PT 2	10.33	705.00	13.33	12.48	10.84	11.55	9.55	7.56	99.66	112.07
PT 3	9.00	633.33	14.00	9.66	10.58	11.46	9.70	7.28	116.93	125.81
PT 4	10.33	700.00	7.66	11.51	11.21	11.17	9.02	7.50	86.55	89.54
PT 5	11.33	553.33	11.33	11.71	9.18	9.51	7.75	6.40	119.25	127.24
PT 6	8.00	725.00	12.33	11.79	9.67	10.14	9.10	7.56	139.44	143.73
PT 7	11.66	767.66	11.66	11.68	9.58	10.11	8.84	7.38	175.22	183.25
PT 8	10.00	683.33	10.33	11.18	10.96	11.14	8.95	7.32	97.88	113.67
PT 9	10.33	551.33	14.33	13.24	9.55	10.00	8.73	7.26	141.44	150.08
PT 10	9.33	716.66	10.00	11.18	10.66	10.68	8.84	6.99	114.00	122.22
PT 11	10.00	686.66	12.33	12.42	10.94	10.59	8.80	7.22	124.33	127.72
PT 12	8.00	690.00	15.33	13.74	10.38	10.42	8.76	7.28	116.00	121.83
PT 13	9.33	697.33	13.66	15.02	11.02	11.32	9.50	7.98	119.77	130.48
PT 14	7.33	604.00	9.66	11.85	10.52	11.28	9.03	7.60	77.07	84.71
PT 15	9.66	598.66	10.33	12.17	10.68	11.29	9.52	7.91	100.00	112.52
PT 16	10.00	711.66	12.66	12.99	11.94	11.87	8.95	7.02	124.66	127.65
PT 17	9.33	670.66	13.33	9.84	8.13	8.28	7.34	5.74	110.33	185.78
PT 18	11.33	813.33	15.66	14.68	11.84	12.01	11.80	9.31	178.83	187.23
PT 19	11.00	601.33	8.66	12.41	10.34	10.75	9.22	7.54	77.77	94.30
PT 20	12.66	642.66	8.66	9.65	9.53	9.91	8.23	6.54	111.59	116.39
PT 21	8.33	770.00	6.33	13.05	10.62	10.62	8.79	7.28	75.05	87.34
SEm (±)	0.92	20.79	0.72	0.85	0.51	0.32	0.29	0.21	4.23	3.34
CD (0.05)	2.64	59.43	2.08	2.44	1.47	0.92	0.84	0.61	12.11	9.55
Mean	9.84	677.07	11.46	12.15	10.42	10.71	9.02	7.34	113.65	125.21

4.1.2.2 Yield and quality attributes

Mean values for yield and yield attributing characters of winged bean genotypes were furnished in Table 5.

There was significant difference between treatments with respect to days to first harvest. PT 4 recorded the shortest days (97.13 days) which was on par with PT 21(97.34 days), PT 14 (104.15 days) and PT 1 (104.76 days). PT 18 recorded longest days for first harvest (192.67 days). Significant differences were observed for days to final harvest. PT 21 recorded the longest harvest duration (335.00 days) which is on par with PT 1 (323.33 days). PT 5 recorded the shortest harvest duration (276.67days).

The maximum pod length of 21.89 cm was recorded by PT 3 which is followed by PT 20 (21.63 cm), PT 6 (21.43 cm) and PT 21 (20.64 cm). These treatments were on par with PT 1 (20.31 cm), PT 4 (20.29 cm) and PT 2 (20.26 cm). The shortest pod length of 14.84 cm was recorded in PT 18. For pod girth, PT 6 recorded maximum value of 8.75 cm which is followed by PT 14 (8.48 cm), PT 16 (8.41 cm) and these treatments were on par with PT 7 (8.32 cm), PT 8 (8.30 cm) and PT 15 (8.22 cm). The least value of 5.03 cm was recorded by PT 18.

Highest value for pod weight was recorded by PT 20 (22.62 g) which is followed by PT 16 (21.83 g), PT 6 (21.74 g) and PT 21 (21.74 g) and lowest weight was observed in PT 18 (10.13 g) followed by PT 5 (14.30 g).

A wide range of variation was noticed for pods per plant. Maximum number of pods was obtained from PT 21 (154.49) which was statistically on par with PT 4 (135.87) and PT 3 (127.24). PT 18 had the least number pods (44.98) followed by PT 5 (47.43) and PT 17 (54.28).

The maximum yield per plant was recorded in PT 21 (2703.33 g) followed by PT 4 (2320.00 g) and PT 2 (2120.00 g) which was statistically on par with PT 7 (2083.33 g), PT 3 (2000.00 g) and PT 1 (2000.00 g). Minimum yield was recorded in PT 5 (696.67 g) followed by PT 18 (750.00 g) and PT 17

Table 5. Mean performance of 21 winged bean genotypes for yield and quality attributes

Genotypes	Days to first harvest	Days to final harvest	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pods / plant	Yield / plant (g)	Yield / plot (kg)	Seeds per pod	100 seed weight (g)
PT 1	104.76	323.33	20.31	7.63	20.41	104.22	2000.00	21.28	12.83	34.59
PT 2	137.81	298.33	20.26	7.89	21.63	107.85	2120.00	20.04	14.83	36.52
PT 3	143.98	281.67	21.89	7.72	19.65	127.24	2000.00	18.81	12.07	33.61
PT 4	97.13	293.33	20.29	7.77	21.43	135.87	2320.00	20.76	12.44	35.99
PT 5	146.24	276.67	17.58	6.76	14.30	47.43	696.67	14.18	10.75	26.96
PT 6	153.70	318.33	21.43	8.75	21.74	98.66	1946.67	22.10	14.28	39.12
PT 7	190.35	298.33	20.16	8.32	20.76	99.42	2083.33	14.60	11.22	37.52
PT 8	123.64	301.67	18.79	8.30	21.15	66.68	1266.67	21.88	14.42	35.03
PT 9	159.46	316.67	17.44	7.01	16.86	104.94	1630.00	18.46	11.33	31.11
PT 10	134.95	308.33	15.65	7.87	15.66	73.10	1320.00	13.75	6.94	29.84
PT 11	145.92	293.33	17.13	7.31	17.78	95.79	1730.00	22.09	11.42	32.77
PT 12	144.33	311.67	18.00	7.22	17.01	91.29	1606.67	16.35	11.77	29.07
PT 13	141.83	293.33	20.31	7.78	20.35	62.10	1133.33	19.75	14.50	43.81
PT 14	104.15	298.33	18.84	8.48	20.90	91.43	1843.33	19.55	12.40	36.88
PT 15	124.95	286.67	18.45	8.22	20.64	66.66	1110.00	15.98	12.55	26.45
PT 16	162.32	300.00	19.99	8.41	21.83	56.58	1030.00	20.12	12.67	38.95
PT 17	130.51	293.33	16.03	7.16	17.05	54.28	853.33	18.65	10.89	32.17
PT 18	192.67	320.00	14.84	5.03	10.13	44.98	750.00	16.28	8.05	27.76
PT 19	111.82	315.00	17.31	6.85	18.24	67.32	1126.67	13.40	9.53	30.51
PT 20	128.86	283.33	21.63	7.20	22.62	67.85	1423.33	15.69	15.07	20.65
PT 21	97.34	335.00	20.64	7.73	21.74	154.49	2703.33	26.99	13.53	20.39
SEm (±)	3.41	4.55	0.59	0.18	0.89	14.61	257.22	1.23	0.55	2.21
CD (0.05)	9.77	13.01	1.69	0.54	2.54	41.75	735.16	3.53	1.57	6.34
Mean	136.98	302.22	18.90	7.59	19.13	86.58	1556.82	18.61	12.07	32.36

(853.33 g).Yield per plot showed significant difference between treatments. The highest yield per plot was recorded in PT 21 (26.99 kg) followed by PT 6 (22.10 kg) and PT 11 (22.09 kg) and the lowest per plot yield of 13.40 kg was recorded in PT 19 followed by PT 10 (13.75 kg) and PT 5 (14.18 kg).

The genotypes varied significantly for seeds per pod. The pods of PT 20 had the maximum number of seeds (15.07) which was on par with PT 2 (14.83), PT 13 (14.50), PT 8 (14.42) and PT 6 (14.28) whereas the minimum number of seeds was recorded in PT 10 (6.94) followed by PT 18 (8.05) and PT 19 (9.53).

Considerable variation among the genotypes was observed for 100 seed weight. Highest weight of 43.81 g was observed in PT 13 which is statistically on par with PT 6 (39.12 g), PT 16 (38.95 g) and PT 7 (37.52 g). Least weight was recorded in PT 21 (20.39 g) followed by PT 20 (20.65 g) and PT 15 (26.45 g).

There was significant difference between treatments with respect to shelling percentage. The highest shelling percentage (58.17%) was recorded in PT 11 followed by PT 6 (57.26 %), PT 4 (55.19 %) and PT 2 (52.37 %). The least value of 41.67 per cent was recorded in PT 8 followed by PT 19 (43.25 %) and PT 5 (44.78 %).

The genotypes varied significantly for days to edible maturity. PT 8 was earliest to mature, which took 10.33 days, which was followed by PT 10 (10.67 days) and PT 19 (11.33 days) while PT 6 was late for this trait. It took 17.33 days to mature which was on par with PT 21 (17.00 days), PT 1 (16.67 days), PT 3 (16.67 days) and PT 15 (16.33 days).

There was no significant difference between genotypes for pod protein and seed protein content. The pod protein value ranges from 2.07 per cent (PT 5) to 3.09 per cent (PT 3) with an average of 2.61 per cent. Similarly, the seed protein value ranges from 13.89 per cent (PT 1) to 17.72 per cent (PT 9) with an average of 15.93 per cent. Pod fibre showed significant difference between the genotypes. PT 17 recorded highest pod fibre percentage of 18.83 per cent which was on par with PT 2 (18.63 %), PT 6 (18.40 %) and PT 18 (17.67%).The

Table 5. Continued…

Genotypes	Shelling percentage	Days to edible maturity	Pod protein (%)	Seed protein (%)	Pod fibre (%)	Tubers / plant	Tuber length (cm)	Tuber girth (cm)	Tuber weight (g)	Duration of crop
PT 1	50.85	16.67	2.73	13.89	17.50	0.00	0.00	0.00	0.00	335.00
PT 2	52.37	16.00	2.64	14.80	18.63	0.00	0.00	0.00	0.00	318.33
PT 3	49.57	16.67	3.09	16.26	15.93	0.00	0.00	0.00	0.00	295.00
PT 4	55.19	16.00	2.49	17.48	17.57	0.00	0.00	0.00	0.00	305.00
PT 5	44.78	11.67	2.07	16.16	16.97	0.00	0.00	0.00	0.00	303.33
PT 6	57.26	17.33	2.82	15.61	18.40	5.33	14.33	9.96	173.66	341.67
PT 7	51.59	11.33	2.17	17.51	15.15	0.00	0.00	0.00	0.00	315.00
PT 8	41.67	10.33	2.70	17.23	15.50	0.00	0.00	0.00	0.00	320.00
PT 9	51.82	14.67	2.87	17.72	16.80	4.00	8.40	7.20	59.33	320.00
PT 10	49.54	10.67	2.20	15.13	15.60	3.33	11.50	10.26	116.33	325.00
PT 11	58.17	13.00	2.94	15.20	15.11	0.00	0.00	0.00	0.00	310.00
PT 12	48.48	14.00	2.62	16.49	16.90	0.00	0.00	0.00	0.00	321.67
PT 13	50.78	16.33	2.44	16.92	15.43	2.66	16.66	9.71	88.66	305.00
PT 14	47.23	14.00	2.45	15.23	15.73	0.00	0.00	0.00	0.00	306.67
PT 15	51.87	16.33	3.09	14.81	16.87	3.00	11.83	9.73	83.33	340.00
PT 16	47.92	16.00	2.85	17.36	15.60	0.00	0.00	0.00	0.00	310.00
PT 17	50.09	16.00	2.74	14.23	18.83	4.33	7.00	8.80	61.00	300.00
PT 18	49.10	13.67	2.17	16.94	17.67	0.00	0.00	0.00	0.00	353.33
PT 19	43.25	11.33	2.63	14.04	14.80	0.00	0.00	0.00	0.00	325.00
PT 20	51.01	16.33	2.61	15.87	16.27	0.00	0.00	0.00	0.00	298.33
PT 21	50.14	17.00	2.69	15.74	15.10	0.00	0.00	0.00	0.00	351.67
SEm (±)	0.81	0.54	0.29	1.23	0.67	0.35	0.88	0.39	8.28	7.96
CD (0.05)	2.34	1.55	NS	NS	1.92	1.02	2.51	1.12	23.68	22.77
Mean	50.12	14.53	2.61	15.93	16.49	1.07	3.32	2.65	27.73	319.04

lowest pod fibre percentage was recorded in PT 19 (14.80 %) followed by PT 21 (15.10 %) and PT 11 (15.11 %).

Six genotypes produced tubers and there was significant difference between genotypes for tuber characters like tubers per plant, tuber length, tuber girth and tuber weight. Maximum tuber number was recorded in PT 6 (5.33) followed by PT 17 (4.33) and PT 9 (4.00) and the least number of tubers were recorded in PT 13 (2.66). For tuber length, PT 13 recorded longest tuber of 16.66 cm followed by PT 6 (14.33 cm) and the shortest tuber length of 7.00 cm was recorded in PT 17. Tuber girth varied from 10.26 cm in PT 10 to 7.20 cm in PT 9. Highest tuber weight of 173.66 g was recorded in PT 6 followed by PT 10 (116.33 g) and PT 13 (88.66 g). The lowest weight was recorded in PT 9 (59.33 g).

There was significant difference between genotypes for duration of the crop. The longest duration of 353.33 days was noted in PT 18 which is on par with PT 21 (351.67 days), PT 6 (341.67 days), PT 15 (340.00 days) and PT 1 (335.00 days). The shortest duration of 295.00 days was recorded in PT 3 followed by PT 20 (298.00 days) and PT 17 (300.00 days).

4.1.3 Morphological characters

Morphological characters like pigmentation on stem and leaf, flower colour, pod and seed colour of all genotypes were given in Table 6, Plates 2, Plate 3, Plate 4 and Plate 5.

Out of 21 winged bean genotypes, four genotypes had greenish purple stem, and rest of the genotypes had green stem. There was no variation for leaf and pod pigmentation. The flower colour varied from light blue to blue. There was no considerable variation for pod wing colour. All the genotypes had green coloured wing except PT 7 which showed purple coloured wing. Seed colour exhibited wide variation *viz.*, tan colour (14 genotypes), black (6 genotypes) and one genotype had brown seeds.

Table 6. Morphological characters of 21 genotypes of winged bean

Genotypes	Stem pigmentation	Leaf pigmentation	Flower colour	Pod colour	Pod wing colour	Seed colour
PT 1	Green	Green	Light blue	Green	Green	Tan
PT 2	Greenish purple	Green	Light blue	Green	Green	Tan
PT 3	Green	Green	Light blue	Green	Green	Black
PT 4	Green	Green	Light blue	Green	Green	Tan
PT 5	Green	Green	Light blue	Green	Green	Tan
PT 6	Green	Green	Light blue	Green	Green	Tan
PT 7	Purple	Green	Blue	Green	Purple	Brown
PT 8	Greenish purple	Green	Blue	Green	Green	Black
PT 9	Greenish purple	Green	Blue	Green	Green	Tan
PT 10	Green	Green	Light blue	Green	Green	Black
PT 11	Purple	Green	Blue	Green	Green	Black
PT 12	Green	Green	Blue	Green	Green	Tan
PT 13	Green	Green	Light blue	Green	Green	Tan
PT 14	Greenish purple	Green	Blue	Green	Green	Tan
PT 15	Green	Green	Light blue	Green	Green	Tan
PT 16	Purple	Green	Light blue	Green	Green	Black
PT 17	Green	Green	Light blue	Green	Green	Tan
PT 18	Green	Light green	Light blue	Green	Green	Tan
PT 19	Green	Green	Light blue	Green	Green	Tan
PT 20	Purple	Green	Light blue	Green	Green	Black
PT 21	Green	Green	Light blue	Green	Green	Tan

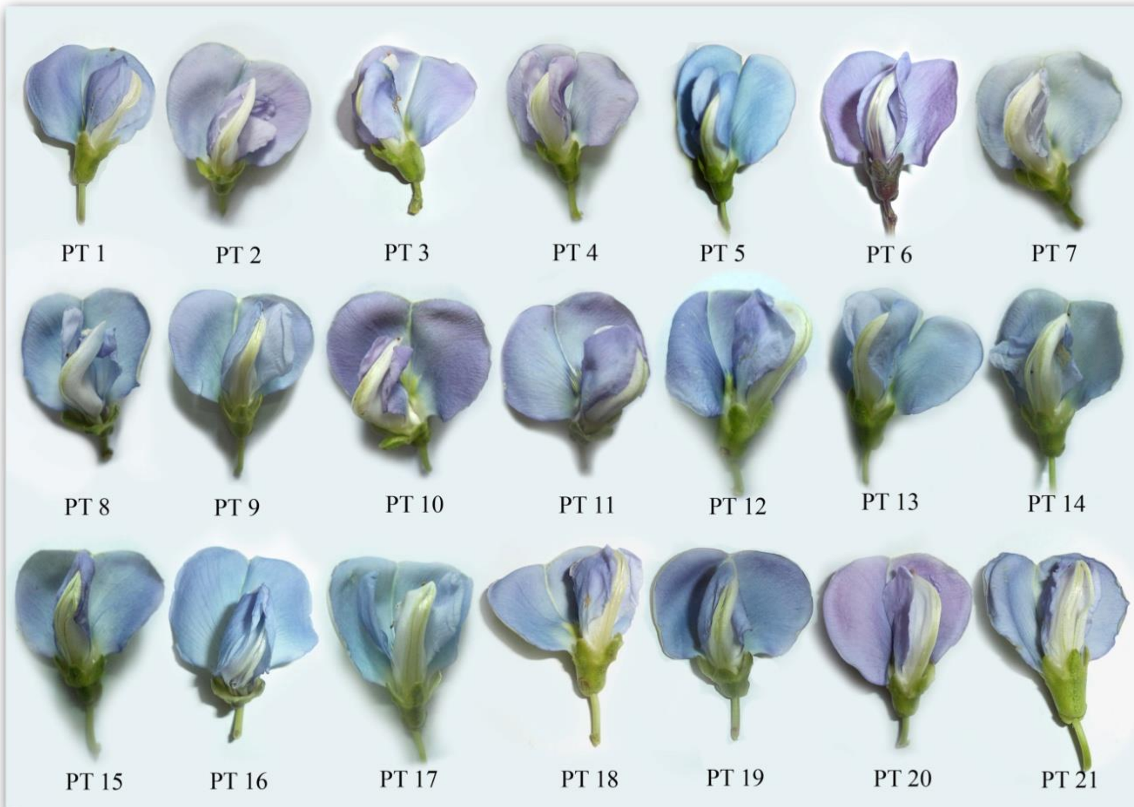

Plate 2. Variability in flower characters of winged bean genotypes

Plate 3 A. Variability in pod characters of winged bean genotypes

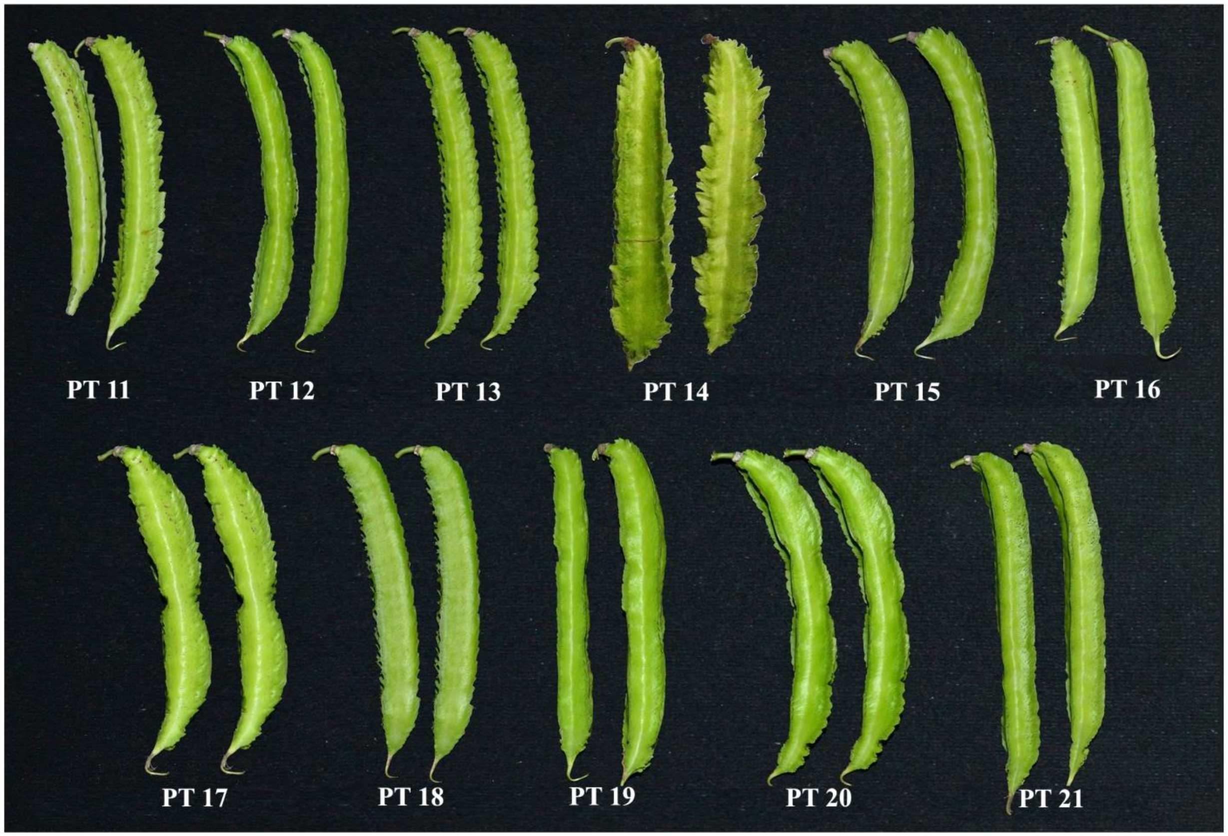

Plate 3 B. Variability in pod characters of winged bean genotypes

Plate 4. Variability in seed colour of winged bean genotypes

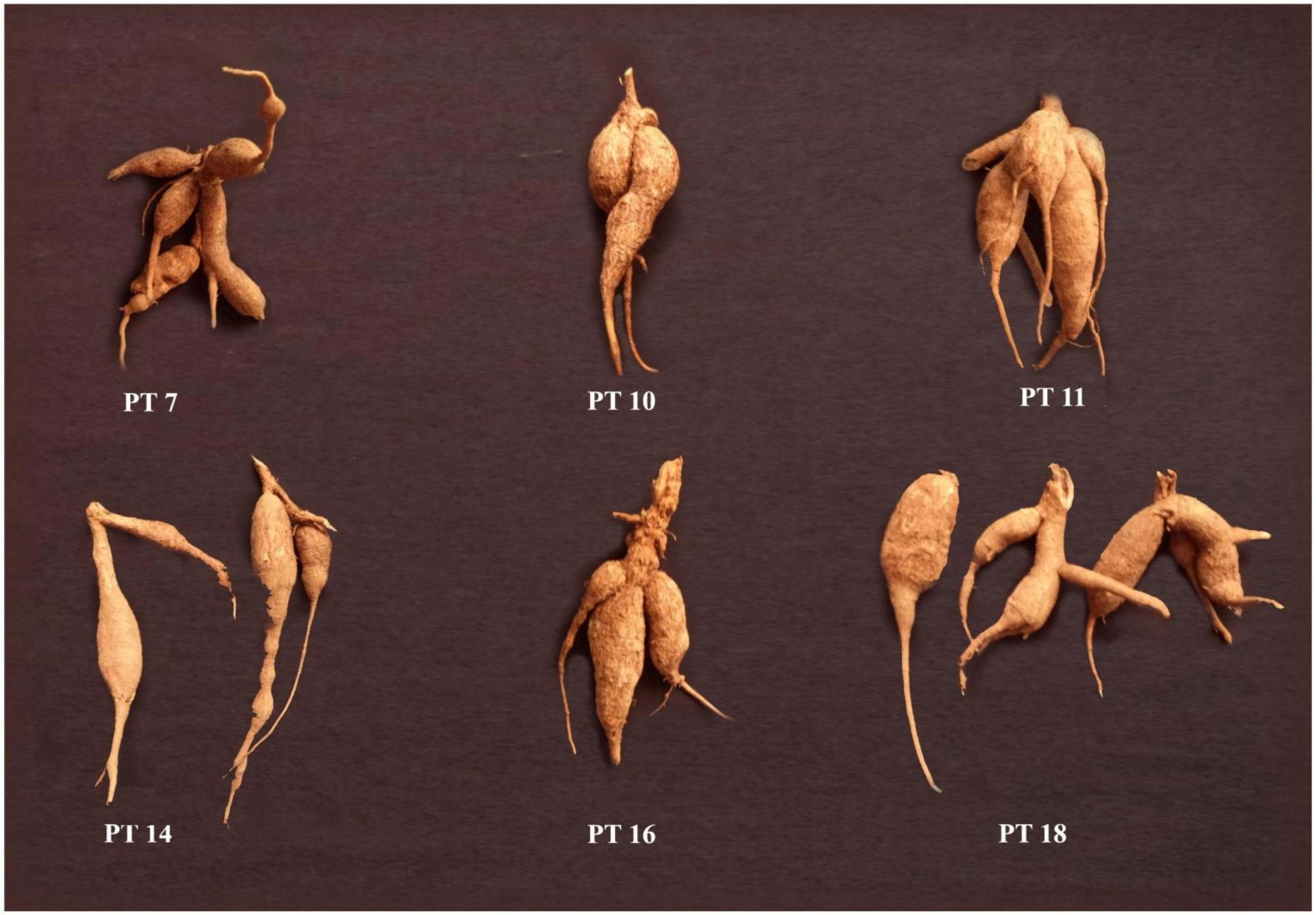

Plate 5. Variability in tuber characters of winged bean genotypes

4.1.4 Genetic parameters

The range, population mean, phenotypic and genotypic variances and genotypic coefficient of variation (GCV) and phenotypic coefficient variation (PCV) for 24 characters were studied and are presented in Table 7 and Fig. 1.

High phenotypic and genotypic variances were observed for characters like yield per plant, pods per plant, vine length, days to first flowering, days to 50 per cent flowering, days to first harvest and days to final harvest. A close association between phenotypic and genotypic variances was noted for days to first flowering, days to 50 per cent flowering, days to first harvest, yield per plot, pod weight, shelling percentage and pod fibre. For most of the characters genotypic variances make up the major portion of phenotypic variances, with very little effect of environment.

Yield per plant recorded high GCV and PCV of 31.19 and 42.33 respectively followed by number of pods per plant (29.97 and 41.86). High GCV and PCV of 24.88 and 25.72 were recorded for days to first flowering. Days to 50 per cent flowering also showed high GCV and PCV of 24.67 and 25.11 respectively. Primary branches per plant recorded a GCV of 21.54 and PCV of 24.19. Moderate level of GCV and PCV were observed in days to first harvest (19.16 and 19.64), seeds per pod (17.00 and 18.74), days to edible maturity (15.41 and 16.72), pod length (10.25 and 11.61), pod girth (10.41 and 11.27) and pod weight (15.55 and 17.52). Low GCV and PCV were recorded for days to final harvest (4.81 and 5.46), shelling percentage (7.82 and 8.32), pod fibre (6.35 and 9.51) and duration of crop (4.75 and 6.42). Days to germination, vine length, petiole length, leaflet length (both terminal and lateral) and leaflet width (both terminal and lateral) showed moderate PCV and low GCV. 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.

Table 7. Estimation of genetic parameters for various characters in winged bean

Characters	Range	Mean	GV	PV	GCV	PCV	H^2 (%)	GA at 5%	Genetic advance as % of mean
Days to germination	7.33 -12.66	9.84	0.89	3.47	9.59	18.93	25.71	0.98	10.02
Vine length (cm)	551.33-813.33	677.07	4285.13	5582.53	9.66	11.03	76.75	118.14	17.44
Primary branches/plant	6.33-15.66	11.46	6.09	7.68	21.54	24.19	79.32	4.53	39.52
Petiole length (cm)	9.65-15.02	12.15	1.33	3.53	9.49	15.46	37.64	1.45	11.93
Length of terminal leaflets (cm)	8.13-11.94	10.42	0.53	1.32	6.99	11.05	40.01	0.95	9.11
Breadth of terminal leaflets (cm)	7.34-11.80	9.02	0.63	0.89	8.79	10.48	70.38	1.37	15.18
Length of lateral leaflets (cm)	8.28-12.01	10.71	0.64	0.95	7.51	9.13	67.50	1.36	12.69
Breadth of lateral leaflets (cm)	5.74-9.31	7.34	0.41	0.55	8.78	10.11	75.64	1.15	15.66
Days to 1st flowering	75.05-178.83	113.65	799.98	853.91	24.88	25.72	93.68	56.39	49.62
Days to 50 % flowering	84.71-187.23	125.21	954.39	987.94	24.67	25.11	96.60	62.55	49.95
Days to 1st harvest	97.13-192.67	136.98	688.97	724.03	19.16	19.64	95.15	52.74	38.50
Days to final harvest	107.98-237.66	302.22	211.01	273.21	4.81	5.46	77.23	26.29	8.69
Pod length (cm)	14.84-21.89	18.90	3.76	4.81	10.25	11.61	78.11	3.53	18.67
Pod girth (cm)	5.03-8.75	7.59	0.62	0.73	10.41	11.27	85.28	1.50	19.76
Pod weight (g)	10.13-22.62	19.13	8.86	11.24	15.55	17.52	78.79	5.44	28.43
Pods / plant	44.98-154.49	86.58	673.47	1313.84	29.97	41.86	51.26	38.27	44.20
Yield / plant (g)	696.6-2703.33	1556.82	235907.6	434395.2	31.19	42.33	54.30	737.33	47.36
Yield / plot (kg)	13.40-26.99	18.61	10.28	14.85	17.23	20.71	69.18	5.49	29.50
Seeds / pod	6.94-15.07	12.07	4.21	5.12	17.00	18.74	82.26	3.83	31.73
100 seed weight (g)	20.39-43.81	32.36	30.05	44.82	16.93	20.68	67.03	9.24	28.55
Shelling %	41.67-58.17	50.12	15.38	17.39	7.82	8.32	88.42	7.59	15.14
Days to edible maturity	10.33-17.33	14.53	5.01	5.91	15.41	16.72	84.91	4.25	29.24
Pod fibre (%)	14.80-18.83	16.49	1.09	2.46	6.35	9.51	44.66	1.44	8.70
Duration of crop	295.00-353.33	319.04	230.02	420.44	4.75	6.42	54.71	23.11	7.24

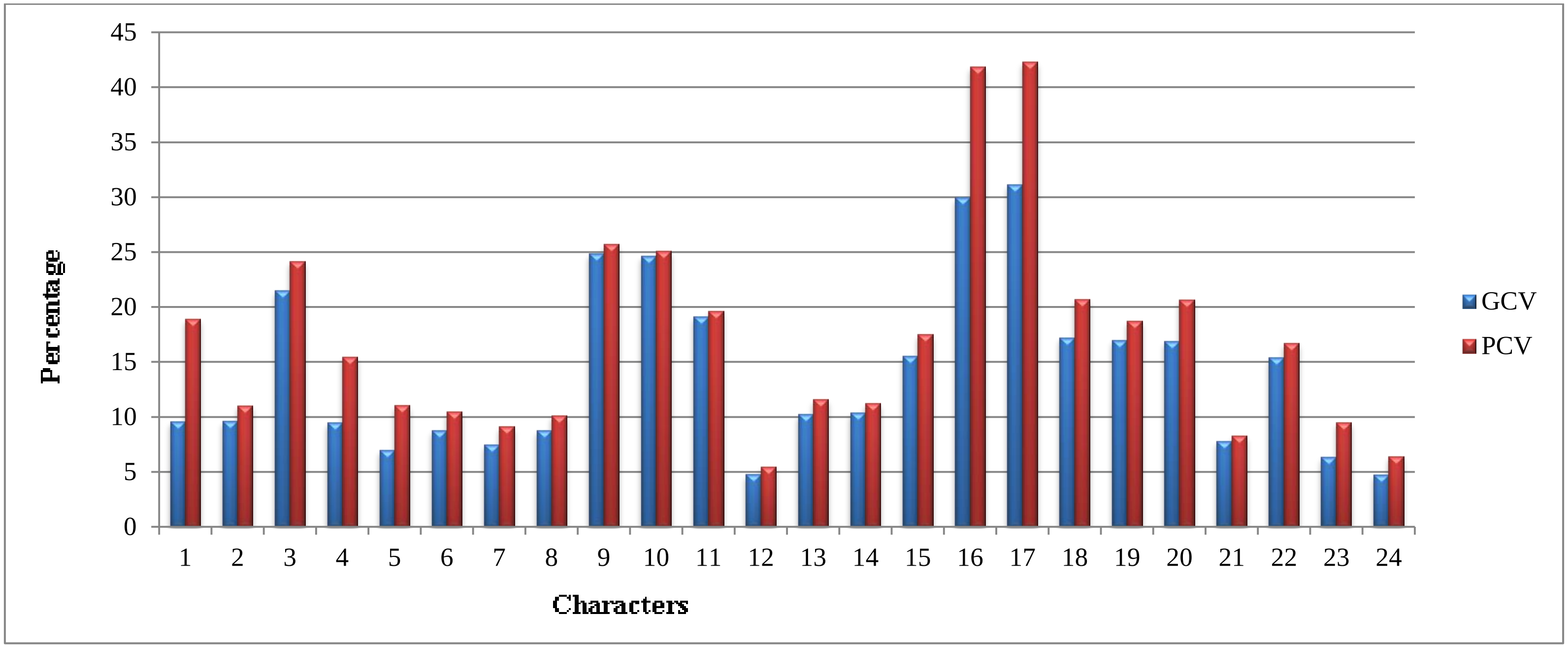

Fig. 1 Genotypic and phenotypic coefficient of variance for different characters in winged bean

X1. Days to germination
X2. Vine length (cm)
X3. Primary branches/plant
X4. Petiole length (cm)
X5. Terminal leaflets length (cm)
X6. Terminal leaflets width (cm)
X7. Lateral leaflets Length (cm)
X8. Lateral leaflets breadth (cm)
X9. Days to 1st flowering
X10. Days to 50 % flowering
X11. Days to 1st harvest
X12. Days to final harvest
X13. Pod length (cm)
X14. Pod girth (cm)
X15. Pod weight (g)
X16. Pods / plant
X17. Yield / plant (g)
X18. Yield / plot (kg)
X19. Seeds / pod
X20. 100 seed weight (g)
X21. Shelling %
X22. Days to edible maturity
X23. Pod fibre (%)
X24. Duration of crop

4.1.5 Heritability and genetic advance

Heritability and genetic advance for different characters are presented in Table 7 and Fig. 2. Most of the characters showed wide range of variation.

High heritability was observed for the characters days to 50 per cent flowering (96.60) followed by days to first harvest (95.15), days to first flowering (93.68), shelling percentage (88.42), pod girth (85.28) and days to edible maturity (84.91). Moderate heritability was observed for duration of crop (54.71) followed by yield per plant (54.30), pods per plant (51.26) and pod fibre (44.66). Days to germination recorded the lowest heritability (25.71).

High genetic advance as percentage of mean was observed for days to 50 per cent flowering (49.95) followed by days to first flowering (49.62), yield per plant (47.36), pods per plant (44.20), primary branches per plant (39.52), days to first harvest (38.50), yield per plot (29.50) and days to edible maturity (29.24). Low genetic advance was observed for duration of the crop (7.24), days to final harvest (8.69), pod fibre per cent (8.70) and the length of terminal leaflet length (9.11). High heritability coupled with high genetic advance was observed for characters like primary branches per plant, days to first flowering, days to 50 per cent flowering, days to first harvest and yield per plot, pod weight, seeds per pod and 100 seed weight. High heritability coupled with moderate genetic advance was observed for vine length, pod length, pod girth, and shelling percentage.

4.1.6 Correlation analysis

The phenotypic, genotypic and environmental correlation coefficients were estimated for the 22 characters and are presented in Table 8, Table 9 and Table 10.

A) Phenotypic correlation

i) Correlation between yield and other characters

Yield per plant showed highest positive correlation with pods per plant (0.959) followed by pod length (0.439), pod weight (0.420), pod girth (0.335),

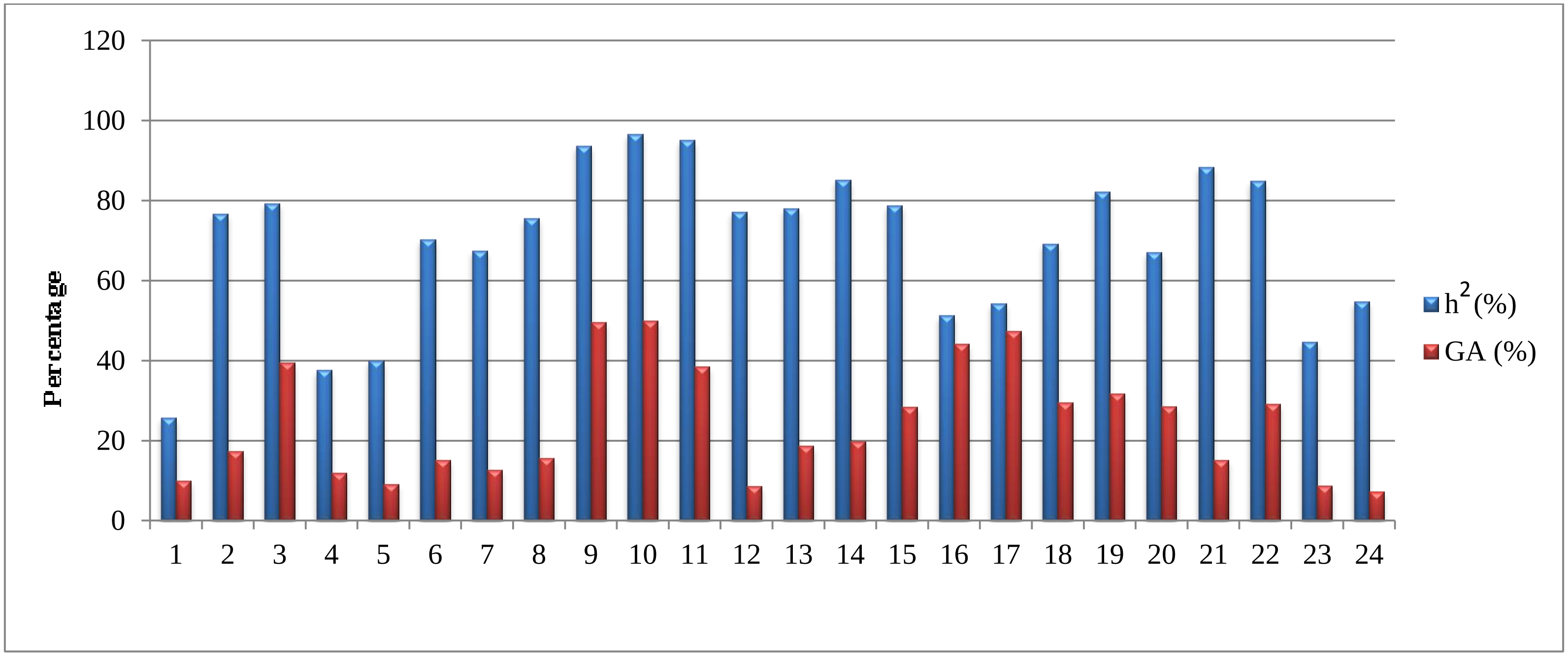

Fig. 2 Heritability and genetic advance as percentage of mean for different characters in winged bean

X1. Days to germination
X2. Vine length (cm)
X3. Primary branches/plant
X4. Petiole length (cm)
X5. Terminal leaflets length (cm)
X7. Lateral leaflets Length (cm)
X8. Lateral leaflets breadth (cm)
X9. Days to 1st flowering
X10. Days to 50 % flowering
X11. Days to 1st harvest
X13. Pod length (cm)
X14. Pod girth (cm)
X15. Pod weight (g)
X16. Pods / plant
X17. Yield / plant (g)
X19. Seeds / pod
X20. 100 seed weight (g)
X21. Shelling %
X22. Days to edible maturity
X23. Pod fibre (%)

Table 8. Phenotypic correlation coefficients for biometric and quality characters in winged bean

X/X	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22
X1	1.00																					
X2	0.243	1.00																				
X3	0.183	***0.870***	1.000																			
X4	0.249	***0.956***	***0.832***	1.000																		
X5	-0.177	-0.018	-0.063	-0.054	1.000																	
X6	-0.193	-0.165	-0.123	-0.200	0.047	1.000																
X7	0.061	*0.316*	*0.252*	*0.257*	***0.357***	0.039	1.000															
X8	-0.045	***0.583***	***0.614***	***0.670***	-0.146	0.036	0.038	1.000														
X9	-0.056	0.129	-0.004	0.158	***0.365***	-0.019	0.237	*0.250*	1.000													
X10	-0.068	-0.035	*-0.252*	-0.013	0.156	-0.034	*0.307*	-0.004	***0.466***	1.000												
X11	-0.119	-0.177	*-0.272*	0.034	0.070	0.057	0.220	0.032	***0.333***	***0.774***	1.000											
X12	-0.049	*0.283*	0.086	*0.284*	0.227	0.014	***0.329***	*0.257*	***0.436***	***0.687***	***0.752***	1.000										
X13	-0.089	0.244	0.011	0.228	*0.290*	0.009	*0.317*	0.186	***0.557***	***0.609***	***0.752***	***0.899***	1.000									
X14	-0.030	-0.201	***-0.345***	-0.196	-0.143	***0.504***	0.007	-0.244	-0.172	0.026	0.142	-0.078	-0.038	1.000								
X15	***-0.352***	*-0.278*	*-0.323*	*-0.258*	-0.154	0.161	-0.019	*-0.281*	-0.206	0.006	0.097	*-0.268*	-0.180	***0.556***	1.00							
X16	-0.166	***-0.390***	***-0.437***	***-0.381***	-0.087	***0.342***	0.025	***-0.451***	-0.174	0.089	0.123	-0.201	-0.130	***0.745***	***0.720***	1.00						
X17	-0.224	-0.213	*-0.318*	*-0.280*	0.214	*0.310*	0.133	*-0.294*	-0.039	0.056	0.135	0.014	0.040	***0.378***	0.247	***0.332***	1.000					
X18	-0.204	-0.198	***-0.327***	*-0.265*	*0.231*	*0.281*	0.216	***-0.338***	-0.049	0.061	0.134	0.016	0.048	***0.439***	***0.335***	***0.420***	***0.959***	1.000				
X19	*-0.311*	*-0.256*	*-0.261*	*-0.292*	*0.323*	***0.457***	*0.265*	-0.197	0.089	0.230	0.200	0.034	0.078	***0.362***	*0.295*	***0.396***	***0.493***	***0.478***	1.000			
X20	-0.160	*-0.283*	*-0.311*	*-0.270*	-0.132	***0.489***	-0.035	-0.149	-0.109	-0.023	0.066	-0.170	-0.101	***0.678***	***0.446***	***0.728***	0.206	*0.278*	***0.496***	1.000		
X21	-0.114	0.081	0.069	0.134	-0.099	0.032	0.127	*0.307*	0.110	0.140	0.199	0.125	0.123	0.214	***0.385***	0.203	***-0.439***	0.050	0.126	0.159	1.000	
X22	-0.124	0.054	0.199	0.037	0.031	***0.359***	-0.012	*0.269*	-0.024	-0.218	-0.218	-0.009	-0.034	-0.110	-0.170	-0.192	-0.043	-0.047	-0.013	0.055	0.027	1.000

(Italics bold - significant at 1% level; Italics without bold - significant at 5% level)

X1. Days to germination
X2. Days to first flowering
X3. Days to 50 % flowering
X4. Days to first harvest
X5. Days to final harvest
X6. Days to edible maturity
X7. Vine length (cm)
X8. Primary branches/plant
X9. Petiole length (cm)
X10. Terminal leaflet length (cm)
X11. Lateral leaflet length (cm)
X12. Terminal leaflet width (cm)
X13. Lateral leaflet width (cm)
X14. Pod length (cm)
X15. Pod girth (cm)
X16. Pod weight (cm)
X17. Pods per plant
X18. Yield per plant (g)
X19. Yield per plot (kg)
X20. Seeds per pod
X21. 100 seed weight
X22. Pod fibre (%)

days to edible maturity (0.281) and days to final harvest (0.231). Primary branches per plant showed high negative correlation with yield (-0.338) followed by days to 50 per cent flowering (-0.327) and days to first harvest (-0.265).

ii) Correlation among the yield component characters

Vine length had high positive correlation with days to final harvest (0.357), days to first flowering (0.316), days to 50 per cent flowering (0.252) and days to first harvest (0.257). Days to 50 per cent flowering showed high positive correlation with days to first flowering (0.870). Pods per plant was positively correlated with pod length (0.378) followed by pod weight (0.332) and negatively correlated with days to 50 per cent flowering (-0.318) and days to first harvest (-0.280).

Yield per plot exhibited a positive correlation with pods per plant (0.493) followed by yield per plant (0.478), days to edible maturity (0.457), pod weight (0.396) and pod length (0.362) and negatively correlated with days to germination (-0.311).

Days to first harvest recorded a positive correlation with days to first flowering (0.956) and days to 50 per cent flowering (0.832). Pod weight was positively correlated with pod length (0.745) and pod girth (0.720) while it was negatively correlated with primary branches per plant (-0.451), days to 50 per cent flowering (-0.437), days to first flowering (-0.390), and days to first harvest (-0.381).

100 seed weight showed a positive correlation with pod girth (0.385) and negative correlation with pod per plant (-0.439). Pod fibre exhibited a positive correlation with days to edible maturity (0.359).

B) Genotypic correlation

i) Correlation between yield and other characters

High positive correlation was observed between yield per plant and pods per plant (0.960), pod length (0.740), pod weight (0.676), pod girth (0.519), days

Table 9. Genotypic correlation coefficients for biometric and quality characters in winged bean

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22
X1	1.000																					
X2	***0.535***	1.000																				
X3	***0.454***	***0.876***	1.000																			
X4	***0.503***	***0.970***	***0.843***	1.000																		
X5	***-0.510***	-0.031	-0.091	-0.072	1.000																	
X6	***-0.453***	-0.179	-0.144	-0.220	0.051	1.000																
X7	-0.172	***0.364***	*0.295*	*0.298*	***0.516***	0.114	1.000															
X8	-0.032	***0.721***	***0.726***	***0.800***	-0.094	0.003	0.074	1.000														
X9	*-0.257*	*0.269*	0.035	***0.316***	***0.648***	0.082	***0.345***	***0.359***	1.000													
X10	-0.109	-0.086	***-0.419***	0.004	*0.255*	0.081	***0.503***	-0.011	***0.583***	1.000												
X11	-0.066	-0.071	***-0.367***	0.030	0.119	0.079	*0.313*	0.058	***0.543***	***1.105***	1.000											
X12	0.126	***0.336***	0.107	***0.353***	***0.333***	0.082	***0.498***	***0.324***	***0.605***	***0.752***	***0.822***	1.000										
X13	0.017	*0.266*	0.003	*0.251*	***0.427***	0.038	***0.439***	0.199	***0.773***	***0.775***	***0.755***	***0.976***	1.000									
X14	-0.194	*-0.233*	***-0.401***	-0.248	-0.127	***0.610***	0.083	*-0.312*	*-0.253*	0.084	0.193	***-0.921***	-0.081	1.000								
X15	***-0.599***	***-0.337***	***-0.368***	*-0.303*	-0.109	0.186	-0.034	***-0.336***	***-0.356***	0.005	0.070	***-0.353***	*-0.267*	***0.616***	1.000							
X16	-0.227	***-0.497***	***-0.533***	***-0.488***	-0.114	***0.498***	-0.030	***-0.500***	***-0.377***	0.008	0.113	*-0.314*	*-0.241*	***0.896***	***0.869***	1.000						
X17	***-0.562***	***-0.355***	***-0.482***	***-0.442***	***0.381***	***0.425***	0.189	***-0.356***	-0.127	0.114	0.077	-0.023	0.041	***0.657***	***0.392***	***0.546***	1.000					
X18	***-0.527***	***-0.324***	***-0.476***	***-0.402***	***0.389***	***0.392***	*0.310*	***-0.405***	-0.117	0.122	0.104	-0.028	0.077	***0.740***	***0.519***	***0.676***	***0.960***	1.000				
X19	***-0.749***	***-0.346***	***-0.337***	***-0.400***	***0.378***	***0.547***	***0.355***	-0.206	0.189	*0.285*	0.132	-0.026	0.031	***0.466***	***0.384***	***0.519***	***0.648***	***0.655***	1.000			
X20	-0.115	-0.313	***-0.359***	*-0.303*	-0.166	***0.600***	-0.044	-0.176	-0.032	0.026	0.083	-0.182	-0.099	***0.874***	***0.574***	***0.852***	***0.363***	***0.473***	***0.623***	1.000		
X21	***-0.460***	0.153	0.127	-0.208	-0.106	0.055	0.136	*0.317*	*0.271*	*0.293*	*0.313*	0.118	*0.201*	*0.242*	***0.528***	*0.319*	0.018	0.081	0.222	*0.253*	1.000	
X22	0.036	0.141	***0.331***	0.086	*-0.271*	***0.518***	0.094	***0.364***	-0.142	*-0.322*	*-0.282*	0.016	-0.045	-0.021	-0.178	-0.129	-0.047	-0.062	0.104	0.147	0.080	1.000

(Italics bold - significant at 1% level; Italics without bold - significant at 5% level)

X1. Days to germination
X2. Days to first flowering
X3. Days to 50 % flowering
X4. Days to first harvest
X5. Days to final harvest
X6. Days to edible maturity
X7. Vine length (cm)
X8. Primary branches/plant
X9. Petiole length (cm)
X10. Terminal leaflet length (cm)
X11. Lateral leaflet length (cm)
X12. Terminal leaflet width (cm)
X13. Lateral leaflet width (cm)
X14. Pod length (cm)
X15. Pod girth (cm)
X16. Pod weight (cm)
X17. Pods per plant
X18. Yield per plant (g)
X19. Yield per plot (kg)
X20. Seeds per pod
X21. 100 seed weight
X22. Pod fibre (%)

to edible maturity (0.392) and days to final harvest (0.389). High negative correlation was observed between yield and days to germination (-0.527), days to 50 per cent flowering (-0.476), primary branches per plant (-0.405), days to first harvest (-0.402) and days to first flowering (-0.324).

ii) Correlation among the yield component characters

Vine length had positive correlation with days to first flowering (0.364), days to first harvest (0.298) and days to final harvest (0.516).

Days to 50 per cent flowering exhibited a high positive correlation with days to first flowering (0.876) and days to germination (0.454). Similarly days to first harvest also showed positive correlation with days to first flowering (0.970), days to 50 per cent flowering (0.843) and days to germination (0.503).

Pods per plant recorded a positive correlation with pod length (0.657) followed by pod weight (0.546), days to edible maturity (0.425), pod girth (0.392) and days to final harvest (0.381) and negative correlation with days to germination (-0.562) followed by days to 50 per cent flowering (-0.482), days to first harvest (-0.442), number of primary branches per plant (-0.356) and days to first flowering (-0.355). Pod weight showed high positive correlation with pod length (0.896), pod girth (0.869) and days to edible maturity (0.498) and recorded a negative correlation with days to 50 per cent flowering (-0.533) followed by primary branches per plant (-0.500), days to first flowering (-0.497) and days to first harvest (-0.488).

Yield per plot had positive correlation with yield per plant (0.655) followed by pods per pant (0.648), days to edible maturity (0.547), pod weight (0.519), pod length (0.466), pod girth (0.384) and days to final harvest (0.378). A negative correlation was exhibited between yield per plot and days to germination (-0.749), days to first harvest (-0.400) and days to first flowering (-0.346). 100 seed weight also showed a positive correlation with pod girth (0.528) and pod weight (0.319) while pod fibre was positively correlated with days to edible maturity (0.518).

C) Environmental correlation

Positive correlation was observed between yield per plant and pods per plant (0.959). Vine length showed a positive correlation with days to germination (0.330). Pod weight had positive correlation with days to first harvest (0.415) and days to 50 per cent flowering (0.325) and showed negative correlation with days to edible maturity (-0.364). Days to first harvest exhibited a positive correlation with days to first flowering (0.736) and days to 50 per cent flowering (0.584). A negative correlation was recorded between primary branches per plant and days to final harvest (-0.336). 100 seed weight recorded positive correlation with primary branches per plant (0.290) and negative correlation with days to 50 per cent flowering (-0.311) and days to first flowering (-0.274). Pod fibre is negatively correlated with pod weight (-0.338).

4.1.7 Path analysis

In path coefficient analysis, the genotypic correlation coefficients among yield and its component characters were partitioned into direct and indirect contribution of each character to pod yield (Table 11, Fig. 3). Vine length, days to first flowering, days to first harvest, days to final harvest, pod length, pod girth, pod weight and pods per plant were selected for path coefficient analysis.

Pods per plant exhibited the highest positive direct effect on pod yield (0.631) followed by pod length (0.347), pod girth (0.229), days to first flowering (0.156) and days to final harvest (0.122). Days to first harvest (-0.244) and pod weight (-0.202) exhibited negative direct effect on pod yield per plant.

Vine length had genotypic correlation of 0.310 with yield. In this, the direct effect was only 0.116. Major portion of indirect effect was through pods per plant (0.119).

The direct effect of days to first flowering on yield was 0.156 but genotypic correlation with yield was -0.324. This character exhibited indirect effect on yield through pod weight (0.100) and vine length (0.042).

Table 10. Environmental correlation coefficients for biometric and quality characters in winged bean

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22
X1	1.000																					
X2	-0.089	1.000																				
X3	*-0.270*	***0.791***	1.000																			
X4	0.000	***0.736***	***0.584***	1.000																		
X5	0.121	0.068	0.171	*0.286*	1.000																	
X6	0.054	-0.053	0.112	-0.031	0.032	1.000																
X7	***0.330***	0.062	-0.022	0.022	-0.173	*-0.286*	1.000															
X8	-0.078	***-0.334***	*-0.258*	-0.243	***-0.336***	0.190	-0.091	1.000														
X9	0.034	-0.151	-0.180	-0.178	0.041	-0.215	0.135	0.151	1.000													
X10	-0.050	0.088	0.057	-0.090	0.038	*-0.273*	0.076	0.007	***0.392***	1.000												
X11	-0.186	*0.273*	0.229	0.077	-0.056	-0.013	-0.020	-0.037	0.132	***0.453***	1.000											
X12	-0.220	0.074	-0.016	-0.041	-0.071	-0.231	-0.141	0.059	*0.289*	***0.683***	***0.613***	1.000										
X13	-0.227	0.168	0.089	0.143	-0.154	-0.112	-0.074	0.140	***0.371***	***0.478***	***0.756***	***0.694***	1.000									
X14	0.140	-0.010	0.035	0.168	-0.200	0.039	*-0.256*	0.008	-0.095	-0.056	0.007	-0.041	0.104	1.000								
X15	-0.215	0.244	0.152	0.178	***-0.360***	0.017	0.044	-0.029	-0.015	0.011	0.202	0.024	0.184	*0.296*	1.000							
X16	-0.162	*0.313*	***0.325***	***0.415***	0.008	***-0.364***	0.220	*-0.265*	0.085	0.236	0.156	0.131	0.245	0.196	0.046	1.000						
X17	-0.033	0.190	0.159	0.187	-0.076	0.110	0.043	-0.211	0.029	0.008	0.225	0.075	0.041	-0.113	-0.045	-0.044	1.000					
X18	-0.012	0.195	0.140	0.159	-0.065	0.055	0.049	-0.234	0.007	0.007	0.183	0.092	-0.002	-0.135	-0.070	-0.070	***0.959***	1.000				
X19	0.009	0.158	0.135	*0.261*	0.176	0.159	0.025	-0.174	-0.017	0.187	***0.346***	0.174	0.201	0.075	0.000	0.051	*0.276*	0.205	1.000			
X20	***-0.295***	-0.083	0.115	-0.022	0.003	-0.072	-0.003	-0.039	*-0.275*	-0.118	0.018	-0.140	-0.113	-0.115	-0.216	0.219	-0.099	-0.133	0.110	1.000		
X21	0.155	*-0.274*	*-0.311*	-0.250	-0.084	-0.041	0.107	*0.290*	-0.057	-0.025	-0.034	0.140	-0.069	0.144	-0.065	-0.106	-0.136	0.003	-0.078	-0.119	1.000	
X22	-0.213	-0.195	-0.134	-0.115	0.132	0.138	-0.189	0.156	0.058	-0.197	-0.150	-0.045	-0.023	*-0.282*	-0.211	***-0.338***	-0.038	-0.033	-0.173	-0.107	-0.038	1.000

(Italics bold - significant at 1% level; Italics without bold - significant at 5% level)

X1. Days to germination
X2. Days to first flowering
X3. Days to 50 % flowering
X4. Days to first harvest
X5. Days to final harvest
X6. Days to edible maturity
X7. Vine length (cm)
X8. Primary branches/plant
X9. Petiole length (cm)
X10. Terminal leaflet length (cm)
X11. Lateral leaflet length (cm)
X12. Terminal leaflet width (cm)
X13. Lateral leaflet width (cm)
X14. Pod length (cm)
X15. Pod girth (cm)
X16. Pod weight (cm)
X17. Pods per plant
X18. Yield per plant (g)
X19. Yield per plot (kg)
X20. Seeds per pod
X21. 100 seed weight
X22. Pod fibre (%)

Days to first harvest had low direct effect (-0.244) and the genotypic correlation with yield also low (-0.402). The rest of its effect on yield was contributed by indirect effect through days to first flowering (0.152), vine length (0.034), pods per plant (-0.279), pod weight (0.098), pod girth (-0.069) and pod length (-0.086).

Though days to final harvest had a genotypic correlation of 0.389 with yield, the direct effect was 0.122. Indirect effect of days to final harvest through other characters was negligible except pods per plant (0.240).

The direct effect of pod length on yield was high (0.347) and genotypic correlation with yield was also high (0.740). Major portion of indirect effects was through pods per plant (0.414).

Pod girth exhibited a genotypic correlation of 0.519 with yield. The direct effect was only 0.229. Indirect effect on yield was mainly through pods per plant (0.247) followed by pod length (0.214) and pod weight (-0.175).

The genotypic correlation of pod weight on yield was high (0.676). In this, the direct effect was only -0.202. Major portion of indirect effects was through pods per plant (0.344) followed by pod length (0.310), pod girth (0.199) and days to first harvest (0.119).

Pods per plant recorded highest positive direct effect on yield per plant (0.631) and the genotypic correlation was also high (0.960). The major portion of indirect effect on yield was through pod length (0.228).

The residue obtained was 0.153 indicating that selected eight characters contributed the remaining 85 percent.

4.1.8 Divergence analysis

Following Mahalanobis statistic, the 21 genotypes of winged bean were subjected to D^2 analysis based on 24 characters to identify the degree of divergence in biological population at genetic level. The results of the analysis are presented below.

Table 11. Direct and indirect effect of yield and yield components of winged bean

Characters	Vine length	Days to first flowering	Days to first harvest	Days to final harvest	Pod length	Pod girth	Pod weight	Pods / plant	Genotypic correlation with yield
Vine length	**0.116**	0.057	-0.073	0.063	0.029	-0.007	0.006	0.119	0.310
Days to first flowering	0.042	**0.156**	-0.237	-0.003	-0.081	-0.077	0.100	-0.224	-0.324
Days to first harvest	0.034	0.152	**-0.244**	-0.008	-0.086	-0.069	0.098	-0.279	-0.402
Days to final harvest	0.060	-0.004	0.017	**0.122**	-0.044	-0.025	0.023	0.240	0.389
Pod length	0.009	-0.036	0.060	-0.015	**0.347**	0.141	-0.181	0.414	0.740
Pod girth	-0.004	-0.052	0.074	-0.013	0.214	**0.229**	-0.175	0.247	0.519
Pod weight	-0.003	-0.077	0.119	-0.014	0.310	0.199	**-0.202**	0.344	0.676
Pods / plant	0.022	-0.055	0.108	0.046	0.228	0.089	-0.110	**0.631**	0.960

Residue (R) = 0.153

(Underlined figures are direct effects)

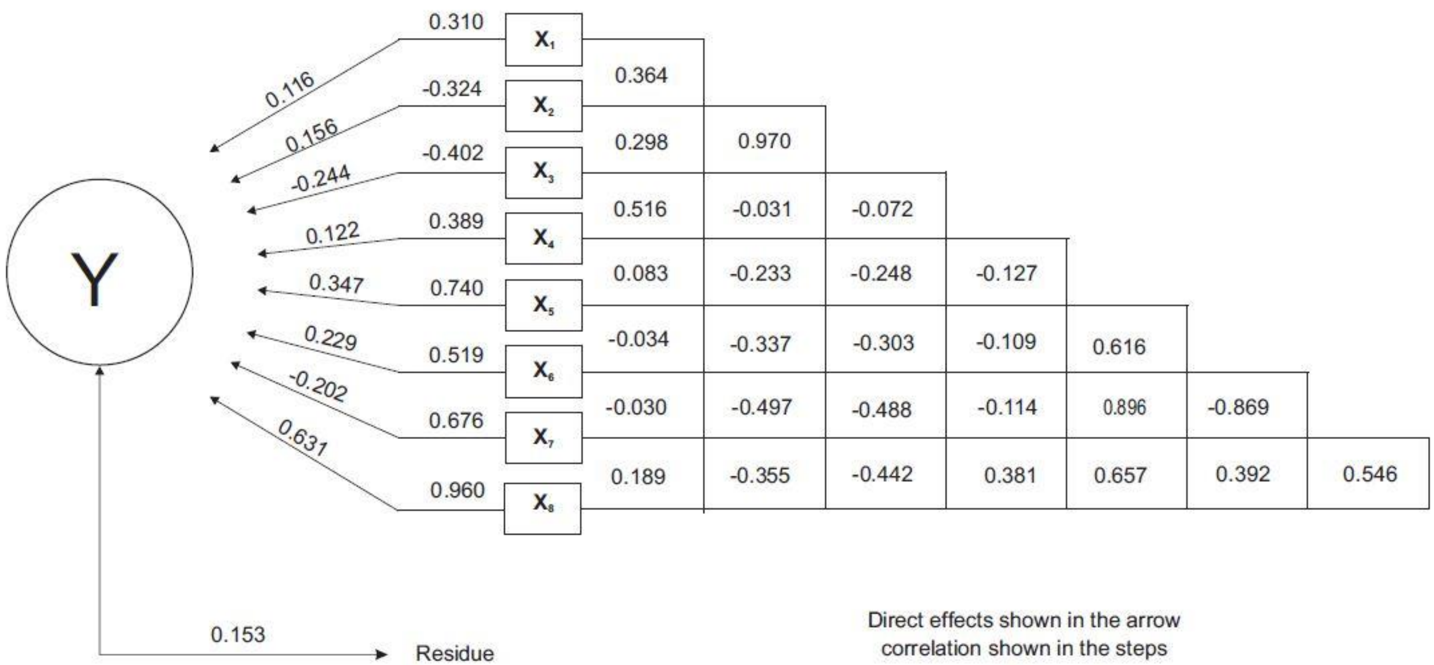

Fig.3. Path diagram showing direct effects and correlation of yield components on total yield of winged bean genotypes

4.1.8.2 Grouping of genotypes in to various clusters

Twenty one genotypes were grouped into five clusters (Fig.4) based on D^2 values. The clustering pattern is furnished in Table 12. Dendrogram generated by UPGMA cluster analysis is shown in Fig. 5.

Out of the five clusters, cluster III was the largest comprising of six genotypes followed by cluster I and II with five genotypes each and cluster IV consist of one genotype and cluster V with four genotypes. The pattern of distribution of genotypes from different eco-geographical regions in to various clusters was at random indicating that there was no parallelism between geographical diversity and genetic diversity.

4.1.9.3 Average intra and inter cluster distances

The average intra and intercluster distances were estimated based on the total D^2 values and presented in Table 13 and Fig. 4. The intracluster distance was observed maximum in cluster IV (122.18) followed by cluster III (122.06) and the minimum for cluster V (0.00). While the maximum intercluster distance of 1819.40 was recorded between cluster II and cluster V followed by cluster I and cluster V (1156.77) and cluster IV and cluster II (957.43) and the minimum intercluster distance of 142.92 was recorded between cluster I and cluster III which is followed by cluster I and cluster II (189.40) and cluster III and cluster IV (304.79) indicating that genotypes of these clusters had maximum number of gene complexes.

4.1.9.4 Cluster means of the characters

The cluster means obtained for the 24 characters in each cluster are presented in Table 14. Cluster I showed the highest cluster mean for pod length (20.06), pod girth (7.91), pod weight (21.22), pods per plant (118.77) and yield per plant (2197.33). The maximum value of cluster mean for vine length (813.33), primary branches per plant (15.66), days to first flowering (178.83), days to 50 per cent flowering (187.23), days to first harvest (192.67) and days to final harvest (320.00) was recorded in cluster IV. The highest cluster mean for

Table 12. Clustering pattern of winged bean genotypes

Clusters	Number of genotypes	Genotypes
Cluster I	5	PT 1, PT 2, PT 4, PT 14, PT21
Cluster II	5	PT 3, PT 8, PT 15, PT 19, PT 20
Cluster III	6	PT 6, PT 10, PT 11, PT 12, PT 13, PT 16
Cluster IV	1	PT 18
Cluster V	4	PT 5, PT 7, PT 9, PT17

Table 13. Average intra and inter cluster distances

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Cluster I	**72.19**	189.40	142.92	461.03	1156.77
Cluster II		**62.39**	328.88	957.43	1819.40
Cluster III			**122.06**	304.79	800.37
Cluster IV				**122.18**	383.19
Cluster V					**0.00**

Diagonal elements represent intracluster values

Off diagonal elements represents intercluster values

Table 14. Cluster means

Character	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Days to germination	9.13	10.46	9.11	11.33	10.66
Vine length (cm)	695.13	631.86	704.55	813.33	635.75
Primary branches / plant	9.20	10.40	12.72	15.66	12.66
Days to first flowering	83.85	100.83	123.03	178.83	136.56
Days to 50 % flowering	91.89	112.54	128.94	187.23	161.59
Days to first harvest	108.23	126.65	147.17	192.67	156.64
Days to final harvest	309.66	293.66	304.16	320.00	296.25
Days to edible maturity	15.93	14.20	14.55	13.66	13.41
Petiole length (cm)	12.36	11.01	12.85	14.68	11.62
Terminal leaflet length (cm)	10.78	10.42	10.77	11.84	9.11
Lateral leaflet length (cm)	11.06	10.91	10.84	12.00	9.47
Terminal leaflet width (cm)	9.08	9.12	8.99	11.80	8.16
Lateral leaflet width (cm)	7.48	7.32	7.34	9.31	6.69
Pod length (cm)	20.06	19.61	18.75	14.84	17.80
Pod girth (cm)	7.91	7.65	7.89	5.03	7.31
Pod weight (g)	21.22	20.46	19.06	10.13	17.24
Pods / plant	118.77	79.15	79.58	44.98	76.51
Yield / plant (g)	2197.33	1385.33	1461.11	750.00	1315.83
Seeds / pod	13.20	12.72	11.92	8.05	11.04
100 seed weight (g)	32.87	29.25	35.59	27.76	31.94
Shelling %	51.15	47.47	52.02	49.10	49.56
Pod protein (%)	2.60	2.82	2.64	2.16	2.46
Seed protein (%)	15.42	15.63	16.11	16.93	16.40
Pod fibre (%)	16.90	15.87	16.17	17.66	16.93

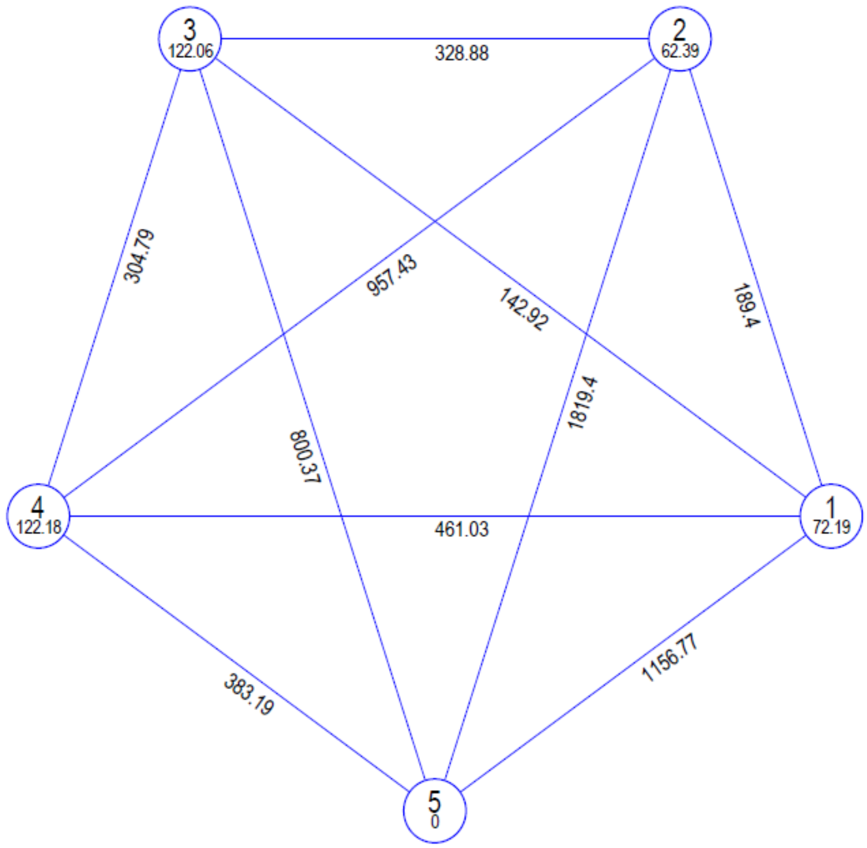

Fig 4. Cluster diagram

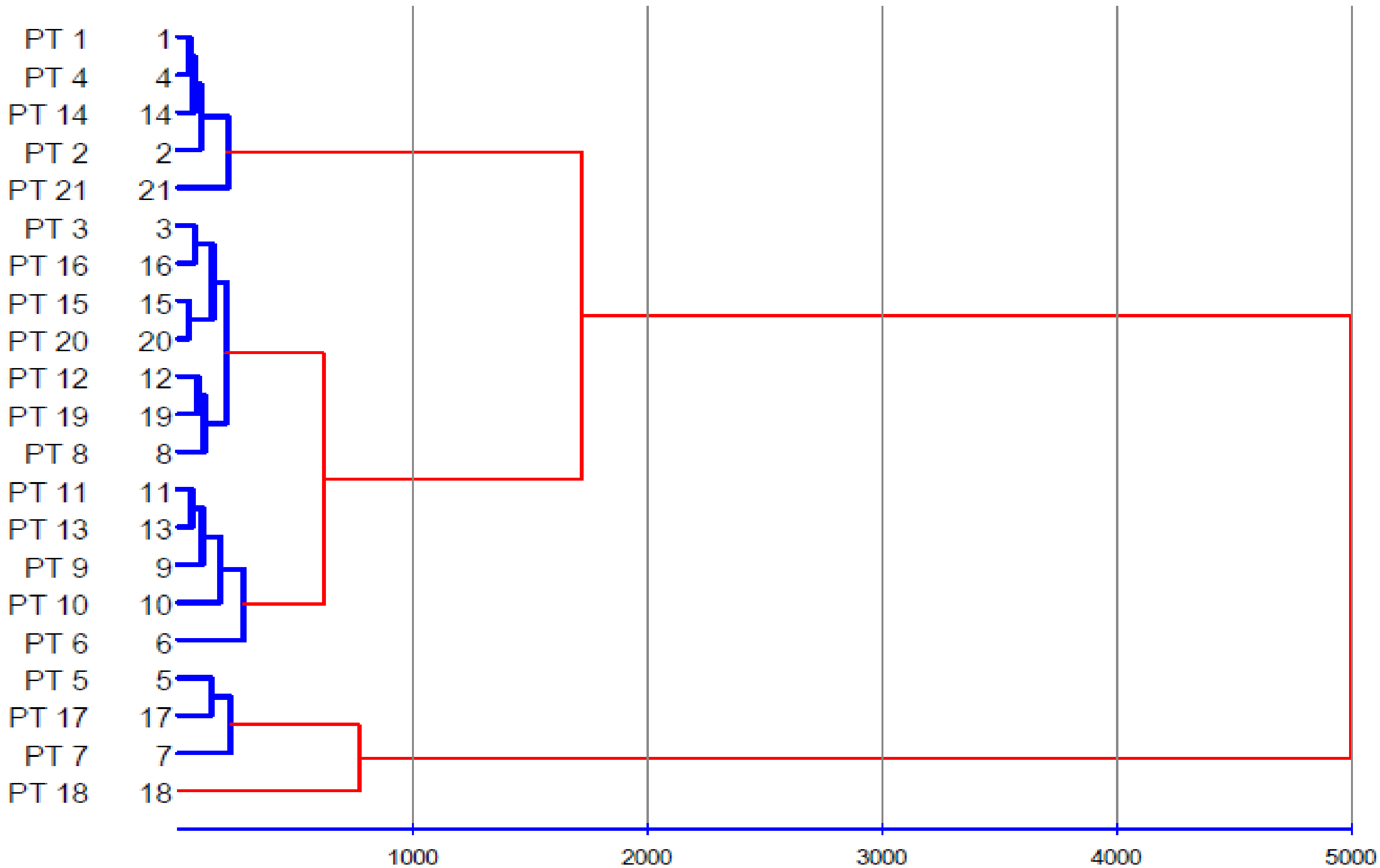

Fig. 5 Dendrogram of winged bean genotypes constructed using UPGMA hierarchal cluster analysis

100 seed weight (35.59) and shelling percentage (52.02) was manifested in cluster III and cluster II had highest mean value for pod protein content (2.82).

In general, Genotypes of cluster I showed earliness for flowering and harvesting with mean values of 83.85 and 108.23 respectively. On the other hand, genotypes of cluster IV were both late flowering and late harvesting types with mean values of 178.83 and 192.67 respectively.

4.1.8 Selection index

A discriminant function analysis was carried out for identifying superior genotypes.

Selection index involving characters *viz.*, vine length (X1), days to first flowering (X2), days to first harvest (X3), days to final harvest (X4), pod length (X5), pod girth (X6), pod weight (X7), pods per plant (X8), yield per plant (X9) and tubers per plant (X10) were selected for the analysis.

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

I = 11.597 X1 - 13.114 X2 + 11.328 X3 + 1.376 X4 + 106.555 X5 + 143.482 X6 - 6.661 X7 + 3.723 X8 + 0.020 X9 -41.974 X10

The index value for each genotype was determined and they were ranked. The scores obtained for the genotypes based on the selection index were given in Table 15.

Based on selection index including both vegetative and qualitative characters PT 21 was ranked first with an index of 24799.37 followed by PT 6 (23324.76). PT 1, PT 4 and PT 7 obtained next three positions with indices of 23165.18, 23085.51 and 22739.01 respectively. The minimum scores were obtained for PT 5 followed by PT 17 with an index of 18879.54 and 19400.60 respectively.

4.1.10 Cataloguing of germplasm

All the 21 genotypes were described morphologically using the modified descriptor developed from the standard descriptor for winged bean by IPGRI

Table 15. Winged bean genotypes ranked according to selection index

Ranks in descending order	Genotypes	Index
1	PT 21	24799.37
2	PT 6	23324.76
3	PT 1	23165.18
4	PT 4	23085.51
5	PT 7	22739.01
6	PT 3	22035.98
7	PT 2	21846.80
8	PT 8	21571.85
9	PT 14	21512.60
10	PT 20	21475.49
11	PT 12	21415.60
12	PT 16	21330.79
13	PT 13	21272.87
14	PT 11	20811.99
15	PT 9	20686.71
16	PT 10	20628.69
17	PT 19	20415.01
18	PT 15	20212.95
19	PT 18	20113.14
20	PT 17	19400.60
21	PT 5	18879.54

(Appendix I). The genotypes were scored for 17 morphological characters on appropriate scales ranging from 0-7 (Table 16).

All the genotypes had climbing habit with abundant plant growth at flowering. All the genotypes produced medium sized deltoid shaped leaves.

Stem pigmentation ranged from green to purple. Most of the genotypes had green stem with exceptions like PT 7, PT 11, PT 16 and PT 20 had purple stem and genotypes PT 2, PT 8, PT 9 and PT 14 showed greenish purple pigmentation.

Out of the 21 genotypes six genotypes (PT 6, PT 9, PT 10, PT 13, PT 15 and PT 18) produced tubers.

Flower pigment pattern showed marked variation. The genotypes PT 7, PT 8, PT 11, PT 12 and PT 14 had blue flowers where as the rest of the genotypes produced light blue coloured flowers. All the genotypes had green coloured calyx except PT 6 which had greenish purple calyx cup.

There was not much variation in pod pigmentation. All the genotypes had green coloured pods, but variation was recorded for pod wing colour. PT 7 recorded purple coloured wings. Purple speck in pods was noted in genotypes like PT 7, PT 8, PT 9, PT 11, PT 14, PT 16 and PT 20.

There was wide variation in pod shape among the genotypes. Rectangular pods were present in PT 1, PT 2, PT 3, PT 4, PT 10, PT 19, PT 20 and PT 21. Genotypes PT 5, PT 11, PT 13 and PT 17 had pods which were flat on suture and the rest had pods which were flat on sides.

All the genotypes produced round shaped smooth surfaced seeds with white hilum colour which was free from any seed motling. The seed colour showed wide variation. Black coloured seeds were noticed in PT 3, PT 8, PT 10, PT 11, PT 16 and PT 20 whereas PT 7 recorded brown seeds and the rest of the genotypes had tan coloured seeds.

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

Genotypes	Plant growth	Leaflet size	Leaflet shape	Stem pigmentation	Tubers	Tuber size	Calyx colour	Corolla colour	Pod colour
PT 1	7	5	2	1	0	0	1	2	2
PT 2	7	5	2	2	0	0	1	2	2
PT 3	7	5	2	1	0	0	1	2	2
PT 4	7	5	2	1	0	0	1	2	2
PT 5	7	5	2	1	0	0	1	2	2
PT 6	7	5	2	1	+	7	2	2	2
PT 7	7	5	2	3	0	0	1	3	2
PT 8	7	5	2	2	0	0	1	3	2
PT 9	7	5	2	2	+	7	1	3	2
PT 10	7	5	2	1	+	7	1	2	2
PT 11	7	5	2	3	0	0	1	3	2
PT 12	7	5	2	1	0	0	1	3	2
PT 13	7	5	2	1	+	7	1	2	2
PT 14	7	5	2	2	0	0	1	3	2
PT 15	7	5	2	1	+	7	1	2	2
PT 16	7	5	2	3	0	0	1	2	2
PT 17	7	5	2	1	0	0	1	2	2
PT 18	7	5	2	1	+	7	1	2	2
PT 19	7	5	2	1	0	0	1	2	2
PT 20	7	5	2	3	0	0	1	2	2
PT 21	7	5	2	1	0	0	1	2	2

Table 16. Continued…

Genotypes	Pod speck	Pod wing colour	Pod surface texture	Pod shape	Seed colour	Seed shape	Seed surface	Hilum colour
PT 1	0	1	3	1	2	1	1	1
PT 2	0	1	3	1	2	1	1	1
PT 3	0	1	3	1	5	1	1	1
PT 4	0	1	3	1	2	1	1	1
PT 5	0	1	3	4	2	1	1	1
PT 6	0	1	3	3	2	1	1	1
PT 7	+	2	3	3	3	1	1	1
PT 8	+	1	3	3	5	1	1	1
PT 9	+	1	3	3	2	1	1	1
PT 10	0	1	3	1	5	1	1	1
PT 11	+	1	3	4	5	1	1	1
PT 12	0	1	3	3	2	1	1	1
PT 13	0	1	5	4	2	1	1	1
PT 14	+	1	3	3	2	1	1	1
PT 15	0	1	3	3	2	1	1	1
PT 16	+	1	3	3	5	1	1	1
PT 17	0	1	3	4	2	1	1	1
PT 18	0	1	3	3	2	1	1	1
PT 19	0	1	3	1	2	1	1	1
PT 20	+	1	3	1	5	1	1	1
PT 21	0	1	3	1	2	1	1	1

4.1.10 Screening for pests and diseases

The crop was monitored for the incidence of pest and diseases. Incidence was very meagre in all the genotypes and the percentage incidence of stem borer and pod borer and hairy caterpillar was given in Table 17 and Plate 6.

Stem borer incidence ranged from zero to 6.54 percent. The incidence was maximum in genotype PT 21 (6.54%) followed by PT 8, PT 17 and PT 9. In the case of pod borer, maximum percentage of incidence was recorded in PT 14 (7.26%) followed by PT 1 and PT 6.

4.1.11 Weather parameters

The weather parameters during the cropping period were presented in Appendix II and Fig. 6. The maximum temperature ranged from 28.3^{0}C to 33.3^{0}C and the minimum temperature ranged from 20.2 to 26.1^{0}C.Sun shine hours ranged from seven to 10.2 hours. The rain fall ranged from zero to 47.0 mm and relative humidity from 84.8 to 98.6 per cent.

Table 17. Incidence of pests and diseases in winged bean

Genotypes	Stem borer incidence (%)	Pod borer incidence (%)
PT 1	0.00 (1.00)	4.44 (2.33)
PT 2	0.00 (1.00)	0.00 (1.00)
PT 3	0.00 (1.00)	0.00 (1.00)
PT 4	3.43 (2.10)	0.00 (1.00)
PT 5	0.00 (1.00)	0.00 (1.00)
PT 6	0.00 (1.00)	3.99 (2.23)
PT 7	2.68 (1.91)	0.00 (1.00)
PT 8	4.48 (2.34)	0.00 (1.00)
PT 9	3.61 (2.14)	0.00 (1.00)
PT 10	0.00 (1.00)	0.00 (1.00)
PT 11	0.00 (1.00)	0.00 (1.00)
PT 12	0.00 (1.00)	0.00 (1.00)
PT 13	0.00 (1.00)	0.00 (1.00)
PT 14	2.78 (1.94)	7.26 (2.87)
PT 15	0.00 (1.00)	2.98 (1.99)
PT 16	0.00 (1.00)	0.00 (1.00)
PT 17	3.81 (2.19)	0.00 (1.00)
PT 18	0.00 (1.00)	0.00 (1.00)
PT 19	3.24 (2.06)	0.00 (1.00)
PT 20	3.43 (2.10)	0.00 (1.00)
PT 21	6.54 (2.74)	2.63 (1.90)
SEm (±)	0.13	0.09
CD (0.05)	(0.39)	(0.27)
Mean	1.61 (1.50)	1.01 (1.30)

6a. Stem borer

6b. Stem borer infested plant

6c. Pod borer

6d. Hairy caterpillar

Plate 6. Pest incidence in winged bean

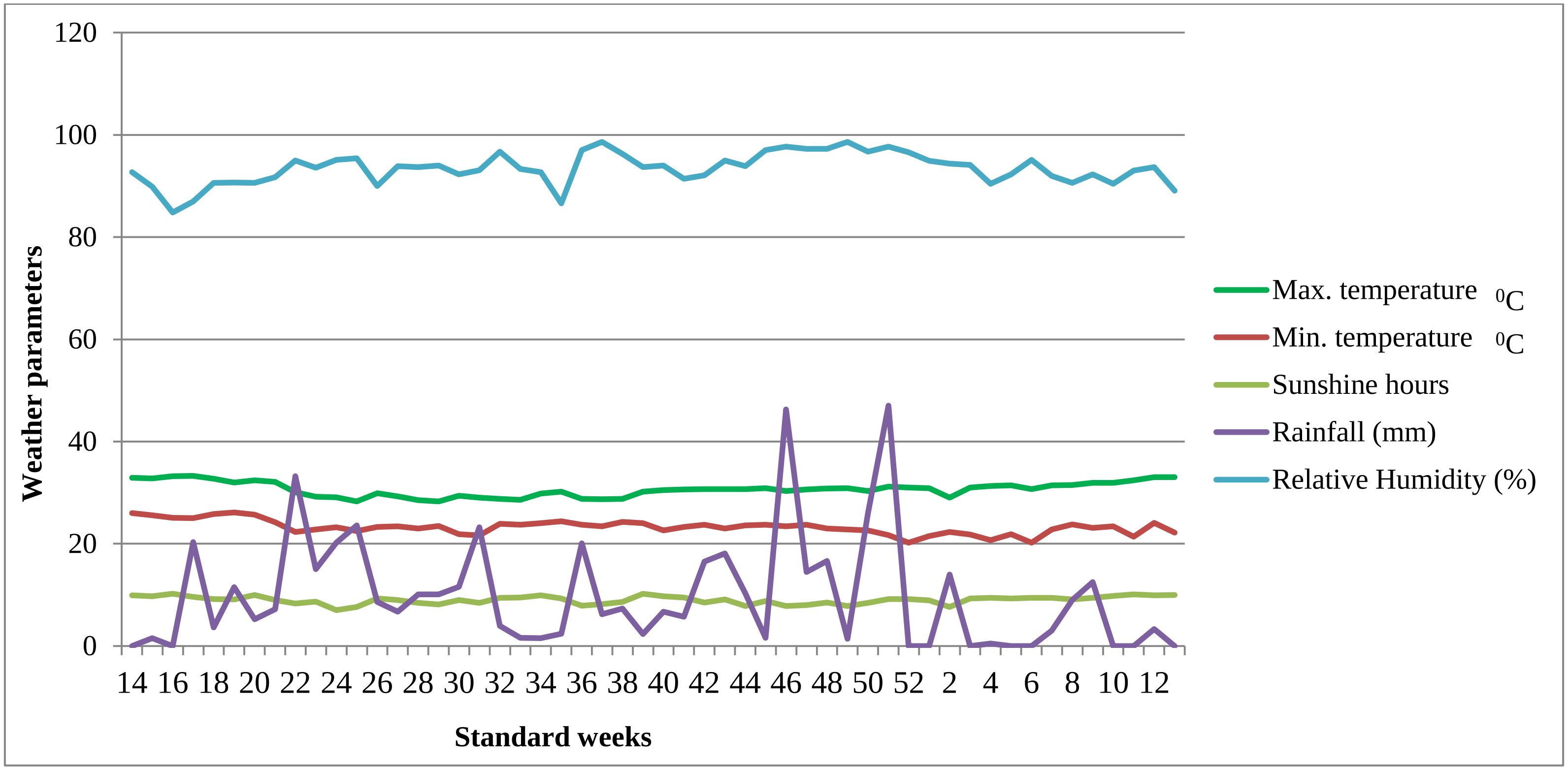

Fig. 6 Weather parameters during cropping period (April 2013 – March 2014)

DISCUSSION

5. DISCUSSION

Selection plays a vital role in crop improvement. The improvement of any crop depends on the available variability, heritability of the character, genetic advance under selection and the association among the characters. 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 source and evaluation under uniform agro-ecological conditions for effective utilization is a pre-requisite for any breeding programme. Hence, this present investigation was undertaken.

Investigations were conducted at the Department of Olericulture, College of Agriculture, Vellayani to identify photoinsensitive, high yielding and year round fruiting genotype(s) of winged bean suitable for cultivation in Kerala during the period April 2013 to March 2014. Twenty one genotypes were used for this experiment, and were laid out in RBD 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.

The experimental results are discussed under the following headings.

5.1 VARIABILITY STUDIES

An insight in to the magnitude of variability present in a crop species is of utmost importance as it provides a basis for effective selection. The observed variability in the population is the sum total of the variations that arise due to genotype and environmental effects. Hence knowledge on the nature and magnitude of genetic variation contributing the gain under selection is vital.

Analysis of variance revealed significant differences among the 21 genotypes of winged bean for all the characters studied *viz.*, days to germination, vine length, number of primary branches per plant, days to first flowering, days to 50 percent flowering, days to first harvest, days to final harvest, petiole length, terminal and lateral leaf let length, terminal and lateral leaf let width, pod length, pod girth, pod weight, number of pods per plant, yield per plant and yield per plot, seeds per pod, 100 seed weight, shelling percentage, days to edible maturity, pod fibre, number of tubers per plant, tuber weight, tuber length and girth, stem borer and pod borer incidence except quality characters like pod protein and seed protein. Such variation indicated the scope for improving the population for these characters as accounted earlier by Pan *et al.* (2005) and Nandan *et al*. (2010) in winged bean.

5.1.1 Growth and yield characters

Ample variability was observed for vegetative characters as obvious from the wide range obtained for vine length, primary branches per plant, petiole length, leaflet length etc. Considerable variability was reported by Dandannavar (2000) and Pan *et al*. (2005) in winged bean. Primary branches per plant also registered wide range of variations as reported by Mohamadali (2001) and Pan *et al*. (2005).

Yield is the most important character of a crop which varies with genotypes. In the present study, genotypes PT 21, PT 4 and PT 2 were superior for yield. PT 21 recorded earliness for flowering (75.05 days), highest yield (2703.33 g) and pods per plant (154.49). PT 20 recorded highest pod weight (22.62 g) whereas pod length was highest in PT 3 (21.88 cm) and pod girth in PT 6 (8.75 cm). The pods of PT 20 had the maximum number of seeds (15.07) and the highest shelling percentage of 58.16 per cent was recorded in PT 11. The pod protein value ranges from 2.06 per cent (PT 5) to 3.08 per cent (PT 3) with an average of 2.61 per cent. Similarly, the seed protein value ranged from 13.89 per cent (PT 1) to 17.72 per cent (PT 9) with an average of 15.93 per cent. PT 17 recorded highest pod fibre percentage of 18.33 per cent. Similar differential performance for yield and yield attributes in different genotypes of winged bean was reported by Thompson and Haryono (1980), Dutta and Gangwar (1983), Philip and Ramachandran (1986), Anju *et al.* (1999), Dandannavar (2000), Mohamadali and Madalageri (2004) and Nandan *et al.* (2010).

5.1.2 Response to photoperiod

Basically winged bean is a short day plant for flowering. These crops require short light and long dark period (10 – 14 hours of continuous dark) for the formation of flower buds. In general photoperiod varies from 11 – 14 hours *i.e.,* it is the maximum length of light period at which flower buds are developed. So the plants will not flower when the light period exceeds the critical photoperiod. The critical photoperiod required for flower induction in winged bean is 12 hours but flowers are commonly produced in 10 hour to 11 hour photoperiod (Hazra and Som, 2006).

In the present investigation, PT 21 showed earliness in flowering (75.05 days) which is followed by PT 14 (77.77 days), PT 19 (77.77 days), PT 1 (80.22 days) and PT 4 (86.55 days). Treatment PT 18 recorded the maximum days required for flowering (178.83 days) followed by PT 7 (175.22 days) and PT 9 (141.44 days). As per the present study PT 4 recorded the shortest days required for first harvest (97.13 days) followed by PT 21 (97.34 days), PT 14 (104.15 days) and PT 1 (104.76 days). PT 18 recorded longest days for first harvest (192.67 days). The harvest duration was maximum for genotypes PT 21, PT 4 and PT 1. Genotypes PT 21, PT 1, and PT 4 showed flowering and fruiting irrespective of photoperiod and temperature, also had long fruiting period (Fig. 7). The peak period of harvesting falls under short day periods *i.e.*, from September to January. Genotypes PT 18 and PT 7 recorded typical short day nature for flowering and fruiting. Flower induction was noticed in October and lasts up to February. This clearly shows that few genotypes can have the ability to flower and fruit irrespective of photoperiod and temperature. Photo insensitive winged bean which does not require specific short day conditions for flowering and pod set is mainly suitable for year round cultivation. Similar observations were made by Pan *et al.* (2004) in dolichos bean.

5.1.3 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

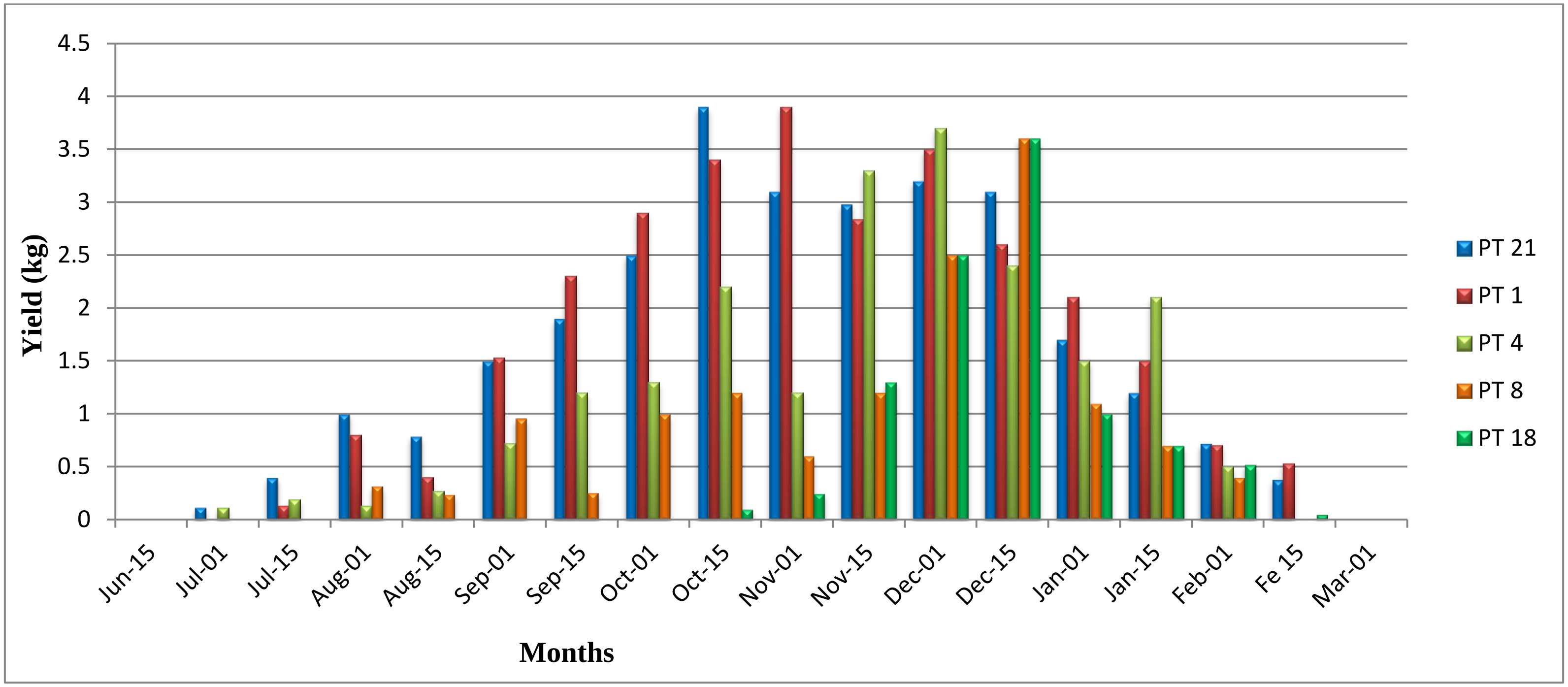

Fig. 7 Fortnightly harvest details of high yielding photoinsensitive genotypes

(PT 18- photosensitive)

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 yield per plant, pods per plant, days to first flowering, days to 50 per cent flowering and primary branches per plant. Moderate PCV and GCV were recorded for days to first harvest, seeds per pod, days to edible maturity, pod length, pod girth and pod weight. Low GCV and PCV were recorded for days to final harvest, shelling percentage, pod fibre and duration of crop. Similar results were obtained by Philip and Ramachandran (1986), Mohamadali and Madalageri (2004) in winged bean.

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 Philip and Ramachandran (1986), Seth *et al.* (1988), Dahiya *et al.* (1989), and Mohamadali and Madalageri (2004) in winged bean and Manju (2006) Madhukumar (2006) and Jithesh (2009) in yard long bean. For the foregoing discussions, it is clear that the characters *viz.*, days to first flowering, days to 50 per cent flowering, pods per plant and yield per plant offer good scope for selection in winged bean.

5.1.4 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 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 of selection based on phenotypic performance (Johnson *et al.*, 1955). Burton (1952) suggested that heritability along with GCV would provide a clear idea about the amount of genetic advance expected through selection.

In the present investigation, the heritability estimates were high for characters like days to first flowering, days to 50 per cent flowering, days to first harvest, pod girth, shelling percentage and days to edible maturity. Moderate heritability was observed for duration of crop, yield per plant, pods per plant and pod fibre. Days to germination recorded the lowest heritability. High heritability can be attributed to the greater role of additive gene and additive x additive gene action, which can be exploited by following simple selection. Similar reports have also been put forward by Mohamadali and Madalageri (2004), Nandan *et al.* (2010) in winged bean and Parmar *et al.* (2013) in dolichos bean.

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 days to 50 per cent flowering, days to first flowering, yield per plant, pods per plant, primary branches per plant, days to first harvest, yield per plot and days to edible maturity. The results are in line with the findings of Mohamadali and Madalageri (2004) and Mohamadali and Madalageri (2007). Days to final harvest, pod fibre and duration of the crop had least genetic advance.

In the present study primary branches per plant, days to first flowering, days to 50 per cent flowering, days to first harvest and yield per plot, pod weight, seeds per pod and 100 seed weight recorded high heritability coupled with high genetic advance indicates 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 Philip and Ramachandran (1986), Seth *et al*. (1988), Dahiya *et al.* (1989) and Singh and Khanna (1995). High heritability coupled with low to moderate genetic advance was observed for vine length, pod length, pod girth, and shelling percentage 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 Philip and Ramachandran (1986) and Mohamadali and Madalageri (2004) and Mohamadali and Madalageri (2007) and Nandan *et al.* (2010) in winged bean.

5.1.5 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. The genotypic correlation between characters provides a reliable measure of the genotypic association between characters and helps to differentiate the vital associations useful in breeding from non vital ones (Falconer, 1981).

In the present study significant and positive phenotypic and genotypic correlation was recorded between pods per plant, pod length, pod weight, pod girth, days to edible maturity and days to final harvest. Pandita *et al.* (1989) reported positive and significant correlation of total pod yield with total number of pods, pod weight and pod length in winged bean. Mohamadali and Madalageri (2004) also reported similar results in winged bean.

Pod weight was positively correlated with pod length and pod girth while it was negatively correlated with days to 50 per cent flowering. These results are in accordance with those of Mohamadali and Madalageri (2004). Similar results were reported by Manju (2006), Deepa and Balan (2006) and Udensi *et al.* (2012) in cowpea. Positive and high phenotypic and genotypic correlation of pod yield per plant with pods per plant implies that selection for this character would lead to simultaneous improvement of yield in winged bean. The other characters that can be taken into consideration for indirect selection for yield include pod length, pod weight and days to edible maturity.

5.1.6 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, days to first flowering, days to first harvest, days to final harvest, pod length, pod girth, pod weight and pods per plant. Pods per plant exhibited the highest positive direct effect on pod yield followed by pod length and pod girth indicating the importance of these characters in yield improvement programme. Days to first flowering and days to final harvest also exerted positive direct effect on yield.

Days to first harvest and pod weight exhibited negative direct effect on pod yield per plant. Indirect effect through pods per plant and days to first harvest were high signifying the importance of these characters.

The high direct effect of pods per plant on yield is in accordance with earlier findings of Pandita *et al.* (1989) in winged bean and Dahiya *et al.* (1991), Basavarajappa and Byre Gowda (2004) in dolichos bean.

The residue was 0.153 indicating that selected eight characters contributed the remaining 85 percent. The result goes in parallel with the study of Mohamadali (2001).

5.1.7 Genetic divergence analysis

Generally geographical diversity was considered as a measure of genetic diversity when no scientific tools were available. However, this is an inferential criterion and may not be useful for discrimination among the populations occupying ecologically marginal habitats.

The multivariate analysis using Mahalanobis' D^2 statistic provides a useful statistical tool for measuring the genetic diversity in germplasm collections with respect to the characters considered together. It also provides a quantitative measure of association between geographic and genetic diversity based on generalized distance. Further, the problem of selecting diverse parents for hybridization programme can be narrowed, if one can identify the characters responsible for the discrimination between the populations.

Following Mahalanobis' D^2 statistic (Mahalanobis, 1936), the 21 genotypes were grouped into five clusters. The greater the distance between two clusters, greater is the divergence between the accessions belonging to the two clusters and vice versa. Cluster III had the maximum number of genotypes (six), followed by cluster I and cluster II (five each). Cluster IV had only one genotype and cluster V with four genotypes.

In the present study the intracluster distance was maximum for cluster IV followed by cluster III indicating that some divergence still existed among the genotypes. Maximum divergence was observed between cluster II and cluster V as shown by their high intercluster distance suggesting that the crosses involving varieties from these clusters would give desirable recombination. The minimum divergence between cluster I and cluster III indicated a close relationship among the genotypes.

Considering cluster means for various characters cluster I was superior and cluster IV was generally poor, whereas cluster II and III was intermediate for most of the characters. Intercrossing among genotypes with better mean performance for various characters will be useful for further crop improvement in winged bean.

Grouping of genotypes in to various clusters did not reflect the geographical origins of the varieties. Similar results were reported by Chaudhary *et al.* (2004), Arora *et al.* (2005), Singh *et al.* (2005) and Anandhi and Sunny (2006) in cluster bean and Mahto and Dua (2009) in winged bean.

5.1.8 Selection index

Selection of genotypes 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. Vine length, days to first flowering, days to first harvest, days to final harvest, pod length, pod girth, pod weight, pods per plant, yield per plant and tubers per plant were used for constructing selection index.

Based on the selection index values, top ranking genotypes *viz.*, PT 21 (24799.37), PT 6 (23324.76), PT 1(23165.18), PT 4 (23085.51) and PT 7 (22739.01) were identified as superior ones in terms of yield and may be recommended as elite types after refinement and multilocation trails. Identification of superior accessions of vegetable cowpea based on discriminant function analysis was done by Manju (2006), Jithesh (2009) and Sivakumar (2012).

5.1.9 Genetic cataloguing

Genetic cataloguing based on standard descriptors helps to easily describe the morphological features of a genotype and thus helps exchange of information about new genotypes in a clear way. This also helps in locating some genotypes with specific morphological characters which can be used for crop improvement.

Twenty one winged bean genotypes upon cataloguing showed distinct variation among each other with respect to vegetative, flower, fruit, seed and tuber characters. All the genotypes had climbing habit with green to purple stem. Flower colour varied from light blue shades to dark blue. Pod shape and wing colour showed wide variation among the genotypes. Seed colour also showed considerable variation between the genotypes. Out of the 21 genotypes six genotypes produce tuber.

Cataloguing in vegetable cowpea was previously attempted by Manju (2006) and Sivakumar (2012).

5.2 SCREENING FOR PESTS AND DISEASES

Stem borer and pod borer incidence was noticed during the cropping period along with few minor pests (Plate 6.) and in general, incidence was very meager in all the genotypes. There was no pronounced yield reduction recorded due to pest and disease infestation. Similar result on stem borer infestation was also reported by Wright and Hunt (2011) in soybean and pod borers by Patel *et al.* (2010) in cowpea.

In the present investigation efforts were made to identify genotype(s) showing flowering and fruiting irrespective of photoperiod and temperature. The 21 genotypes showed wide variation for almost all the characters studied. Genotype PT 21 showed earliness for flowering (75 DAS) followed by PT 14 and PT 19. Based on these observations the genotypes were classified into photo insensitive (PT 1, PT 2, PT 4, PT 6, PT 8, PT 14, PT 19, PT 21) and photo sensitive (PT 3, PT 5, PT 7, PT 9, PT 10, PT 11, PT 12, PT13, PT 15, PT 16, PT 17, PT 18) genotypes. This shows that few genotypes can have the ability to flower and fruit throughout the year and can be utilised for developing types suitable for year round cultivation.

SUMMARY

6. SUMMARY

The present investigation was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during 2013-2014. The study aims at identification of photo insensitive, high yielding and year round fruiting genotype(s) of winged bean suitable for cultivation in Kerala.

The twenty one genotypes of winged bean collected from different parts of Kerala and state agricultural universities were evaluated for yield and yield attributes in randomised block design with three replications. The genotypes 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.

Analysis of variance revealed that the genotypes under study differed significantly for almost all the characters studied except quality characters like pod protein and seed protein content.

The assessed germplasm had sufficient variability and offered scope for selection based on characters like vine length, days to first flowering, days to first harvesting, pod length, pod girth, pod weight and pods per plant.

The genotype PT 21 showed earliness for flowering (flowering commences in 75 DAS *i.e.,* in June which receives long photoperiod) followed by PT 14 and PT 19. Also the genotypes PT 21, PT 1 and PT 4 showed prolonged harvest up to February irrespective of photoperiod and temperature. These genotypes recorded maximum yield and the peak period of harvest falls under short day periods (September – January). Genotypes PT 18 and PT 7 showed typical short day nature for flowering and flowering was observed from first week of October to February.

High values of phenotypic coefficient of variation and genotypic coefficient of variation were observed for yield per plant, pods per plant, days to first flowering, days to 50 per cent flowering and primary branches per plant where as moderate values for both PCV and GCV were recorded for days to first harvest, seeds per pod, days to edible maturity, pod length, pod girth and pod weight. The lowest GCV and PCV were recorded for days to final harvest, shelling percentage, pod fibre and duration of crop.

High GCV and PCV indicate the presence of high degree of genetic variation and ample scope for improvement of these characters through selection. Narrow difference between GCV and PCV suggests that environmental influence is minimal for the traits studied.

Heritability estimates were high for days to 50 per cent flowering, days to first harvest, days to first flowering, shelling percentage, pod girth and days to edible maturity. High heritability coupled with high genetic advance was observed for characters like vine length, days to first flowering, days to 50 per cent flowering, days to first harvest and days to final harvest suggesting additive gene action for these traits and hence simple and early selection will be effective.

Correlation studies revealed that at both phenotypic and genotypic levels characters like pods per plant, pod length, pod weight, pod girth, days to edible maturity and days to final harvest had significant and positive correlation with yield indicating that selection for these characters may improve yield.

Path coefficient analysis indicated that pods per plant exhibited the highest positive direct effect on pod yield followed by pod length, pod girth, days to first flowering and days to final harvest whereas pod length, pod girth and pods per plant recorded high indirect effect which signifies the importance of these characters.

Genetic divergence analysis showed appreciable divergence among the twenty one genotypes of winged bean. The clustering pattern indicated that cluster III had the maximum number of genotypes (six) followed by cluster I and II with five genotypes each and cluster IV consist of one genotype and cluster V with four genotypes. The maximum divergence was noticed between cluster II and cluster V while the closer proximity existed between cluster I and cluster III.

Cluster mean values obtained suggest that lowest cluster mean for days to first flowering and days to first harvesting was manifested in cluster I, also showed highest cluster mean for days to final harvest, days to edible maturity, pod length, pod girth, pod weight, pods per plant and yield per plant. In general, genotypes of cluster I showed earliness for flowering and harvesting and genotypes of cluster IV were both late flowering and late harvesting types.

Selection index was worked out based on ten characters for identifying superior genotypes. The genotype PT 21 (Nemom collection) from cluster I recorded the highest index value followed by PT 6 (local collection, Munnar) from cluster III and PT 1 (Parassala collection) from cluster I.

The accessions were genetically catalogued based on the descriptor list for winged bean. The result revealed distinct variations among the genotypes for vegetative, inflorescence, fruit, seed and tuber characters.

Present investigation showed that the crop was free from major pest and diseases. The incidence was recorded for stem borer, pod borer and few minor pests. The percentage incidence was less than ten percent.

Comparison among the genotypes for various biometric characters clearly showed that PT 21, PT 1, PT 4 and PT 6 as promising genotypes based on their photoinsensitive nature and superiority in yield and other yield contributing characters. These may be used for further crop improvement programmes for developing photoinsensitive and high yielding varieties suited for year round cultivation in Kerala.

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APPENDICES

APPENDIX- I

Descriptors for morphological cataloguing of winged bean genotypes

4.1 Vegetative characters

4.1.1 Plant growth: 3 Sparse / 5 Moderate / 7 Abundant

4.1.2 Leaflet size: 3 Small / 5 Medium / 7 Large

4.1.3 Leaflet shape: 1 Ovate / 2 Deltoid / 3 Ovate-lanceolate / 4 Lanceolate / 5 Long lanceolate

4.1.4 Stem colour: 1. Green / 2 Greenish purple / 3 Purple / 4 Other (specify)

4.1.5 Presence of tuber: 0 Absent / + Present

4.1.6 Tuber size: 3 Small (< 2 cm) / 5 Medium (2-3 cm) / 7 Large (> 3 cm)

4.2 Inflorescence and fruit characters

4.2.1 Calyx colour: 1 Green / 2 Greenish purple / 3 Purple / 4 Other (specify)

4.2.2 Corolla colour of wings and standard: 1 White / 2 Light blue / 3 Blue / 4 Other (specify)

4.2.3 Pod colour: 1 Cream / 2 Green / 3 Pink / 4 Purple / 5 Other (specify)

4.2.4 Presence of pod specks: 0 Absent / + Present

4.2.5 Pod wing colour: 1 Green / 2 Purple / 3 Other (specify)

4.2.6 Pod surface texture: 3 Smooth / 5 Medium / 7 Rough

4.2.7 Pod shape: 1 Rectangular / 2 Semi-flat / 3 Flat on sides / 4 Flat on suture

4.3 Seed characters

4.3.1 Seed colour: 1 Cream / 2 Tan / 3 Brown / 4 Purple / 5 Black / 6 Brown-black/ 7 Other (specify)

4.3.2 Presence of seed mottling: 0 Absent / + Present

4.3.3 Hilum colour: 1 White / 2 Black / 3 Other (specify)

4.3.4 Seed shape: 1 Round / 2 Oval / 3 Other (specify)

4.3.5 Seed surface: 1 Smooth / 2 Wrinkled

APPENDIX - II

Weather data for the cropping period

(April 2013 to March 2014)

Standard week	Temperature (^oC)		Sunshine hours	Rainfall (mm)	Relative Humidity (%)
	Maximum	Minimum			
14	32.9	26.0	9.9	0.0	92.7
15	32.8	25.6	9.7	1.5	89.9
16	33.2	25.1	10.2	0.0	84.8
17	33.3	25.0	9.6	20.3	87.0
18	32.7	25.8	9.2	3.6	90.6
19	32.0	26.1	9.1	11.5	90.7
20	32.4	25.7	10.0	5.2	90.6
21	32.1	24.2	9.0	7.2	91.7
22	30.1	22.3	8.3	33.2	95.0
23	29.2	22.8	8.7	15.0	93.6
24	29.1	23.2	7.0	20.2	95.1
25	28.3	22.5	7.6	23.6	95.4
26	29.9	23.3	9.3	8.6	90.0
27	29.3	23.4	9.0	6.7	93.9
28	28.5	23.0	8.4	10.1	93.7
29	28.3	23.5	8.1	10.1	94.0
30	29.4	21.9	9.0	11.6	92.3
31	29.0	21.6	8.4	23.2	93.1
32	28.8	23.9	9.4	3.9	96.7
33	28.6	23.7	9.5	1.6	93.3
34	29.8	24.0	9.9	1.5	92.7
35	30.2	24.4	9.3	2.4	86.6
36	28.8	23.7	7.9	20.1	97.0
37	28.7	23.4	8.2	6.2	98.6
38	28.8	24.3	8.6	7.3	96.3
39	30.2	24.0	10.2	2.3	93.7
40	30.5	22.6	9.7	6.7	94.0

Standard week	Temperature (^{o}C)		Sunshine hours	Rainfall (mm)	Relative Humidity (%)
	Maximum	Minimum			
41	30.6	23.3	9.5	5.7	91.4
42	30.7	23.7	8.5	16.5	92.1
43	30.7	23.0	9.1	18.1	95.0
44	30.7	23.6	7.8	10.3	93.9
45	30.9	23.7	8.8	1.6	97.0
46	30.3	23.4	7.8	46.3	97.7
47	30.6	23.7	8.0	14.5	97.3
48	30.8	23.0	8.5	16.6	97.3
49	30.9	22.8	7.8	1.4	98.6
50	30.3	22.6	8.4	26.0	96.7
51	31.2	21.7	9.2	47.0	97.7
52	31.0	20.2	9.2	0.0	96.6
1	30.9	21.5	8.9	0.0	94.9
2	29.0	22.3	7.6	14.0	94.4
3	31.0	21.8	9.3	0.0	94.1
4	31.3	20.7	9.4	0.5	90.4
5	31.4	21.9	9.3	0.0	92.3
6	30.7	20.2	9.4	0.0	95.1
7	31.4	22.8	9.4	3.0	92.0
8	31.5	23.8	9.1	9.0	90.6
9	31.9	23.1	9.4	12.5	92.3
10	31.9	23.4	9.8	0.0	90.4
11	32.4	21.4	10.1	0.0	93.0
12	33.0	24.1	9.9	3.3	93.7
13	33.0	22.2	10.0	0.0	89.1

IDENTIFICATION OF PHOTO INSENSITIVE GENOTYPE(S) OF WINGED BEAN (*Psophocarpus tetragonolobus* (L.) DC.)

by

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ABSTRACT

The present investigation entitled “Identification of photoinsensitive genotype(s) of winged bean (*Psophocarpus tetragonolobus* (L.) DC.)” was conducted at the Department of Olericulture, College of Agriculture, Vellayani, during 2013-2014. The study envisaged identification of photo insensitive, high yielding and year round fruiting genotype(s) of winged bean suitable for cultivation in Kerala.

Twenty one genotypes of winged bean were collected from different parts of Kerala, state agricultural universities and available germplasm of the Department of Olericulture, College of Agriculture, Vellayani were grown in the field in RBD with three replications.

Analysis of variance showed significant difference between the genotypes for almost all the characters studied. Among the genotypes, PT 21 recorded earliness for flowering, flowering commences in June (75 DAS) and had highest yield (2703.33 g) and pods per plant (154.49). This is followed by PT 14 and PT 19. Also the genotypes PT 21, PT 1 and PT 4 showed prolonged harvest up to February, irrespective of photoperiod and temperature. The genotypes PT 18 and PT 7 showed typical short day nature *i.e.*, the flowering was recorded in October.

High phenotypic and genotypic coefficients of variation were observed for most of the yield contributing characters. High heritability coupled with high genetic advance was observed for characters like primary branches per plant, days to first flowering, days to 50 per cent flowering, days to first harvest and yield per plot, pod weight, seeds per pod and 100 seed weight. The highest phenotypic and genotypic correlation with yield was observed for pods per plant. The path analysis revealed that pods per plant exhibited the highest positive direct effect on pod yield followed by pod length and pod girth.

The twenty one genotypes were grouped in to five clusters based on Mahalanobis D^2 analysis. Cluster III was the largest with six genotypes followed by cluster I and II with five genotypes each. Cluster IV had only one genotype

and cluster V with four genotypes. The intercluster distance was maximum between cluster II and cluster V where as it was minimum between the cluster I and cluster III.

The selection indices were worked out for twenty one genotypes based on yield and yield attributing characters. Genotype PT 21 (Nemom collection) was ranked first followed by PT 6 (local collection, Munnar), PT 1 (Parassala collection), PT 4 (Anchal collection) and PT 7 (local collection, Palakkad).

Genotypes PT 21, PT 1, and PT 4 showed photoinsensitivity *i.e.,* flowering and fruiting irrespective of photoperiod and had long fruiting period.

On the basis of the present study PT 21, PT 1 and PT 4 were identified as the high yielding, photoinsensitive genotypes suitable for year round cultivation and can be utilized for further crop improvement programmes.

സംഗ്രഹം

“വർഷം മുഴുവൻപൂക്കുകയുംകായ്ക്കുകയുംചെയ്യുന്നചതുരപയർ(സോഫോകാർപസ്ടെട്രഗോണൊലോബസ്)ഇനംഉരുത്തിരിച്ചെടുക്കൽ”എന്നനിരീക്ഷണംവെള്ളായണികാർഷികകോളേജിലെഒളരികൾച്ചർ വിഭാഗത്തിൽഏപ്രിൽ2013മുതൽമാർച്ച്2014വരെയുള്ളകാലഘട്ടത്തിൽനടത്തി.

കേരളത്തിൽവർഷംമുഴുവൻകൃഷിചെയ്യാൻയോജിച്ചവിളവുകൂടിയചതുരപയർഇനംഉരുത്തിരിച്ചെടുക്കുകഎന്നതായിരുന്നുഈപഠനത്തിൻറെഉദ്ദേശ്യം

പലസ്ഥലങ്ങളിൽനിന്നുംശേഖരിച്ച21ചതുരപയർഇനങ്ങളുപയോഗിച്ച്RBDഎന്നരീതിയിൽമൂന്ന്ആവർത്തനങ്ങളായാണ്ഈപരീക്ഷണംനടത്തിയത്.

PT21എന്നഇനംവിത്ത്ഇട്ട്75ദിവസംകൊണ്ട്പൂക്കുന്നതായുംനേരത്തേവിളവ്ലഭിച്ചുതുടങ്ങിയതായുംനിരീക്ഷണത്തിലൂടെകണ്ടെത്തി.ഇതുകൂടാതെമറ്റുചിലഇനങ്ങളായPT1,PT4മുതലായവയുംനേരത്തേപൂക്കുകയുംകായ്ക്കുകയുംചെയ്യുന്നഇനങ്ങളാണെന്ന്ണ്ടെത്തുകയുണ്ടായി.ഇതോടൊപ്പംതന്നെഈഇനങ്ങൾമികച്ചവിളവ്തരുന്നതായുംതുടർച്ചയായികൂടുതൽകാലംവിളവ്നീണ്ടുനിൽക്കുന്നതായുംനിരീക്ഷണത്തിലൂടെകണ്ടെത്തി.

എന്നാൽPT18,PT7എന്നിവചിലപ്രത്യേകസമയങ്ങളിൽമാത്രംപൂക്കുന്നഇനങ്ങളാണെന്ന്കണ്ടെത്തി.ഒക്ടോബർമുതൽഫെബ്രുവരിവരെയുള്ള മാസങ്ങളിലാണ്ഇവപുഷ്പിക്കുന്നത്.

ചതുരപയർഇനങ്ങളുടെവ്യത്യസ്ഥതാപഠനത്തിനായികോഎഫിഷ്യൻസ്ഓഫ്വേരിയേഷൻ,ഹെറിറ്റബിലിറ്റി,ജെനെറ്റിക്അഡ്വാൻസ്,കോറിലേഷൻ,പാത്ത്അനാലിസിസ്,സെലെക്ഷൻഇൻഡക്സ്,ക്ലസ്റ്റർഅനാലിസിസ്തുടങ്ങിയരീതികൾഅവലംബിച്ചു.ഇതിലൂടെശിഖരങ്ങളുടെഎണ്ണം,പൂക്കുന്നതിനാവശ്യമായദിവസങ്ങൾ,ആദ്യവിളവ്,കായയുടെതൂക്കം,വിത്തുകളുടെഎണ്ണം,100വിത്തുകളുടെതൂക്കംഎന്നിവവിളവുമായിഅനുബന്ധപെട്ടിരിക്കുന്നതായികണ്ടെത്തി.

കാര്യമായരോഗകീടബാധകളൊന്നുംനിരീക്ഷണസമയങ്ങളിൽചതുരപയറിൽകണ്ടെത്തെയില്ല.

ഈനിരീക്ഷണത്തിലൂടെPT21,PT1, PT4എന്നീഇനങ്ങൾഏത്കാലാവസ്ഥയിലുംപൂക്കുന്നവയുംനല്ലവിളവ്നല്കുന്നവയാണെന്നുംആയതിനാൽകേരളത്തിൽവർഷംമുഴുവൻകൃഷിചെയ്യാൻയോജിച്ചഇനങ്ങളാണെന്നുംകണ്ടെത്തി.