GENOTYPE X ENVIRONMENT INTERACTION IN BLACKGRAM (*Vigna mungo* L. Hepper)

by
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(2012-11-201)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Genotype x Environment interaction in blackgram (*Vigna mungo* L. Hepper)"** is a bonafide record of research done by me during the course of study and the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Genotype x Environment interaction in blackgram (*Vigna mungo* L. Hepper)"** is a record of research work done independently by **Gambhire Vilas Bhagwat (2012 - 11 - 201)** 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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ABBREVIATIONS

AMMI: Additive main effects and multiplicative interaction

E1 : Environment 1

E2 : Environment 2

E3 : Environment 3

E4 : Environment 4

E5 : Environment 5

E6 : Environment 6

Fig : Figure

F_7 : Seven filial generation

F_8 : Eight filial generations

F_9 : Nine filial generation

G : Genotype

GA : Genetic advance

G x E : Genotype x Environment

GCV : Genotypic Coefficient of Variation

H^2 : Heritability

IPCA1: Interaction Principal Component Analysis 1

IPCA2: Interaction Principal Component Analysis 2

PCV : Phenotypic Coefficient of Variation

Introduction

1. INTRODUCTION

Blackgram (*Vigna mungo* (L.) Hepper) is an important pulse crop occupying unique position in Indian agriculture. The pulse 'blackgram' plays an important role in Indian diet, as it contains vegetable protein and supplement to cereal based diet. It provides a major share of the protein requirement of the vegetarian population of the country. The grains contain about 26 per cent protein, which is almost three times that of cereals and also another minerals and vitamins. In addition, it is an important source of animal feed. The crop is resistant to adverse climatic conditions and hence, can be cultivated in many situations where other crops fail. Blackgram is cultivated as a catch crop under the residual moisture after the harvest of main crop. Being a crop which fixes atmospheric nitrogen, it improves the soil fertility also (Kanade, 2006).

Although the crop is important in many ways, the relative improvement of blackgram is limited by lack of variability for the components of seed yield particularly pod length, pod number and seed mass (Kajjidoni *et al.*, 2009). Its cultivation in India is about 3.25 million hectares and annual production is 1.45 million tons. National productivity of black gram is alarmingly reduced to around 500 kg/ha (Pawar, 2001). Unfortunately, unlike those of cereals, the existing production level of pulses does not meet the emerging demands.

In Kerala, cultivation of pulses especially black gram as third crop i.e., in summer fallows in paddy growing areas was a common practice by the farmers. However, this trend has come down in the near past due to non availability of labourers for harvesting and low yield of traditional varieties.

The systematic collection of black gram has displayed inadequate variability for biotic and abiotic genes. It is possible that genes for high productivity could have been lost due to overriding role of natural selection (Roopalakshmi *et al.*, 2003) and the genetic base of the present day collection remains poor (Delannay *et al.*, 1983) due to lack of variability owing to its autogamaous nature.

The creation of variability is difficult through hybridization due to its high self-pollination and flower drop (Deepalakshmi and Anandakumar, 2004). The major constrains in achieving higher yield of black gram is absence of suitable ideotypes for different cropping systems and environments, poor harvest index and susceptibility to diseases (Souframanien and Gopalakrishnan, 2004). The low production levels of pulses can be attributed to the inherently low levels of productivity in the pulse crops. Eventhough pulses are very important crops used widely in India; there are no significant breakthroughs in the yield levels of pulses (Brahmaprakash *et al.*, 2004).

Lack of suitable varieties and genotypes with adaptation to local conditions are important among the factors affecting the significant decline in the pulse production in India. Genotype x Environment interaction is an important and essential component of plant breeding programs dedicated to cultivar development (Natarajan, 2001). According to Shanthi *et al.* (2007), though several improved varieties in black gram have been developed, most of them show inconsistent performance under varied environmental conditions due to genotype x environment interaction.

Hence, the present study is an attempt to assess the genotype x environmental interaction in black gram cultures which are developed by pure line selection from segregating generation of inter varietal crosses.

Review of literature

2. REVIEW OF LITERATURE

Blackgram (*Vigna mungo* (L.) Hepper) is an important pulse crop occupying unique position in Indian agriculture. Black gram provides a major share of the protein requirement of the vegetarian population of the country. The crop is resistant to adverse climatic conditions and improves the soil fertility by fixing atmospheric nitrogen in the soil (Kanade, 2006). National productivity of black gram is very low remaining around 500 kg ha^{-1}(Pawar, 2001). The systematic collection of black gram has displayed inadequate variability for biotic and abiotic stress genes. The creation of variability is difficult through hybridization due to its high self-pollination and flower drop (Deepalakshmi and Anandakumar, 2004). Besides, the major constrains in achieving higher yield of black gram are absence of suitable ideotypes for different cropping system, poor harvest index and susceptibility to disease (Souframanien and Gopalakrishnan, 2004).

The research programme entitled "Genotype x environment interaction in black gram (*Vigna mungo* (L.) Hepper)" was conducted at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period August 2012 - December 2014 and the relevant literature on various aspects of the research in blackgram is reviewed in this chapter.

2.1. Genetic variability in blackgram

Genotype x environment interaction, an important source of phenotypic variation, is of great importance in the development and evolution of plant cultivars. As it is under the control of genes, the breeders are able to select suitable genotypes in advance generations by growing them under different environmental conditions. According to Pervin *et al.* (2007), the assessment of variability is important to find the genotype x environmental interaction in black gram.

Parameswarappa *et al.* (1989), has observed wide range of variability in blackgram genotypes and the magnitude of variability differed in different seasons. Ghafoor *et al.* (1998), has studied pod length and seeds per pod in blackgram and observed that those traits do not exhibit much genetic variation which is associated with narrow genetic base.

Nataranjan and Rathinasamy (1999) reported that the genotypic coefficient of variation and phenotypic coefficient of variation estimates were higher for grain yield per plant (GCV=17.1%, PCV=35.9%), whereas lower for days to maturity (GCV=1.6 %, PCV=2.0 %).

Ghafoor *et al.* (1998), observed high variance for days to maturity, branches per plant, pods per plant, biological yield per plant, grain yield per plant and harvest index. For other characters *viz.*, pod length, seeds per pod and 100-seed weight, low variance was observed.

Studies by Ghafoor *et al.* (2001), reported medium to high variance for days to maturity, number of branches, number of pods, pod length, biomass and grain yield in blackgram. Low genetic variance was observed for other characters, including number of seeds per pod, 100-seed weight and harvest index.

Priti *et al.* (2006), indicated the existence of considerable amount of variability in blackgram for all the characters studied except pod length, number of seeds per pod, 100-seed weight and protein content. The yield per plant exhibited highest values of genotypic and phenotypic coefficient of variation (GCV and PCV).

According to Pervin *et al.* (2007), the highest phenotypic variation was observed for plant height at first flowering (PHFF), while the lowest phenotypic variation was observed for number of branches at maximum flowering in blackgram. The highest and the lowest genotypic variation were recorded in PHFF and number of pods per plant, respectively.

Ali *et al.* (2008), concluded that the diversity in black gram genotypes for yield and yield attributing characters may be due to early maturity, number of cluster per plant, pod per plant and pod length.

Konda *et al.* (2008), revealed highly significant variation among the blackgram genotypes for all the traits. The traits were days to fifty percent flowering, plant height, branches per plant, clusters per plant, pods per plant, seeds per pod, pod length, length of reproductive period, 100-seed weight, grain yield per plant and protein per cent.

Gandhi *et al.* (2012), observed that genotypic coefficient of variation and phenotypic coefficient of variation and heritability were significantly high for characters like plant height, number of branches per plant, days taken for first flowering, clusters per plant, pods per plant, seeds per pod, seed yield per plant, 100-seed weight, protein and amino acid content. The highest estimates of GCV were recorded for days to maturity followed by cluster per plant, pods per plant, pod bearing branches and 100-seed weight.

Sowmini and Jayamani, (2013) in black gram reported higher estimates of PCV for all the traits compared with GCV. However, GCV was found to be high for the traits single plant yield, number of clusters per plant and number of pods per plant.

Panigrahi *et al.* (2014), observed wide range of variation for ten yield attributing characters in black gram and based on the variation they grouped the genotypes in to twelve clusters.

Higher estimates of PCV were observed for all the traits, when compared with GCV. High estimates of PCV and GCV was observed for primary branches per plant, number of clusters per plant, number of pods per plant and single plant yield as reported by Ramya *et al.* (2014).

2.2. Heritability and Genetic advance in blackgram

Majid *et al.* (1982), found highest genetic advance(GA) and GA as percent of mean for number of pods per plant. Patil and Narkhede (1987) reported high heritability and high expected genetic advance for yield per plant, pod length and plant height in black gram.

Priti *et al.* (2006), reported that high estimates of heritability (broad sense), and genetic advance was observed for number of branches per plant, number of clusters per plant, number of pods per plant and yield per plant. The heritability and genetic advance as percentage of mean for ten characters were estimated based on genetic components derived from diallel analysis involving 10 homozygous parents of diverse origin by Singh and Singh, (2006). The heritability ranged from 1.70 to 46.48 per cent in F_1 and 19.85 to 58.69 per cent in F_2. High estimates of heritability (>30 per cent) were recorded for days to flower, maturity and plant height in both F_1 and F_2 while the test weight, grain yield per plant and protein content exhibited high heritability only in F_2 generation. Moderate 10 to 30 per cent heritability was observed for pod length, seeds per pod and harvest index in F_1 and F_2 generations. The genetic advance over the mean of respective traits were maximum for plant height followed by days to flower, harvest index, protein content and days to maturity.

Reddy *et al.* (2011), reported that heritability in broad sense was high for all the characters except for number of seeds per pod and pod length. High heritability coupled with high genetic advance as per cent mean was observed for plant height, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant.

The moderate heritability and expected genetic advance as percentage of mean in respect of pod number, plant height and yield per plant in blackgram was observed by Majumder *et al.* (2011).

High heritability along with high genetic advance was recorded for all quantitative traits as reported by Gandhi *et al.*, (2012). The heritability estimates for most of the characters under study were high except for plant height, number of clusters per plant and yield per plant.

According to Sowmini and Jayamani (2013), high genetic advance as per cent of mean was recorded for plant height, number of clusters per plant, number of pods per plant, single plant yield and hundred seed weight. High heritability coupled with high genetic advance as per cent of mean was observed for hundred seed weight.

High heritability per cent and high genetic advance as percentage of mean was found for number of primary branches and seed yield per plant by Ramya *et al.* (2014).

2.3. G x E interaction in blackgram

G x E interactions are of immense importance to the plant breeders in developing improved varieties by comparing them over a series of environments revealing that differences in the relative rankings (Eberhart and Russell, 1966).

Yadav and Kumar (1983), conducted stability analysis of yield and six yield related characters in 31 cultivars of *Vigna mungo* and indicated that the different stability parameters were independent of one another. Early-flowering varieties with low yield were the most stable. The population as a whole showed low stability for yield.

Yadav and Tomar (1985), reported that location as well as the sowing date influenced the protein content in blackgram. Location effect was more pronounced and protein content was higher in the late sown crop. The genetic variability for protein was exploitable with both linear and non-linear components of genotype x environment interaction.

Mishra (1990), studied genotype by environment interaction and stability in twenty one black gram genotypes grown during summer, *kharif* and *rabi* seasons.

The genotype x environment interaction was highly significant indicating differential performance of the genotypes under varied environments.

Stability for seed yield was evaluated in 21 black gram genotypes grown in 4 environments (seasons) during 1995-97 at Vamban. Analysis of variance for stability of seed yield showed significant differences amongst the genotypes. Nine genotypes showed stability for seed yield, with VBG42 (513 kg/ha), VBG51 (526 kg/ha), VBG52 (604 kg/ha) and VBG57 (499 kg/ha) outyielding control Vamban 2 (426 kg/ha). These results combined with genotype grouping indicated that VBG42, VBG52 and VBG57 were the most superior genotypes (Manivannan, 1999).

Patil and Narkhede, (1995) studied 14 genotypes in five environments and observed significant genotype x environment interactions.

The genotype-environment interaction for grain yield per plant was studied in ten black gram genotypes under six diverse environments. Significant differences among the genotypes and the environments indicated the presence of variability among the genotypes as well as environments (Zubair *et al.*, 2002). The genotype '9010' showed the highest average yield and lesser sensitivity to environmental changes.

According to Prakash (2006), in blackgram genotype x environment interactions was highly significant for hundred seed weight and pod length.

Shanthi *et al.* (2007) evaluated twenty blackgram genotypes over three seasons from Rabi 2001, 2003 and Kharif 2002. Out of these entries, nine entries *viz.*, VBG 23, VBG 62, VBG 69, VBG 71, VBG 73, VBG 81, VBG 89, VBG94 and VBN (Bg) 4 were having higher yield per plant and lower CV values. Out of these VBG 89, VBN (Bg) and VBG 62 have recorded higher mean yield per plant, average responsiveness to season and stability.

Pervin *et al.* (2007), reported genotype x environment interaction with twenty four lines of blackgram for yield contributing characters *viz.,* number of pods per plant, pod weight, pod length and seed weight per plant. Wide range of variabilitiy was oserved for all these traits. Joint regression analysis revealed that G x E interaction was significant for plant height at first flower and number of pods per plant.

Konda *et al.* (2009), observed that all the genotypes in blackgram had significant S^2di value indicating unstable nature for protein content. They were unstable for character across the environments though few cultivars were identified with higher protein content of 24-25 per cent.

Babu *et al.* (2009), by using Eberhart and Russel model observed non significant G x E interaction for days to flowering and maturity, plant height, number of branches and pods, pod length, 1000-seed weight and protein content based on the study in 12 blackgram genotypes under six environments. Significant G x E interaction was observed for number of seeds per pods and seed yield. By AMMI analysis they observed that three genotypes are stable for seed yield.

Saikat *et al.* (2009), reported that morphological and seed protein variations in 12 blackgram genotypes from the eastern, northern, and southern parts of India. The morphological response of the genotypes over two years (2006 and 2007) in four consecutive environments (*rabi* and *kharif*) revealed three clusters with overlapping genotypes.

Rao (2011), reported significant variance arising from genotype and genotype x environment in blackgram. The mean sum of squares for genotypes was significant over the environments for grain yield and yield contributing traits like pods per plant and 100 seed weight revealing the presence of genetic variability among the genotypes. Significant mean sum of squares due to genotype x environment (G x E) interactions indicated that the genotypes interacted with the environment conditions. Both linear and non linear components of G x E interactions were significant showing the importance of linear and nonlinear components in expression for all the traits.

Eleven genotypes of black gram were tested at three locations to study their yield stability. The genotype-environment interaction and both variance due to genotypes and environments were significant. The partitioning of G x E interaction into linear and non-linear components indicated that both predictable and unpredictable components shared the interaction (Revanappa *et al.*, 2011).

Highly significant differences were observed over environments for traits namely, plant height, number of branches per plant, number of cluster per plant, number pods per plant in black gram and indicated the divergence among growing environments (Senthilkumar and Chinna, 2012).

Senthilkumar and Chinna, (2012), evaluated thirty five black gram genotypes over three diverse environments. The mean square due to G x E interaction (linear) was significant for plant height, number of branches per plant, number of clusters per plant, number of pods per plant and seed yield per plant. Highly significant mean squares was observed for pooled deviation for all the characters except days to first flowering, number of pods per cluster and hundred seed weight revealing the importance of non linear component accounting for total G x E interaction for these characters. The highly significant effect of genotype by environment for all the characters indicated differential response of genotypes to various environments. Estimates for stability parameters revealed that no genotypes were stable for all traits studied. The genotypes LBG 623, RU 8709, COBG 683 and HG 157 were found to have non-significant deviation from regression and regression coefficient around unity along with desirable mean value for seed yield per plant. These genotypes said to be suitable for both unfavorable high input and favorable low input environments for seed yield per plant.

The performance of photosensitive lines of black gram were analyzed by Babu *et al.* (2013) in the post rainy period of 2005-06 and 2006-07. During 2005-06, accession IC426765 performed better than LBG-20 in plant height. The superior performance of these accession in plant height indicate its potential to be used in breeding programmes for improvement of plant height in black gram.

The stability analysis of plant height, by (Mohan *et al.*, 2013) showed that the mean performance of the genotypes ranged from 30.64cm to 48.75cm with population mean 40.37cm. Out of thirty five genotypes, twenty three genotypes had b= 1, near to unity showing average response to the environment. Eighteen genotypes had b>1 showing their better adoption to favorable environment. Twelve genotypes had b<1 showing least response to the environment. Only five genotypes had S2di=0 indicating consistent performance over all the eight environments. Considering high mean (> population mean), b=1 and S^2di =0 showing fourteen genotypes. Genotypes namely, Pusa105, EC 251557-A and PLM 891 were selected as desirable and stable for plant height over eight environments.

The analysis of variance of phenotypic stability indicated highly significant G x E interaction for majority of traits indicating differential response of genotypes to varied environments. The significance of G x E (linear) and pooled deviation for seed yield per plant and its related traits suggested importance of both linear and non-linear components in building up total G x E interaction (Chaudhari *et al.*, 2013).

The phenotypic stability of 21 genotypes of black gram grown during *Kharif* 1999, 2000 and 2001, was studied for 6 traits, *viz.*, clusters per plant, pods per plant, pod length, seeds per pod, 100-seed weight and grain yield per plant. The genotypes showed significant genotype x environment interaction for all the traits. Only linear component of variation was significant, indicating that the differences among the regression coefficients pertaining to various genotypes on the environmental means were real (Sirohi and Singh, 2013).

Chandana *et al.* (2014), reported that stability of plant height is important in determining the stability of yield as plant height was contributing to seed yield per plant indirectly through number of pods per plant and harvest index.

According to Singh *et al.* (2014), the mean performance for various traits *viz.,* number of pod bearing braches per plant, number of secondary branches per plant, number pod per cluster showed gradual decrease with extended sowing dates.

Materials and methods

3. MATERIALS AND METHODS

The study entitled on "Genotype x Environment interaction in black gram (*Vigna mungo* (L.) Hepper)" was carried out at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the period August 2013 - December 2014. The objective of the study was to assess the genotype x environmental interaction in black gram cultures. The study was undertaken in three different seasons of sowing namely *kharif*, *rabi* and summer under two conditions open condition and as an inter crop in coconut garden (Plate 1). The study mainly focused on development of stable genotypes in black gram for cultivation as sole crop and inter crop for central zone of Kerala. The materials used and methodologies adopted in the study are presented in this chapter.

3.1 Materials

3.1.1 Experimental site

The field experiments were conducted at the Department of Plant Breeding and Genetics, College of Horticulture, Instructional farm Vellanikkara, Thirssur, Kerala. The area is situated at 29^0 102' North latitude and 75^0 462' East longitudes at an altitude of 215.2 m above MSL. The soil of the experimental site is red loam and belonging to Vellanikkara series which comes under the Order Oxisol.

3.1.2 Experimental material

The materials used for the study consisted of ten black gram cultures developed by pureline selection from four crosses in the stabilized generation at the Department of Plant Breeding and Genetics, and four varieties namely, TAU-1, T-9, Sumanjana and Syama were used as check. The details of the genotypes used are presented in Table1.

Plate 1. Field view of the experiment

a) Open condition

b) Shade condition

Plate 2. Determinate plant habit in blackgram

a) Determinate plant habit in blackgram

3.2 Methods

The crops were raised under three dates of sowing namely, September 2013, February 2014 and August 2014. The field experiment was laid out under open condition and under coconut garden in randomized block design with two replications. The details of the environment are presented in Table 2. The plot size was 5 m x 0.8 m and plants were raised at a spacing of 30 x 10 cm^2. Standard cultural and plant protection practices were followed according to package of practices recommendations: Crops by Kerala Agricultural University (KAU, 2011). Hand weeding was done 30 days after sowing (DAS) in all the three dates of planting under both the conditions. The crop was harvested when the 90 per cent of the pods in the plants were dried. All the observations were recorded after harvest except days to flowering.

Table 1.Details of cultures and check varieties used for the experiment

S.N	Treatments/ Cultures	Details of Cultures	Renamed cultures	Original Cross combination
1.	T_1	4.1.1	BG - COH 1	T9 x TAU 1
2.	T_2	4.5.2	BG - COH 2	T9 x Rusami
3.	T_3	4.5.3	BG - COH 3	T9 x Rusami
4.	T_4	4.5.7	BG - COH 4	T9 x Rusami
5.	T_5	4.5.8	BG - COH 5	T9 x Rusami
6.	T_6	4.5.9	BG - COH 6	T9 x Rusami
7.	T_7	4.5.9	BG - COH 7	T9 x Rusami
8.	T_8	4.5.18	BG - COH 8	T9 x Rusami
9.	T_9	4.6.1	BG - COH 9	T9 x Sumajana
10.	T_{10}	6.4.1	BG - COH 10	Sumanjana x T9
11.	TAU-1	-	-	-
12.	T-9	-	-	-
13.	Sumanjana	-	-	-
14.	Syama	-	-	-

Table 2. Details of the environment

SL. No.	Season / condition	Environment
1	Kharif 14 open condition	Environment 1
2	Kharif 14 shade condition	Environment 2
3	Rabi 13 open condition	Environment 3
4	Rabi 13 shade condition	Environment 4
5	Summer 14 open condition	Environment 5
6	Summer 14 open condition	Environment 6

3.2.2 Observations

Observations were recorded from twenty plants per replication from each treatment.

3.2.2.1 Days to flowering

Number of days taken for the first flowering in each plot was recorded.

3.2.2.2 Height of plant

Height of plant was recorded at the time of harvest from ground level to the growing point of the plant and expressed in centimeters.

3.2.2.3 Number of branches and pod bearing branches per plant

Number of branches and pod bearing branches per plant was recorded at time of harvest from each replication.

3.2.2.4 Number of pods per plant

Number of pods per plant were counted and recorded from each treatment.

3.2.2.5 Length of pod

Length of pod was measured using a scale and expressed in centimeter from 10 pods in all the twenty plants after harvest.

3.2.2.6 Number of seeds per pod

The number of seeds per pod was counted from ten pods in all the twenty plants after harvesting.

3.2.2.7 The test weight

Weight of 100 grains was taken at random from each cultures and expressed in grams.

3.2.2.8 Yield per plant

The weight of grain per plant after hulling was taken and expressed in grams.

3.2.2.9 Protein content

Protein content was estimated by Lowry's method and is expressed as percentage, (Sadasivam and Manickam, 1996). 500 mg of fine powder of black gram grain was made by pestle and mortar. Then it was homogenized in 25 ml phosphate buffer (pH – 7.4). The supernatant was collected after centrifugation. This was used as sample. 0.2 ml of sample was pipetted out into a test tube and made up to 1 ml by adding distilled water. A blank was set up with 0.1 ml distilled water. Then 5 ml of alkaline copper sulphate (50 ml of 2 per cent sodium carbonate in 0.1 N sodium hydroxide, mixed with 1 ml of 0.5 per cent copper sulfphate in 1 per cent potassium sodium tartarate) reagent was added to each tube and mixed well, incubated at room temperature for 10 minutes. Then added 0.5 ml of Folin-Ciocalteau reagent and kept in darkness for 30 minutes. Similarly 0.2 ml to 1ml standard protein solution (0.2mg BSA/ml) was also pipetted out into test tubes and volume made up to 1ml with distilled water. Reagents were added as in the case of test sample. Blue colour developed was read in a UV-Vis spectrophotometer at 660nm. A standard curve using the standard protein absorbance against concentration was plotted and from this the protein content in the sample was calculated and expressed in percentage.

3.2.3. Statistical analysis

Data collected from the six locations with respect to the quantitative traits, as mentioned above, were tabulated and subjected to location wise analysis of variance and stability.

3.2.3.1 Analysis of variance

3.2.3.1.2 Environment wise analysis of variance

The data collected for all the biometrical traits for all the six individual environments were subjected to analysis of variance suggested by Panse and Sukhatme, (1954). Duncan test, based on minimal critical difference was performed in order to identify the actual difference among genotypes for each particular trait and respective ranking order.

Table 3. Analysis of variance of Randomized Block Design

Source of variation	**Degrees of freedom (df)**	**Sum of Squares (SS)**	**Mean Squares (MS)**	**Expectations of MS**
Replications	r – 1	-	-	-
Between genotypes	t – 1	SS_1	MS_1	$\sigma^2_e + r\sigma^2_g$
Within varieties or error	(r – t)(t – 1)	SS_2	MS_2	σ^2_e
Total	(rt – 1)	-	-	-

Where: r = number of replications t = number of genotypes

Environmental variance = σ2e

$$\text{Genotypic variance } (\sigma 2g) = \frac{MS1 - MS2}{r}$$

Phenotypic variance (σ2p) = σ2g + σ2e

Phenotypic, genotypic and environmental coefficients of variation were estimated by following the formula as suggested by Burton and De vane (1953).

Phenotypic coefficient of variation (PCV) = (σp/Mean)*100

Genotypic coefficient of variation (GCV) = (σg/Mean)*100

Environmental coefficient of variation (ECV) = (σe/Mean)*100

Were σp, σg and σe are phenotypic, genotypic and environmental standard deviations, respectively. According to Sivasubramanian and Madhavamenon (1973), PCV and GCV are classified as low if less than 10 per cent, moderate if is between 10 and 20 per cent, and high if is more than 20 per cent.

3.2.3.1.3. Heritability

Heritability (Broad sense) for all the traits were computed by the formula suggested by Lush (1940).

$$H = \sigma^2 g / \sigma^2 p$$

Heritability values were categorized as low if less than 30 per cent, moderate if between 30 and 60 per cent and high if more than 60 per cent.

3.2.3.1.4. Genetic advance

Genetic advance is a measure of genetic gain under selection. The expected genetic gain is estimated as,

$$GA = \sigma 2g / \sigma 2p \times K$$

Where,

σ2g - genotypic variance

σ2p - Phenotypic variance and

K- Selection differential at a particular level of selection intensity

Genetic advance was expressed as percentage of mean as

$$\text{Genetic advance per cent} = \frac{\text{Genetic advance}}{\text{Mean}} \times 100$$

3.2.3.1.3. Pooled analysis of variance

The data of environments where significant differences for genotypes were observed were used for pooled analysis of variance by forming a two way table. Pooled analysis was done as data pooled over open condition in three different seasons, data pooled over shaded condition as well as data pooled over all the six environments.

Table 4. Pooled analysis of variance

Source of variation	**Degrees of freedom (df)**	**Sum of Squares (SS)**	**Mean Squares (MS)**
Genotype	g-1	-	$\sigma^2_{e} + r\,\sigma^2_{ge} + re\,\sigma^2_{g}$
Environment	e-1	-	$\sigma^2_{e} + r\,\sigma^2_{ge} + rg\,\sigma^2_{e}$
G x E Interaction	(g-1) (e-1)	-	$\sigma^2_{e} + r\,\sigma^2_{ge}$
Pooled error	e(r-1) (g-1)	-	σ^2_{e}
Total	r(ge-1)	-	-

$$\text{MS due to pooled error} = \frac{\text{SS in E1+SSin E2 ---- + SS in En}}{\text{Error df in E1+Error df E2 + ---- Error df En}}$$

3.2.3.2 Stability analysis

3.2.3.2.1 Eberhart and Russell model

Analysis of variance for stability was done when the pooled analysis of variance was significant. Eberhart and Russell (1966), method was followed to estimate the three parameters of stability namely mean, regression coefficient (bi) and mean squared deviation (S^2di) for each genotype. This method was used to estimate the stability parameters pooled over three seasons under open condition and shaded condition and pooled over all the six environments.

The linear model proposed by Eberhart and Russell (1966) was,

$$Yij = \mu i + bi\ Ij + \sigma ij$$

Where,

Yij = Mean performance of i^{th} genotype in j^{th} environment

μi = Average performance of j^{th} genotype over all environments

bi = Regression coefficient that measures the response of the i^{th} genotype to varying environments.

σij = Deviation from regression of the i^{th} genotype at j^{th} environment.

Lj = Environmental index as the deviation of the mean of all genotypes in j^{th} environment from grand mean.

Analysis of variance for stability

The analysis of variance as proposed by Eberhart and Russell (1966) is given below.

Table 5. Analysis of variance for stability

Sl.No.	Source	Df	Expectations	MS
1	Total	(ge -1)	ε i ε j Yij^2 – CF	MS_1
2	Genotypes	(g -1)	l/e ε i Yi^2 – CF	
3	Environment + (GXE)	g(e – 1)	g i ε j Yij – Yi^2/e	
4	Environment (linear)	(g – 1)	I / g (ε i Yij $lj)^2$/ ε j Ij^2	
5	Genotype x Environment (linear)	(g – 1)	ε j [(ε j ε Yij $lj)^2$ / ε j I j] - {I /g (ε j Yj $lj)^2$ / ε j I j^2]	MS_2
6	Pooled Deviation	g(e – 2)	ε i ε j $σij^2$	MS_3
7	Deviation due to genotypes -1	(e – 2)	[ε j ε Yij^2 – $(Yi)^2$ / e] - [(ε j Yij $lj)^2$ / ε j Ij^2] = ε j $σij^2$	MS_3- 1
8	Genotypes - g	e(r – 2)	[ε j Y^2 – $(Yg)^2$ /e] - [(ε j Y gi lj^2 / ε j Ij^2] = ε j $σij^2$	MS_3- g
9	Pooled error	e(r –1) (g – 1)	-	$σ^2$e

Where g = Genotype, r = replication, e = environment.

3.2.3.2.2 Estimates of stability parameters

The regression coefficient (bi) and mean square deviation from the linear regression (s^2di) were estimated as follows.

3.2.3.2.3 Computation of regression coefficient

The regression coefficient is the regression of the performance of each genotype under different environments on the environmental means of over all the genotypes. This was estimated as follows.

$$bi = \varepsilon ij\ Yij\ Ij / \varepsilon\ j\ Ij^2$$

Where,

εij Yij Ij = the sum of products of environmental index (Ij) with corresponding mean of that genotype at each environment (yij)

$\varepsilon j\ Ij^2$ = the sum of the squares of the environmental index (Ij)

(a) For each value of regression coefficient Ij^2 is common and equal to

$$\varepsilon\ j\ ij^2 = I_1{}^2 +..+ Ii^2 +..I_{54}{}^2$$

(b) on the other hand εij Yij Ij for each genotype is the sum of products of environmental index (Ij) with the corresponding mean (x) of the genotype in each environment.

These values can be obtained in the following manner,

[X] x [Ij] = [εj Yij Ij] = [S]

Where,

[X] = Matrix of means

[Ij] = Vector for environmental index and

[S] = Vector for sum of products (Ie) εij Yij Ij

(c) Then bi values for each genotype was calculated by dividing εij Yij Ij for each genotype by $\varepsilon\ j\ Ij^2$.

Where,

Ij = environmental index of jth environment which can be calculated as fallows.

3.2.3.2.4 Computation of environmental index (Ij)

$Ij = \varepsilon i\ Yij / g - \varepsilon\ i\ \varepsilon\ j\ Yij / ge$ with $\varepsilon\ j\ Ij = 0$

$$= \frac{\text{Total of all the genotypes at jth location}}{\text{Number of genotypes}}$$

= Grand Total / Total number of observations

Computation of mean square deviation (S^2di) from linear regression

$= S^2di = (\varepsilon\ j\ Sij\ 2/e - 2 - S\ e^2 / r)$

Where,

$\varepsilon\ j\ Sij^2 = [\varepsilon\ j\ Y^2ij - Yi^2 / g] - (\varepsilon\ j\ Yij\ Ij)^2 / \varepsilon\ j\ Ij^2$

Where,

$\varepsilon j\ S^2ij$ = variance due to deviation from the regression for a genotype.

$\varepsilon i\ Yij^2 - Yi^2 / g$ = variance due to dependent variable

$(\varepsilon\ j\ Yij\ Ij)^2 / \varepsilon\ j\ Ij^2 = [\varepsilon\ j\ Yij\ Ij)\ (\varepsilon\ j\ Yij\ Ij) / \varepsilon\ j\ Ij^2 = bi\ \varepsilon\ j\ Yij\ Ij]$

From $\varepsilon\ j\ S^2ij$ values the stability parameter S^2di for each genotype is computed as fallows

$S^2\ di = [\varepsilon\ j\ Sij^2 / (e - 2)] - S^2 / r$

$$\text{Mean square Deviation} = \frac{\text{Deviation from regression}}{\text{Degrees of freedom for each environment}}$$

= Pooled error / Number of replications

S^2 = Estimate of pooled error   r = Number of replications

e = Number of environments   g = Number of genotypes

3.2.3.2.5 Test of significance

(1) The following tests of significance were carried out,

To test the significance of the differences among genotype means namely

$M_0 = M_1 = M_2 = M_3 = ... = M_{54.}$

The F test used was,

$$F = \frac{\text{Mean squares due to genotypes}}{\text{Mean squares due to pooled deviation}} = \frac{MS_1}{MS_3}$$

2) To test that the genotypes did not differ due to regression on environmental index.

$M_0 = b_1 = b_2 = ... = b_{54.}$

The F test used was,

$$F = \frac{\text{Mean squares due to genotypes x environment (linear)}}{\text{Mean squares due to pooled deviation}} = \frac{MS_1}{MS_3}$$

3) Individual deviation from linear regression is tested as follows

$F = [c\ \varepsilon\ j\ S^2ij / (e - 2)] / (\text{pooled error} / rt)$ value

$P = 0.05$ at $g - 2$ *df*

4) The hypothesis that regression coefficient does not differ from unity or from zero was tested by the appropriate' test for

(1-b) $1 - b / SE\ (b) = t \quad P = < 0.05$ for $(g - e)$ dt.

$$SE\ (b) = \frac{\sqrt{\text{MS due to pooled deviation}}}{\varepsilon\ j\ I\ j^2}$$

3.2.3.2.6. Genotypic stability

A genotype with unity regression coefficient ($bi = 1$) and the deviation not significantly differing from zero ($S^2di = 0$) was taken to be stable genotype with unit response.

Mean standard error of b

Mean of b = b = ε I bi / g

$$SE(b) = \frac{\sqrt{MS \text{ due to pooled deviation}}}{\varepsilon j I j^2}$$

Population means (μ) and standard error was calculated as

$$\text{Population means } (\mu) = \frac{\text{Grand total}}{\text{Number of observations}}$$

$$SE(\text{mean}) = \frac{\sqrt{MS \text{ due to pooled deviation}}}{\text{Number of environment - 1}}$$

3.2.3.2.7 Additive main effects and Multiplicative Interaction (AMMI) (Zobel *et al.*, 1998).

The AMMI Statistical model is a hybrid model. It makes use of standard ANOVA procedures to separate the additive variance from the multiplicative variance (genotype by environment interaction) and then uses a multiplicative procedure – principal components Analysis (PCA) to extract the pattern from the G x E portion of the ANOVA analysis. The results in a least squares analysis, which, with further graphical presentation of the numerical results (Biplot analysis), often allows a straight forward interpretation of the underlying causes of G x E. The mathematical statement of the hybrid model is:

$$Y_{ge} = \mu + \alpha g + \sigma e + \Sigma^{N}{}_{N=1} \lambda + {}_{n}\gamma g + n\rho\, ge$$

Where,

g = is genotypes

e = is environments

yge = is the yield of genotype g in environment e

μ = is the grand mean

αg = are the genotypes mean deviations

σe = are the environment mean deviations

N = is the number of IPCAs (Interaction Principal Component Axis) retained in the model

λn = is the singular value for I PCA axis n

σen = are the environment eigenvector values for IPCA axis n, and

ρge are the residuals.

Table 6. Analysis of variance for Stability-AMMI Model

Source	df	SS	MS	F
Total	(ger - 1)			
Treatment	(ge -1)			
Genotype	(g-1)			
Environment	(e - 1)			
Interactions	(g -1) (e-1)			
IPCA 1				
IPCA 2				
Residual				
Blocks	(r – 1)			
Error	(r – 1) (ge – 1)			

Results

4. RESULTS

Ten cultures of blackgram was evaluated along with four check varieties to find out G x E interaction the results of the study are presented here.

4. 1 Assessment of variability under different environments

4.1.1 Variability under environment 1

The results on the mean values of the different biometrical traits observed under the first environment, is presented in Table 7 and their genetic parameters in Table 8. The results show that there is exists wide variability between Ts for most of the characters studied. There was no variability observed for days to flowering and number of pod bearing branches.

4.1.1.1 Days to flowering

Days to flowering for Treatments varied between 33 days of T12 to 38 days of T1, T4, T5, T8 and T14. However, there was no variability observed for the trait. The PCV value was 12.06 and GCV was 11. 84. Genetic advance calculated as per cent of mean was 1.73 and broad sense heritability was 0.98.

4.1.1.2 Plant height

The plant height ranged from 34.53 cm of T1 to 47.95 cm of T7. The PCV value for plant height was 11.14 and the GCV value was 11.10. Genetic advancement was 9.28 and the genetic advance as percentage of mean was 22.78. Broad sense heritability was 0.99.

4.1.1.3 Number of branches per plant

The highest number of branches per plant was seen in T14 8.75 and lowest number 6.70 was seen in T3 and T5. The PCV value for number of branches per plant was 11.72 and the GCV value was 11.44. Genetic advancement was 1.80 and the genetic advance as percentage of mean was 22.99. Broad sense heritability observed was 0.98.

4.1.1.4 Number of pod bearing branches per plant

The highest number of pod bearing branches per plant was 11.15 of T7 and lowest number 6.0 was seen in T5. The PCV value for number of pod bearing branches per plant was 4.80 and the GCV value was 4.72. Genetic advancement was 3.46 and the genetic advance as percentage of mean was 9.58. Broad sense heritability observed was 0.98.

4.1.1.4 Number of pods per plant

The number of pods per plant ranged from the 42.60 of T13 to 60.50 of T9. The PCV value for number of pods per plant was 11.98 and the GCV value was 11.94 with a genetic advancement of 12.65 and the genetic advance as percentage of mean of 24.52. Broad sense heritability was 0.99.

4.1.1.5 Length of pod

The range for length of pod was between 4.67 cm of T11 to 5.70 of T6. The PCV value for length of pods per plant was 5.00 and the GCV value was 4.19 with genetic advancement of 0.36 and the genetic advance as percentage of mean as 7.25. Broad sense heritability was 0.84.

4.1.1.6 Number of seeds per pod

The number of seeds per pod ranged from 4.45 of T10 to 9.75 of T9. The PCV value for number of seeds per pod was 10.80 and the GCV value was 8.49. Genetic advancement was 0.76 and the genetic advance as percentage of mean was 13.76. Broad sense heritability was 0.79.

4.1.1.7 Test weight

The test weight ranged from 3.49g of T1 to 5.34g of T6. The PCV value for test weight was 12.48 and the GCV value was 12.08. Genetic advancement was 1.01 and the genetic advance as percentage of mean was 24.09. Broad sense heritability was 0.97.

4.1.1.8 Yield per plant

The yield per plant ranged from 13.43g of T13 to 18.45g of T10. The PCV value for yield per plant was 9.27 and GCV value was 9.25. Genetic advancement was 3.01 and the genetic advance as percentage of mean was 19.01. Broad sense heritability was 1.00.

4.1.1.10 Protein content

The protein content ranged from 17.07 per cent of T6 to 19.24 percent of the T4. The PCV value for protein content was 4.01 and GCV value was 1.59. Genetic advancement was 0.23 and the genetic advance as percentage of mean was 1.30. Broad sense heritability was 0.44.

Table 7. Mean performance of black gram genotypes under environment 1.

Genotypes	Days to flowering	Plant height (cm)	Number of branches per plant	Number pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
T1	38^{a}	34.53^{a}	7.10^{abc}	6.15^{a}	48.30^{c}	4.77^{a}	7.20^{ab}	3.49^{a}	15.56^{d}	18.73^{cd}
T2	34^{a}	35.00^{ab}	6.90^{ab}	6.35^{a}	55.40^{dc}	4.85^{ab}	5.25^{a}	4.28^{cd}	15.55^{d}	18.66^{cd}
T3	36^{a}	40.00^{c}	6.70^{a}	6.45^{a}	46.25^{bc}	4.97^{abc}	5.20^{a}	4.55^{cd}	14.75^{c}	18.84^{de}
T4	38^{a}	39.17^{e}	8.25^{efg}	7.50^{a}	55.15^{de}	4.75^{a}	6.35^{a}	4.51^{cd}	16.37^{e}	19.24^{g}
T5	38^{a}	36.90^{b}	6.70^{a}	6.00^{a}	58.00^{ef}	4.85^{ab}	6.05^{a}	4.44^{cd}	16.56^{e}	19.15^{fg}
T6	34^{a}	39.50^{c}	7.85^{def}	7.00^{a}	52.60^{d}	5.70^{d}	6.20^{a}	5.34^{e}	18.32^{g}	17.07^{a}
T7	37^{a}	47.95^{e}	8.40^{fg}	11.15^{a}	57.45^{ef}	5.25^{bc}	5.25^{a}	4.57^{d}	17.46^{f}	17.17^{a}
T8	38^{a}	47.60^{e}	7.55^{bcd}	7.10^{a}	57.95^{ef}	5.22^{bc}	5.70^{a}	3.60^{a}	16.25^{e}	18.10^{b}
T9	35^{a}	42.62^{d}	7.70^{cde}	7.15^{a}	60.50^{f}	4.82^{ab}	9.75^{b}	4.57^{d}	15.40^{d}	18.73^{cd}
T10	35^{a}	40.52^{c}	7.85^{def}	7.60^{a}	60.40^{f}	5.07^{abc}	4.45^{a}	4.53^{cd}	18.45^{g}	18.56^{c}
T11	35^{a}	43.77^{d}	7.05^{abc}	6.75^{a}	46.05^{bc}	4.67^{a}	5.05^{a}	4.08^{bc}	14.45^{bc}	19.16^{fg}
T12	33^{a}	35.82^{ab}	10.25^{h}	9.35^{a}	43.40^{ab}	5.32^{cd}	5.15^{a}	3.72^{ab}	15.37^{d}	19.18^{fg}
T13	36^{a}	40.41^{c}	8.00^{def}	7.15^{a}	42.60^{a}	5.09^{abc}	4.75^{a}	3.68^{ab}	13.43^{a}	19.11^{fg}
T14	38^{a}	40.02^{abc}	8.75^{g}	8.05^{a}	44.35^{ab}	5.25^{bc}	4.75^{a}	3.57^{a}	14.12^{a}	19.05^{ef}

Table 8. Genetic parameters of black gram genotypes under environment 1

Parameters	Days to flowering	Plant height (cm)	No. of branches plant	No. of pod bearing branches plant	No. of pods per plant	Length of pod (cm)	No. of Seeds per pod	Test weight (g)	Yield Per plant (g)	Protein content (%)
Phenotypic coefficient of variation	12.06	11.14	11.72	4.80	11.98	5.00	10.80	12.48	9.27	4.01
Genotypic coefficient of variation	11.84	11.10	11.44	4.72	11.94	4.19	8.49	12.08	9.25	1.59
Genetic advancement 5%	1.73	9.28	1.80	3.46	12.65	0.36	0.76	1.01	3.01	0.23
Genetic advance as percentage of mean 5 %	23.94	22.78	22.99	9.58	24.52	7.25	13.76	24.09	19.01	1.30
Broad sense heritability	0.98	0.99	0.98	0.98	0.99	0.84	0.79	0.97	1.00	0.44

4.1.2 Variability under environment 2

The results on the mean values of the different biometrical traits observed under the second environment is presented in Table 9 and their genetic parameters in Table 10. The results show that there exists wide variability between Ts for all the characters studied.

4.1.2.1 Days to flowering

The days to flowering varied from 35 days of T3, T6, T9 to 38 days of T11, T12 and T14. The PCV value for days to flowering was 12.87 and the GCV value was 12.62. Genetic advancement was 1.72 and the genetic advance as percentage of mean was 25.49. Broad sense heritability was 0.98.

4.1.2.2 Plant height

The plant height ranged from 37.22 cm of T1 to 51.81 cm of T12. The PCV value for plant height was 10.85 and the GCV value was 10.77. Genetic advancement was 9.37 and the genetic advance as percentage of mean was 22.05. Broad sense heritability was 0.99.

4.1.2.3 Number of branches per plant

The number of branches per plant ranged from 5.90 of T4 to 9.30 of T12. The PCV value for number of branches per plant was 14.74 and the GCV value was 14.58. The genetic advancement was 2.13 and the genetic advance as percentage of mean was 29.70. Broad sense heritability was 0.99.

4.1.2.4 Number of pod bearing branches per plant

The number of pod bearing branches per plant ranged from 5.70 of T5 to 8.05 of T12. The PCV value for number of pod bearing branches per plant was 2.99 and the GCV value was 2.94. The genetic advancement was 2.16 and the genetic advance as percentage of mean was 5.97. Broad sense heritability was 0.98.

4.1.2.5 Number of pods per plant

The number of pods per plant ranged from 45.85 of T12 to 57.85 of T10. The PCV value for number of pods per plant was 7.37 and the GCV value was 7.31 with genetic advancement was 7.71 and the genetic advance as percentage of mean was 14.93. Broad sense heritability was 0.99.

4.1.2.6 Length of pod

The length of pod ranged from 3.75 cm of T13 to 5.20 cm of T6. The PCV value for pod length was 8.15 and the GCV value was 7.55. Genetic advancement was 0.66 and the genetic advance as percentage of mean was 14.40. Broad sense heritability was 0.93.

4.1.2.7 Number of seeds per pod

The number of seeds per pod varied from 4.20 of T11 and T14 to 5.30 of T6. The PCV value for number of seeds per pod was 8.02 and the GCV value was 7.34. Genetic advancement was 0.68 and the genetic advance as percentage of mean was 13.83. Broad sense heritability was 0.92.

4.1.2.8 Test weight

The test weight ranged from 3.35 g of T12 to 4.63 g of T3 and T10. The PCV value for test weight was 11.17 and the GCV value was 10.83. Genetic advancement was 0.91 and the genetic advance as percentage of mean was 21.63. Broad sense heritability was 0.99.

4.1.2.9 Yield per plant

The character yield per plant ranged from 13.50g of T13 to 18.28g of T6. The PCV value for yield per plant was 9.44 and GCV value was 9.42. Genetic advancement was 3.08 and the genetic advance as percentage of mean was 19.35. Broad sense heritability was 1.00.

4.1.2.10 Protein content

The protein content varied from 16.79 per cent of T12 to 23.04 per cent of T9. The PCV value for protein content was 9.43 and GCV value was 8.53. Genetic advancement was 3.23 and the genetic advance as percentage of mean was 15.92. Broad sense heritability was 0.90.

Table 9. Mean performance of black gram genotypes under environment 2

Genotypes	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
T1	36.10^{c}	37.22^{a}	6.35^{abc}	6.10^{a}	49.45^{abc}	4.85^{cd}	4.85^{bc}	4.38^{c}	15.49^{d}	21.69^{c}
T2	36.00^{b}	37.85^{a}	7.40^{de}	6.95^{bcdef}	56.20^{ef}	4.75^{bcd}	4.90^{bc}	4.50^{c}	16.52^{e}	20.33^{c}
T3	35.00^{a}	38.97^{ab}	6.50^{abcd}	6.25^{abc}	51.60^{bcd}	4.60^{bc}	5.70^{d}	4.63^{c}	17.52^{f}	19.05^{bc}
T4	36.00^{b}	40.57^{abc}	5.90^{a}	5.75^{a}	54.80^{def}	4.67^{bcd}	5.05^{bc}	4.53^{c}	16.31^{e}	19.18^{bc}
T5	36.00^{b}	37.65^{a}	5.95^{a}	5.70^{a}	53.20^{cde}	4.85^{cd}	4.85^{bc}	4.53^{c}	16.24^{e}	22.39^{d}
T6	35.00^{a}	38.77^{ab}	8.15^{ef}	7.40^{cdef}	49.45^{ab}	5.20^{d}	5.30^{cd}	4.36^{c}	18.28^{g}	22.87^{d}
T7	36.00^{b}	43.87^{cd}	7.00^{bcd}	6.45^{abcd}	55.25^{def}	4.80^{cd}	5.25^{cd}	3.57^{ab}	17.38^{f}	22.39^{d}
T8	36.00^{b}	46.85^{de}	7.25^{cde}	6.70^{abcde}	55.25^{def}	4.65^{bc}	5.10^{c}	4.31^{c}	16.16^{e}	20.03^{c}
T9	35.00^{a}	43.95^{cd}	6.65^{abcd}	6.45^{abcd}	54.95^{def}	4.87^{cd}	5.15^{c}	4.53^{c}	15.51^{d}	23.04^{d}
T10	36.00^{b}	49.58^{ef}	6.55^{abcd}	6.30^{abc}	57.85^{f}	4.77^{cd}	5.20^{cd}	4.63^{e}	17.59^{f}	18.03^{b}
T11	38.00^{e}	41.85^{bc}	6.10^{ab}	5.90^{b}	47.45^{ab}	4.22^{ab}	4.20^{a}	3.40^{a}	15.12^{c}	19.51^{c}
T12	38.00^{e}	51.81^{f}	9.30^{h}	8.05^{f}	45.85^{a}	3.85^{a}	4.55^{ab}	3.35^{a}	14.10^{b}	16.79^{a}
T13	37.00^{d}	47.64^{de}	8.55^{h}	7.65^{ef}	48.20^{ab}	3.75^{a}	4.85^{bc}	3.72^{b}	13.50^{a}	19.92^{c}
T14	38.00^{e}	38.20^{ab}	8.60^{h}	7.55^{def}	48.05^{ab}	4.57^{bc}	4.20^{a}	3.46^{ab}	13.60^{a}	20.46^{c}

Table 10. Genetic parameters of black gram genotypes under Environment 2

Parameters	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
Phenotypic coefficient of variation	12.87	10.85	14.74	2.99	7.37	8.15	8.02	11.17	9.44	9.43
Genotypic coefficient of variation	12.62	10.77	14.58	2.94	7.31	7.55	7.34	10.83	9.42	8.53
Genetic advancement 5%	1.72	9.37	2.13	2.16	7.71	0.66	0.68	0.91	3.08	3.23
Genetic advance as% of mean 5 %	25.49	22.05	29.70	5.97	14.93	14.40	13.83	21.63	19.35	15.92
Broad sense heritability	0.98	0.99	0.99	0.98	0.99	0.93	0.92	0.99	1.00	0.90

4.1. 3 Variability under environment 3

The result on the mean values of the different biometrical traits observed under the third environment is, presented in Table11 and their genetic parameters in Table 12. The results show that there exist variability between genotypes for many of the characters except days to flowering, number of pods per plant, number of seeds per pod and test weight.

4.1.3.1 Days to flowering

Mean value for days to flowering ranged from 33.10 to 35.55 of T1 and T14. There was no variability observed for days to flowering in the third environment. The PCV value for days to flowering was 10.23 and the GCV value was 8.96. Genetic advancement was 0.74 and the genetic advance as percentage of mean was 16.15. Broad sense heritability was 0.88.

4.1.3.2 Plant height

The plant height ranged from 36.40 cm of T12 to 56.10 cm of T11. The PCV value for plant height was 14.70 and the GCV value was 13.21. Genetic advancement was 10.82 and the genetic advance as percentage of mean was 24.48. Broad sense heritability was 0.90.

4.1.3.3 Number of branches per plant

The number of branches per plant ranged from 3.85 of T7 to 5.75 of T10. The PCV value for number of branches per plant was 11.74 and the GCV value was 8.96. The genetic advancement was 0.95 and the genetic advance as percentage of mean was 20.18. Broad sense heritability was 0.76.

4.1.3.4 Number of pod bearing branches per plant

The number of pod bearing branches per plant ranged from 3.75 of T9 to 5.75 of T10. The PCV value for number of pod bearing branches per plant was 3.09 and the

GCV value was 1.23. Genetic advancement was 0.34 and the genetic advance as percentage of mean was 1.01. Broad sense heritability was 0.40.

4.1.3.5 Number of pods per plant

The number of pods per plant ranged from 25.5 of T10 to 39.00 of T12. There was no variability observed for the trait. The PCV value for number of pods per plant was 15.69 and the GCV value was 13.49. Genetic advancement was 7.83 and the genetic advance as percentage of mean was 23.92. Broad sense heritability was 0.86.

4.1.3.6 Length of pod

For length of pod mean values varied from 3.77 cm of T10 to 5.72 cm of T1. The PCV value for pod length was 8.26 and the GCV value was 5.49. Genetic advancement was 0.31 and the genetic advance as percentage of mean was 7.53. Broad sense heritability was 0.66.

4.1.3.7 Number of seeds per pod

For the number of seeds per pod, no variability observed between genotypes. The PCV value for number of seeds per pod was 6.78 and the GCV value was 4.62. Genetic advancement was -0.31 and the genetic advance as percentage of mean was -6.47. Broad sense heritability was 0.68.

4.1.3.8 Test weight

There was no variability observed for test weight of genotypes. The PCV value for test weight was 6.20 and the GCV value was 4.62. Genetic advancement was -0.18 and the genetic advance as percentage of mean was -6.47. Broad sense heritability was 0.74.

4.1.3.9 Yield per plant

The yield per plant ranged from 10.98g of T13 to 20.35g of T6. The PCV value for yield per plant was 18.96 and GCV value was 18.57. Genetic advancement was 5.48 and the genetic advance as percentage of mean was 37.48. Broad sense heritability was 0.98.

4.1.3.10 Protein content

The protein content varied from 19.14 per cent of T12 to 23.51 per cent of T3. The PCV value protein content was 6.69 and GCV value was 4.60. Genetic advancement was 1.40 and the genetic advance as percentage of mean was 6.53. Broad sense heritability was 0.69.

Table 11. Mean performance of black gram genotypes under environment 3

Genotypes	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield Per Plant (g)	Protein content (%)
T1	33.10^{a}	39.32^{a}	4.75^{abcd}	4.65^{bcd}	29.90^{a}	5.72^{b}	4.35^{a}	4.22^{a}	12.09^{a}	21.22^{bc}
T2	33.15^{a}	39.80^{a}	5.25^{cd}	4.70^{cd}	28.45^{a}	4.00^{a}	3.95^{a}	4.40^{a}	15.94^{c}	19.81^{a}
T3	35.30^{a}	44.90^{abc}	5.35^{cd}	5.30^{de}	38.45^{a}	4.15^{ab}	5.05^{a}	4.18^{a}	19.18^{d}	23.51^{b}
T4	35.15^{a}	52.29^{bcd}	4.60^{abc}	4.60^{abcd}	26.30^{a}	4.22^{ab}	4.55^{a}	4.23^{a}	12.93^{ab}	21.83^{cde}
T5	33.75^{a}	46.92^{abcd}	5.10^{bcd}	5.05^{de}	30.75^{a}	3.95^{a}	3.95^{a}	4.39^{a}	14.95^{bc}	22.37^{ef}
T6	32.60^{a}	53.98^{cd}	5.25^{cd}	5.15^{de}	35.90^{a}	4.72^{ab}	4.95^{a}	4.40^{a}	20.35^{d}	22.68^{ef}
T7	33.90^{a}	43.06^{ab}	3.85^{a}	3.80^{ab}	33.30^{a}	4.47^{ab}	4.70^{a}	4.06^{a}	15.70^{c}	21.30^{bc}
T8	34.65^{a}	42.07^{ab}	4.75^{abcd}	4.75^{cd}	35.50^{a}	3.75^{a}	4.90^{a}	4.77^{a}	19.66^{d}	22.44^{ef}
T9	32.80^{a}	36.17^{a}	4.40^{abc}	3.75^{a}	30.30^{a}	4.37^{ab}	5.05^{a}	4.63^{a}	15.89^{c}	19.35^{a}
T10	32.10^{a}	42.09^{ab}	5.75^{d}	5.75^{e}	25.25^{a}	3.77^{a}	4.25^{a}	4.21^{a}	11.94^{a}	22.07^{def}
T11	32.40^{a}	56.10^{d}	4.10^{ab}	4.10^{abc}	32.55^{a}	3.85^{a}	4.20^{a}	4.31^{a}	12.52^{a}	23.19^{g}
T12	34.60^{a}	36.40^{a}	4.40^{abc}	4.45^{abcd}	39.00^{a}	4.27^{ab}	4.20^{a}	4.00^{a}	12.46^{a}	19.14^{a}
T13	35.50^{a}	44.15^{abc}	5.05^{bcd}	5.05^{de}	38.35^{a}	4.89^{ab}	5.20^{a}	4.22^{a}	10.89^{a}	20.62^{b}
T14	35.55^{a}	37.73^{a}	4.70^{abc}	4.15^{abc}	29.50^{a}	4.05^{ab}	4.55^{a}	4.26^{a}	10.96^{a}	21.41^{c}

Table 12. Genetic parameters of black gram genotypes under environment 3

Parameters	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
Phenotypic coefficient of variation	10.23	14.70	11.74	3.09	15.69	8.26	6.78	6.20	18.96	6.69
Genotypic coefficient of variation	8.96	13.21	8.96	1.23	13.49	5.49	4.62	4.62	18.57	4.60
Genetic advancement 5%	0.74	10.82	0.95	0.34	7.83	0.31	-0.31	-0.18	5.48	1.40
Genetic advance as % of mean 5 %	16.15	24.48	20.18	1.01	23.92	7.53	-6.47	-6.47	37.48	6.53
Broad sense heritability	0.88	0.90	0.76	0.40	0.86	0.66	0.68	0.74	0.98	0.69

4.1.4 Variability under environment 4

The results on the mean values of the different biometrical traits observed under the fourth environment is presented in Table 13 and their genetic parameters in Table14. The results show that there exists wide variability between treatments for most of the characters studied. There was no variability observed for number of branches per plant and test weight.

4.1.4.1 Days to flowering

The days to flowering ranged from 33.40 days of T14 to 38.15 days of T2. The PCV value for days to flowering was 8.35 and the GCV value was 6.31. Genetic advancement was 0.34 and the genetic advance as percentage of mean was 9.83. Broad sense heritability was 0.76.

4.1.4.2 Plant height

The plant height ranged from 36.02 cm of T11 to the 52.85 cm of T10. The PCV value for plant height was 12.52 and the GCV value was 11.50. Genetic advancement was 9.42 and the genetic advance as percentage of mean was 21.78. Broad sense heritability was 0.92.

4.1.4.3 Number of branches per plant

For the number of branches per plant no variability was observed among the genotypes. The PCV value for number of branches per plant was 7.09 and the GCV value as 5.63. Genetic advancement was 0.31 and the genetic advance as percentage of mean was 9.21. Broad sense heritability was 0.79.

4.1.4.4 Number of pod bearing branches per plant

The number of pod bearing branches per plant ranged from 3.05 of T14 to 4.05 of T9. The PCV value for number of pod bearing branches per plant was 2.22 and the

GCV value was 1.00. Genetic advancement was -0.33 and the genetic advance as percentage of mean was -0.93. Broad sense heritability was 0.45.

4.1.4.5 Number of pods per plant

The number of pods per plant ranged from 24.75 of T8 to 37.45 of T11. The PCV value for number of pods per plant was 10.96 and the GCV value as 8.47. Genetic advancement was 4.00 and the genetic advance as percentage of mean was 13.48. Broad sense heritability was 0.77.

4.1.4.6 Length of pod

The length of pod varied from 3.50 cm of T11 to 4.40 cm of T4. The PCV value for pod length was 5.51 and the GCV value was 3.32. Genetic advancement was 0.17 and the genetic advance as percentage of mean was 4.12. Broad sense heritability was 0.60.

4.1.4.7 Number of seeds per pod

The number of seeds per pod varied from 3.85 of T13 to 6.20 of T2.The PCV for number of seeds per pod was 5.26 and the GCV value was 5.83. Genetic advancement was -0.62 and the genetic advance as percentage of mean was -13.33. Broad sense heritability was 0.90.

4.1.4.8 Test weight

For the test weight value there was no variability observed for genotypes. The PCV value for test weight was 6.86 and the GCV value was 5.22. Genetic advancement was 0.35 and the genetic advance as percentage of mean was 8.20. Broad sense heritability was 0.76.

4.1.4.9 Yield per plant

The yield per plant ranged from 10.79 g of T 1 to the 15.15 g of T 10. The PCV value for yield per plant was 10.58 and GCV value was 10.10. Genetic advancement was 2.44 and the genetic advance as percentage of mean was 19.87. Broad sense heritability was 0.95.

4.1.4.10 Protein content

The protein content varied from 17.35 per cent of T11 to the 23.84 per cent of T 7. The PCV value for protein content was 8.79 and GCV value was 7.29. Genetic advancement was 2.62 and the genetic advance as percentage of mean was 12.46. Broad sense heritability was 0.83.

Table 13. Mean performance of black gram genotypes under environment 4

Genotypes	Days to flowering	Plant height (cm)	Number of branches Per plant	Number pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
T1	35.00^{abc}	47.71^{d}	3.25^{a}	3.60^{ab}	32.80^{bcd}	4.22^{c}	4.55^{ab}	4.20^{a}	10.79^{a}	20.24^{cd}
T2	38.15^{g}	46.27^{d}	3.15^{a}	3.15^{ab}	26.15^{a}	3.55^{ab}	6.20^{b}	4.32^{a}	12.34^{ab}	19.15^{b}
T3	37.80^{g}	38.98^{b}	2.95^{a}	3.30^{ab}	37.30^{cd}	4.07^{abc}	5.90^{b}	4.24^{a}	12.26^{ab}	23.55^{g}
T4	36.45^{cdef}	51.32^{e}	3.65^{a}	3.40^{ab}	26.45^{a}	4.40^{c}	4.40^{ab}	4.58^{a}	11.83^{ab}	22.40^{f}
T5	36.70^{def}	38.07^{ab}	3.60^{a}	3.60^{ab}	28.10^{ab}	3.90^{abc}	5.15^{ab}	5.15a	13.56^{bc}	23.56^{g}
T6	35.55^{bcd}	45.41^{d}	3.25^{a}	3.40^{ab}	35.85^{cd}	4.10^{abc}	5.00^{ab}	4.34^{a}	13.76^{bc}	20.10^{c}
T7	37.35^{efg}	45.30^{d}	3.20^{a}	3.80^{ab}	33.60^{cd}	4.22^{c}	4.90^{ab}	5.07^{a}	11.73^{ab}	23.84^{h}
T8	34.65^{ab}	38.47^{ab}	4.00^{a}	3.60^{ab}	24.75^{a}	4.22^{c}	5.35^{ab}	4.21^{a}	12.63^{ab}	20.74^{d}
T9	34.80^{abc}	38.19^{ab}	3.70^{a}	4.05^{b}	34.90^{cd}	3.92^{abc}	4.50^{ab}	4.57^{a}	11.80^{ab}	19.58^{b}
T10	36.35^{cdef}	52.85^{e}	3.70^{a}	3.80^{ab}	28.40^{ab}	4.15^{abc}	5.90^{b}	4.14^{a}	15.15^{c}	20.45^{cd}
T11	36.25^{bcdef}	36.02^{a}	3.05^{a}	3.45^{ab}	37.45^{d}	3.50^{a}	3.65^{a}	4.58^{a}	11.78^{ab}	17.35^{a}
T12	36.70^{def}	55.19^{fg}	3.45^{a}	3.25^{ab}	35.50^{cd}	4.05^{abc}	4.65^{ab}	4.44^{a}	11.59^{ab}	21.61^{e}
T13	36.00^{bcde}	56.10^{g}	3.50^{a}	3.50^{ab}	35.05^{cd}	4.17^{bc}	3.85^{a}	4.63^{a}	10.80^{a}	20.49^{cd}
T14	33.40^{a}	41.62^{c}	3.25^{a}	3.05^{a}	32.25^{bc}	4.02^{abc}	4.40^{ab}	4.36^{a}	11.86^{ab}	20.68^{d}

Table 14.Genetic parameters of black gram genotypes under environment 4

Parameters	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of Pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
Phenotypic coefficient of variation	8.35	12.52	7.09	2.22	10.96	5.51	·5.26	6.86	10.58	8.79
Genotypic coefficient of variation	6.31	11.50	5.63	1.00	8.47	3.32	5.83	5.22	10.10	7.29
Genetic advancement 5%	0.34	9.42	0.31	-0.33	4.00	0.17	-0.62	0.35	2.44	2.62
Genetic advance as % of mean (5 %)	9.83	21.78	9.21	-0.93	13.48	4.12	-13.33	8.20	19.87	12.46
Broad sense heritability	0.76	0.92	0.79	0.45	0.77	0.60	0.90	0.76	0.95	0.83

4.1.5 Variability under environment 5

The result on the mean values of the different biometrical traits observed under the fifth environment is presented in Table 15 and their genetic parameters in Table 16. The results showed that wide variability between treatments for many of the characters studied. Their was no variability observed for number of branches per plant, number of pod bearing branches, length of pod and number of seeds per pod.

4.1.5.1 Days to flowering

The days to flowering varied from 34.10 days of T4 to the 38.30 days of T13. The PCV value for days to flowering was 7.62 and the GCV value was 3.33. Genetic advancement was -0.95 and the genetic advance as percentage of mean was -3.07. Broad sense heritability was 0.44.

4.1.5.2 Plant height

The plant height ranged from 35.55 cm of T14 to 48.50 cm of T1. The PCV value for plant height was 11.02 and the GCV value was 10.58. Genetic advancement was 8.96 and the genetic advance as percentage of mean was 20.93. Broad sense heritability was 0.96.

4.1.5.3 Number of branches per plant

For the character number of branches per plant, there was no variability observed. The PCV value for number of branches per plant was 4.04 and the GCV value was 6.86. Genetic advancement was -0.85 and the genetic advance as percentage of mean was -24.01. Broad sense heritability was 0.59.

4.1.5.4 Number of pod bearing branches per plant

For the character number of pod bearing branches per plant, there was no variability observed. The PCV value for number of pod bearing branches per plant was

3.38 and the GCV value was 2.90. Genetic advancement was -1.88 and the genetic advance as percentage of mean was 5.11. Broad sense heritability was 0.86.

4.1.5.5 Number of pods per plant

The number of pods per plant ranged from 24.45 of T11 to 35.05 of T7. The PCV value for number of pods per plant was 10.96 and the GCV value was 8.47. Genetic advancement was 4.00 and the genetic advance as percentage of mean was 13.48. Broad sense heritability was 0.77.

4.1.5.6 Length of pod

For the character length of pods, there was no variability observed. The PCV value for number of pods per plant was 5.51 and the GCV value was 3.32. Genetic advancement was 0.17 and the genetic advance as percentage of mean was 4.12. Broad sense heritability was 0.60.

4.1.5.7 Number of seeds per pod

There was no variability observed for the character number of seeds per pod. The PCV value for number of seeds per pod was 5.26 and the GCV value was 5.83. Genetic advancement was -0.62 and the genetic advance as percentage of mean was -13.33. Broad sense heritability was 0.90.

4.1.5.8 Test weight

The test weight ranged from 4.01g of T14 to 4.95g of T5. The PCV value for test weight was 6.90 and the GCV value was 5.27. Genetic advancement was 0.35 and the genetic advance as percentage of mean was 8.31. Broad sense heritability was 0.76.

4.1.5.9 Yield per plant

The yield per plant ranged from 10.10 g of T11 to 15.51g of T10. The PCV value for yield per plant was 11.01 and GCV value was 10.86. Genetic advancement was 2.69 and the genetic advance as percentage of mean was 22.08. Broad sense heritability was 0.99.

4.1.5.10 Protein content

The protein content varied from 18.02 per cent of T14 to the 24.10 per cent of T8. The PCV value for protein content was 9.06 and GCV value was 6.66. Genetic advancement was 2.06 and the genetic advance as percentage of mean was 10.07. Heritability in broad sense was 0.74.

Table 15. Mean performance of black gram genotypes under environment 5

Genotypes	Days to flowering	Plant height (cm)	Number of branches per plant	Number pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
T1	38.15^{c}	48.50^{g}	3.30^{a}	2.85^{a}	27.40^{abc}	4.15^{a}	4.65^{a}	4.10^{a}	11.32^{abc}	19.26^{c}
T2	36.90^{bcde}	44.90^{defg}	3.50^{a}	2.85^{a}	29.65^{abcd}	4.55^{a}	4.70^{a}	4.24^{ab}	11.20^{abc}	21.47^{e}
T3	36.15^{bcd}	48.65^{g}	3.75^{a}	2.95^{a}	33.95^{cd}	4.22^{a}	4.50^{a}	4.43^{bc}	12.45^{bcd}	21.11^{e}
T4	34.10^{a}	35.55^{a}	3.90^{a}	3.05^{a}	27.50^{abc}	4.45^{a}	4.55^{a}	4.55^{bc}	13.20^{cd}	20.38^{d}
T5	37.45^{cde}	46.05^{efg}	3.90^{a}	3.10^{a}	33.30^{bcd}	3.85^{a}	4.85^{a}	4.95^{c}	13.32^{cd}	22.06^{f}
T6	35.05^{ab}	43.85^{def}	3.65^{a}	3.20^{a}	31.35^{abcd}	4.47^{a}	5.20^{a}	4.57^{bc}	13.22^{cd}	21.45^{e}
T7	36.15^{bcd}	47.80^{fg}	3.60^{a}	3.15^{a}	35.05^{d}	3.97^{a}	4.55^{a}	4.46^{bc}	11.91^{abcd}	22.69^{g}
T8	37.95^{de}	44.30^{defg}	3.70^{a}	3.30^{a}	34.35^{cd}	3.87^{a}	4.80^{a}	3.64^{a}	12.48^{bcd}	24.10^{b}
T9	36.80^{bcde}	42.00^{cde}	3.60^{a}	3.40^{a}	28.15^{abcd}	4.12^{a}	4.90^{a}	4.44^{bc}	14.03^{de}	21.36^{e}
T10	35.65^{abc}	44.90^{defg}	3.65^{a}	3.30^{a}	27.45^{abc}	3.90^{a}	4.35^{a}	4.34^{bc}	15.51^{e}	20.28^{d}
T11	35.00^{ab}	36.20^{ab}	3.60^{ao}	2.85^{a}	24.45^{a}	4.02^{a}	4.50^{a}	4.13^{ab}	10.10^{a}	18.64^{b}
T12	37.70^{de}	37.75^{abc}	3.25^{a}	2.85^{a}	26.45^{ab}	4.12^{a}	4.30^{a}	4.04^{ab}	11.62^{abc}	18.05^{a}
T13	38.30^{e}	40.45^{bcd}	3.60^{a}	3.05^{a}	29.60^{abcd}	4.05^{a}	4.90^{a}	4.31^{bc}	11.78^{abcd}	18.83^{b}
T14	38.40^{e}	35.55^{a}	3.50^{a}	3.10^{a}	28.45^{abcd}	3.97^{a}	4.80^{a}	4.01^{ab}	10.80^{ab}	18.02^{a}

Table 16. Genetic parameters of black gram genotypes under environment 5

Parameters	Days to flowering	Plant height	Number of branches per plant	Number of pod bearing branches	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
Phenotypic coefficient of variation	7.62	11.02	4.04	3.38	10.96	5.51	5.26	6.90	11.01	9.06
Genotypic coefficient of variation	3.33	10.58	6.86	2.90	8.47	3.32	5.83	5.27	10.86	6.66
Genetic advancement 5%	-0.95	8.96	-0.85	1.88	4.00	0.17	-0.62	0.35	2.69	2.06
Genetic advance as % of mean (5 %)	-3.07	20.93	-24.01	5.11	13.48	4.12	-13.33	8.31	22.08	10.07
Broad sense heritability	0.44	0.96	0.59	0.86	0.77	0.60	0.90	0.76	0.99	0.74

4.1.6 Variability under environment 6

The results on the mean values of the different biometrical traits observed under the sixth environment is presented in Table17 and their genetic parameters in Table 18. The results show that there exists wide variability between treatments for most of the characters studied. There was no variability observed for number of branches and number of seeds per pod.

4.1.6.1 Days to flowering

The days to flowering mean ranged from 33.60 of T11 to the 37.30 of T1. The PCV value for days to flowering was 6.25 and the GCV value was 3.83. Genetic advancement was 0.14 and the genetic advance as percentage of mean was 4.84. Heritability in broad sense was 0.61.

4.1.6.2 Plant height

The plant height ranged from 36.07 cm of T13 to 57.55 cm of T1. The PCV value for plant height was 12.52 and the GCV value was 11.50. Genetic advancement was 9.42 and the genetic advance as percentage of mean was 21.78. Heritability in broad sense was 0.92.

4.1.6.3 Number of branches per plant

For the trait number of branches per plant, there was no variability observed. The PCV for the number of branches per plant was 5.73 and GCV was 1.27 with genetic advancement was 0.02 and the genetic advance as percentage of mean was 0.58. Heritability in broad sense was 0.22.

4.1.6.4 Number of pod bearing branches per plant

The number of pod bearing branches per plant ranged from 2.65 of T14 to the 3.25 of T6. The PCV value for number of pod bearing branches per plant was 2.22 and the GCV value was 0.96. Genetic advancement was -0.30 and the genetic advance as percentage of mean was -0.86. Heritability in broad sense was 0.43.

4.1.6.5 Number of pods per plant

The number of pods per plant ranged from 22.40 of T2 to the 38.50 of T9. The PCV value for number of pods per plant was 10.88 and the GCV value was 9.06 with a genetic advancement of 4.68 and the genetic advance as percentage of mean as 15.55. Heritability in broad sense was 0.83.

4.1.6.6 Length of pods

The length of pods ranged from 3.60 cm of T12 to the 4.87 cm of T3. The PCV value for pod length was 7.46 and the GCV value was 5.45. Genetic advancement was 0.34 and the genetic advance as percentage of mean was 8.20. Heritability in broad sense was 0.73.

4.1.6.7 Number of seeds per pod

For the character number of seeds per pod, there was no variability observed. The PCV value for number of seeds per pod was 14.49 and the GCV value was 5.29. Genetic advancement was 0.18 and the genetic advance as percentage of mean was 3.97. Heritability in broad sense was 0.37.

4.1.6.8 Test weight

The test weight ranged from 3.52 g of T11 to the 4.83g of T6. The PCV value for test weight was 9.87 and the GCV value was 9.42. Genetic advancement was 0.75 and the genetic advance as percentage of mean was 18.53. Heritability in broad sense was 0.95.

4.1.6.9 Yield per plant

The yield per plant ranged from 10.01g of T12 to 15.12g of T10. The PCV value for yield per plant was 14.51 and GCV value was 14.41. Genetic advancement was 3.56 and the genetic advance as percentage of mean was 29.48. Heritability in broad sense was 0.99.

4.1.6.10 Protein content

The protein content ranged from 16.61 per cent of T14 to 22.15 per cent of T8. The PCV value for protein content was 8.57 and GCV value was 7.13. Genetic advancement was 2.35 and the genetic advance as percentage of mean was 12.22. Heritability in broad sense was 0.83.

Table17. Mean performance of black gram genotypes under environment 6

Genotypes	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
T1	37.30^{b}	57.55^{c}	3.65^{a}	3.25^{b}	31.90^{de}	4.37^{abc}	4.75^{a}	3.91^{abc}	10.79^{bc}	19.42^{cd}
T2	35.25^{ab}	41.60^{abcd}	3.30^{a}	2.90^{ab}	22.40^{a}	4.30^{abc}	5.65^{a}	4.58^{ef}	10.92^{bc}	19.55^{cd}
T3	37.30^{b}	39.07^{ab}	3.30^{a}	2.95^{ab}	35.75^{fg}	4.87^{c}	5.65^{a}	4.42^{def}	12.33^{f}	20.77^{ef}
T4	35.55^{ab}	43.30^{bcd}	3.35^{a}	2.70^{a}	29.55^{cd}	4.07^{ab}	4.15^{a}	4.05^{bcd}	14.32^{g}	18.93^{c}
T5	36.50^{b}	42.72^{abcd}	3.55^{a}	3.05^{ab}	35.10^{ef}	4.07^{ab}	5.25^{a}	4.48^{def}	12.27^{ef}	20.49^{e}
T6	35.85^{ab}	44.75^{bcd}	3.50^{a}	3.25^{b}	28.35^{bc}	4.57^{bc}	4.60^{a}	4.83^{f}	14.32^{g}	19.05^{c}
T7	34.95^{ab}	40.69^{abc}	3.55^{a}	3.00^{ab}	25.15^{ab}	4.22^{abc}	4.60^{a}	4.50^{def}	11.64^{de}	19.24^{cd}
T8	35.65^{ab}	46.95^{cd}	3.40^{a}	2.75^{ab}	32.40^{def}	4.10^{ab}	4.35^{a}	3.63^{ab}	11.17^{cd}	22.15^{g}
T9	36.05^{ab}	43.35^{bcd}	3.50^{a}	2.90^{ab}	38.50^{g}	4.05^{ab}	4.15^{a}	4.07^{bcd}	14.32^{g}	19.29^{cd}
T10	35.20^{ab}	38.88^{ab}	3.45^{a}	3.10^{ab}	32.50^{def}	4.07^{ab}	4.75^{a}	4.15^{cde}	15.12^{h}	21.24^{f}
T11	33.60^{a}	41.81^{abcd}	3.40^{a}	2.95^{ab}	27.25^{bc}	3.82^{ab}	3.55^{a}	3.55^{a}	10.46^{ab}	21.27^{f}
T12	36.45^{b}	48.42^{d}	3.05^{a}	2.70^{a}	22.60^{a}	3.60^{a}	3.85^{a}	4.11^{bcde}	10.01^{a}	17.73^{b}
T13	36.30^{b}	36.07^{a}	3.50^{a}	2.70^{a}	32.60^{def}	3.95^{ab}	4.55^{a}	3.52^{a}	10.45^{ab}	16.89^{a}
T14	35.80^{ab}	38.07^{ab}	3.30^{a}	2.65^{a}	31.85^{de}	4.05^{ab}	3.95^{a}	3.78^{abc}	10.89^{bc}	16.61^{a}

Table18. Genetic parameters of black gram genotypes under environment 6

Parameters	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
Phenotypic coefficient of variation	6.25	12.52	5.73	2.22	10.88	7.46	14.49	9.87	14.51	8.57
Genotypic coefficient of variation	3.83	11.50	1.27	0.96	9.06	5.45	5.29	9.42	14.41	7.13
Genetic advancement 5%	0.14	9.42	0.02	-0.30	4.68	0.34	0.18	0.75	3.56	2.35
Genetic advance as % of mean 5 %	4.84	21.78	0.58	-0.86	15.55	8.20	3.97	18.53	29.48	12.22
Broad sense heritability	0. 61	0.92	0.22	0.43	0.83	0.73	0.37	0.95	0.99	0.83

4.2 Analysis of stability (Eberhart and Russell's model)

Genotype x environment interaction determines the ability of an individual genotype to perform under different environments. As the experiment was conducted under two situations to find out the best genotype for each condition, stability analysis was done by the linear regression model in two different ways. Genotypes under three dates of sowing pooled over open condition and shaded condition to find out best genotypes suitable for each condition. Secondly data pooled over all the six environments were analysed to find out the best genotypes for all the conditions.

4.2.1 Analysis of variance pooled over open condition

Details of analysis variance pooled over three sets of data for open condition is presented in Table 19. There was significant deviation between environments for all the characters except test weight. Genotype and genotype x environment interaction was significant for all the traits tested. As the G x E interaction was significant further statistical analysis was attempted by partitioning genotype - environment mean squares into components namely variance due to genotype x environment (linear) and pooled deviation (non-linear).

Table19. Pooled ANOVA over three open conditions

Source of variation	df	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Test weight (g)	Protein content (%)	Yield per plant (g)
Total	41	27.89	3.55	4.09	124.68	0.13	3.27	6.84
Environments(E)	2	47.51*	64.92*	67.47*	2069.08*	0.04	30.01*	44.58*
Genotypes (G)	13	26.29*	0.24*	0.54*	22.21*	0.21*	1.68*	7.78*
G x E	26	27.18*	0.48*	0.86*	26.34*	0.10*	2.01*	3.47*
Pooled error		4.20	6.68	0.37	8.89	4.22	2.25	0.31

4.2.2 Analysis of variance for stability under open condition

The analysis of variance for stability is presented in Table 20. Environment (linear) was significant in all traits except plant height and test weight. G x E interaction linear was significant for number of branches, number of pods and yield per plant.

Table20. Analysis of variance for stability for different traits under open condition

Source of variation	df	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Test weight (g)	Protein content (%)	Yield per plant (g)
Total	41	27.89	3.55	4.00	124.68	0.13	3.27	6.84
Genotype(G)	13	26.29	0.24	0.54	22.21	0.21*	60.02	7.78
Environment -linear (E)	1	95.02	129.84*	134.94*	4138.15*	0.08	1.54*	89.17*
G x E linear	13	21.47	0.71*	1.15	38.23*	0.13	1.54	1.06*
Pooled deviation–linear	14	30.54	0.23	0.53	13.43	0.07	2.29	5.46
Pooled error	42	4.20	0.06	0.37	8.89	0.04	0.02	031
Non linear : linear		1.42:1	0.74:1	0.46:1	035:1	0.53:1	1.48:1	5.15:1

4.2.3 Stability parameters (Eberhart and Russell's Model)

4.2.3.1 Stability parameters of black gram genotypes pooled over open conditions.

The character wise estimate of stability parameters are presented in Table 21a and Table 21b.

4.2.3.1.1 Days to flowering

There was no significant difference for the trait days to flowering.

4.2.3.1.2 Plant height

Mean values for plant height ranged between 36.65 cm and 46.27 cm of T12 and T7 respectively. T8 had significant regression (bi) value while, significant deviation from regression was showed by T1, T2, T3, T4, T6, T10, T11 and T12. Genotypes T5, T7, T9, T13 and T14 only were stable.

4.2.3.1.3 Number of branches per plant

For the number of branches per plant, mean values ranged between 4.91 of T11 and 5.96 of T12. None of genotypes had significant bi value however; significant S^2di values were showed by T2, T7, T10 and T12.

4.2.3.1.4 Number of pod bearing branches per plant

Mean values of number of pod bearing branches per plant ranged between 4.55 of T1 and 5.55 of T10. T8 had significant bi value and significant S^2di value was showed by T7.

4.2.3.1.5 Number of pods per plant

For the number of pods per plant mean value ranged from 34.10 of T14 and 42.60 of T8. Significant bi values were showed by T1, T9 and T14. Only T12 had significant S^2di.

4.2.3.1.6 Length of pods and number of seeds per pod

For length of pod and number of seeds per pod, there was no significant difference between stability parameters.

4.2.3.1.7 Test weight

For, test weight mean value ranged from 3.92 g of T12 and 4.77 g of T6. T1 and T6 had significant bi value and T7 and T8 had significant S^2di.

4.2.3.1.8 Yield per plant

For yield per plant, mean value ranged from 11.96 g of T14 and 17.30 g of T6. T7 had significant bi value and T1, T2, T3, T4, T6, T8, T10, T13 and 14 had significant S^2di.

4.2.3.1.9 Protein content

Mean values of protein content ranged from 18.77 per cent of T12 and 21.54 per cent of T8. None of genotypes had significant bi value, however, all genotypes showed significant S^2di.

Table 21a Estimates of stability pooled over open condition (Eberhart and Russell model)

Genotypes	Plant height (cm)			Number of branches per plant			Number of pod bearing branches per plant			Number of pods per plant		
	Mean	bi	S^2di	Mean	Bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
T1	40.78	1.84	73.38*	5.05	0.88	0.01	4.55	0.73	-0.14	35.20	0.93*	-8.89
T2	39.90	1.65	26.30*	5.21	0.76	0.31*	4.63	0.78	-0.16	37.83	1.23	0.98
T3	44.58	1.55	15.20*	5.26	0.65	0.29*	4.90	0.76	0.36	39.55	0.49	-3.67
T4	42.33	3.02	88.93*	5.58	1.07	0.12	5.05	1.02	-0.37	36.31	1.32	2.06
T5	44.29	2.88	0.81	5.23	0.64	0.03	4.71	0.63	0.13	40.68	1.21	7.59
T6	45.77	3.74	11.14*	5.58	0.97	0.03	5.11	0.85	-0.17	39.95	0.91	-6.52
T7	46.27	-1.19	1.48	5.28	1.22	0.73*	6.03	1.93	3.01*	41.93	1.09	1.74
T8	44.65	-1.50*	-4.17	5.33	0.92	-0.06	5.05	0.87*	-0.37	42.60	1.09	-7.45
T9	40.26	-1.60	3.66	5.23	1.00	0.02	4.76	0.90	0.30	39.65	1.48*	-7.41
T10	42.50	0.59	3.23*	5.75	0.94	0.43*	5.55	0.95	0.12	37.70	1.58	11.52
T11	45.35	2.63	0.23*	4.91	0.85	0.08	4.56	0.90	-0.35	34.35	0.86	8.42
T12	36.65	0.23	150.34*	5.96	1.72	0.39*	5.55	1.52	0.02	36.28	0.55	53.37*
T13	41.67	0.91	-2.62	5.55	1.04	-0.04	5.08	0.92	-0.21	36.85	0.44	20.24
T14	37.76	-0.77	1.71	5.65	1.27	-0.08	5.10	1.17	0.04	34.10	0.73*	-8.53

* significant at 0.05%

Table22b. Estimates of stability for pooled over open condition (Eberhart and Russell model)

Genotypes	Test weight (g)			Yield per plant (g)			Protein content (%)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
T1	3.94	7.23*	0.05	12.99	1.08	2.37*	19.73	0.77	0.81*
T2	4.31	0.47	-0.04	14.23	1.35	1.90*	19.98	0.55	2.64*
T3	4.39	-2.72	-0.02	15.46	0.96	17.10*	21.15	1.56	0.45*
T4	4.43	-1.36	0.05	14.17	0.76	3.30*	20.48	0.85	0.20*
T5	4.59	2.18	-0.05	14.95	0.89	-0.14	21.19	1.17	0.34*
T6	4.77	-9.29*	0.05	17.30	1.67	8.77*	20.40	1.99	0.22*
T7	4.37	-3.48	0.44*	15.02	1.58*	-0.30	20.39	1.64	4.85*
T8	4.01	7.08	0.17*	16.13	1.35	13.79*	21.54	1.74	6.13*
T9	4.54	-0.35	0.04	15.10	0.45	0.28	19.81	0.38	3.12*
T10	4.36	-2.83	0.07	15.30	0.50	19.27*	20.30	1.17	0.23*
T11	4.17	1.60	-0.02	12.36	1.21	-0.17	20.33	1.15	6.63*
T12	3.92	3.14	0.27*	13.15	0.96	1.42	18.77	-0.10	0.82*
T13	4.07	6.21	-0.04	12.03	0.35	2.21*	19.52	0.42	1.04*
T14	3.95	6.11	0.01	11.96	0.82	2.37*	19.48	0.64	4.29*

* significant at 0.05%

4.2.3.2 Stability analysis under shade condition

4.2.3.2.1 Pooled analysis of variance under shade condition

The analysis of variance pooled over data under shade condition is presented in the Table 22. The data shows that mean sum of square due to environments were significant for all the traits. Genotypes were significantly differed for all the traits except number of pod bearing branches. Genotype x environmental interaction was significant for all the traits except number of seeds per pod.

Table 23. Pooled analysis of variance under shade condition

Source of variation	df	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Number of seeds per pod	Test weight (g)	Protein content (%)	Yield per plant (g)
Total	41	1.23	32.61	3.61	2.98	116.52	0.16	0.39	0.19	3.43	5.37
Environments (E)	2	0.72*	26.45*	65.62*	56.71*	2016.04*	1.24*	0.59*	0.62*	8.10*	66.72*
Genotypes (G)	13	0.76*	42.22*	0.37*	0.14	14.22*	0.17*	0.86*	0..22*	3.14*	4.97*
G x E	26	1.50*	28.27*	0.46*	0.26*	21.55*	0.07*	0.14	0.14*	3.22*	0.85*
Pooled error		0.27	2.06	7.97	7.23	1.62	3.70	0.25	0.50	0.01	0.20

4.2.3.2.2 Analysis of variance for stability under shade condition

The analysis of variance for stability was presented in Table 23. Genotypes differed for the traits number of branches, number of pod bearing branches, length of pods and yield per plant. Environment linear showed significant differences except in days to flowering, plant height, number of pods and length of pod. Genotype x environment linear was significant for number of branches, number of pod bearing branches and number of pods.

Table 24. Analysis of variance of stability for different traits under shade condition

Source of variation	Df	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pod (cm)	Test weight (g)	Yield per plant (g)	Protein content (%)
Total	41	1.23	32.61	3.61	2.98	116.52	0.16	0.19	5.37	3.43
Genotype (G)	13	0.76	42.22	0.37*	0.14*	14.22	0.17*	0.22	4.97*	3.14
Environment(E) (Linear)	1	1.44	52.87	131.25*	113.43*	4032.06*	2.48*	10.24*	133.44*	16.20*
G x E (Linear)	13	1.35	22.93	0.88*	0.48*	21.65*	0.09	0.16	0.82	3.16
Pooled deviation (non linear)	14	1.52	31.22	0.04	0.05	19.92	0.05	0.12	0.82	3.05
Pooled error	42	0.27	2.06	0.07	0.07	1.62	0.03	0.05	0.20	0.01
Non linear: linear		1.12:1	1.36:1	0.04:1	0.10:1	0.92:1	0.55:1	0.75	0.98:1	0.96:1

4.2.3.2.3 Estimates of stability parameters under shade condition

The stability parameters estimated over three seasons under shade condition is presented in Table 24a and 24b.

4.2.3.2.3.1 Days to flowering

The mean values for days to flowering ranged between 35.28 of T9 and 37.05 of T12. T6 and T11 had significant bi value and T1, T2, T3, T7 and T14 had significant S^2di.

4.2.3.2.3.2 Plant height

For plant height mean values ranged between 39.30 cm of T14 and 51.80 cm of T12. T3, T4 and T9 had significant bi value and T1, T5, T10, T12 and T13 had significant S^2di.

4.2.3.2.3.3 Number of branches per plant

The mean value for number of branches ranged between 4.18 of T11 to 5.26 of T12. T5, T13 and T14 had significant bi value and none of genotypes had significant S^2di.

4.2.3.2.3.4 Number of pod bearing branches per plant

The mean value ranged between 3.95 of T4 and 4.68 of T6 for number of pod bearing branches. T1, T5, T11 and T13 had significant bi value and none of treatments had significant S^2di.

4.2.3.2.3.5 Number of pods per plant

The mean value for number of pods ranged between 34.65 of T12 and 42.78 of T9. T1, T2 and T3 had significant bi value and T4, T5, T6, T7, T8, T9, T10, T11, and T12 had significant S^2di.

4.2.3.2.3.6 Length of pod

The mean value for length of pod ranged between 3.83 cm of T12 and 4.62 cm for T6. T5 and T13 had significant bi value and T3 had significant S^2di.

4.2.3.2.3.7 Number of seeds per pod

There was no significant difference for the character number of seeds per pod.

4.2.3.2.3.8 Test weight

For seed weight mean value ranged from 3.84 g of T11 and 4.72 g of T5. T2 and T5 had significant bi value and T7, T8 and T12 had significant S^2di.

4.2.3.2.3.9 Yield per plant

For yield per plant mean value ranged from 11.58 g of T13 and 15.45 g of T6. Significant bi values were showed by T7 and T10 and significant S^2di was showed by T 4, T9 and T12.

4.2.3.2.3.10 Protein content

Mean value of protein content ranged from 18.71 per cent of T12 and 22.14 per cent of T5. T5, T7 and T11 had significant bi values and all genotypes except T5 and T7 had significant S^2di.

Table 24a Estimates of stability parameters under shade condition (Eberhart and Russel model)

Genotypes	Days to flowering			Plant height (cm)			Number of branches per plant			Number of pod bearing branches per plant			Number of pods per plant		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
T1	36.13	-2.81	1.55*	47.49	1.75	192.88*	4.41	0.77	-0.02	4.31	0.77*	-0.06	38.05	0.82*	-1.53
T2	36.46	1.91	3.87*	41.90	2.98	-0.06	4.61	1.11	-0.07	4.33	1.12	0.09	34.91	1.54*	-0.84
T3	36.70	-4.89	1.71*	39.01	-0.01*	-2.05	4.25	0.90	-0.02	4.16	0.90	-0.05	41.55	0.72*	-1.56
T4	36.00	1.06	0.01	45.06	4.06*	-2.02	4.30	0.64	-0.03	3.95	0.79	-0.04	36.93	1.27	11.78*
T5	36.40	-1.05	-0.13	39.48	-0.46	12.99*	4.36	0.63*	-0.07	4.11	0.69*	-0.06	38.80	1.01	35.91*
T6	35.46	-1.85*	-0.26	42.97	1.97	9.96	4.96	1.27	-0.05	4.68	1.16	0.06	37.88	0.85	17.17*
T7	36.10	2.50	1.97*	43.29	0.98	5.42	4.58	0.96	-0.02	4.41	0.89	-0.03	38.00	1.26	18.95*
T8	35.43	0.64	0.66	44.09	-3.44	0.43	4.88	0.94	0.10	4.35	1.03	-0.04	37.46	1.25	45.50*
T9	35.28	-2.38	0.03	41.83	-2.28*	-1.74	4.61	0.81	0.05	4.46	0.88	0.13	42.78	0.86	10.93*
T10	35.85	1.84	0.06	47.10	2.67	77.60 *	4.56	0.79	0.04	4.40	0.83	-0.04	39.58	1.30	17.73*
T11	35.95	9.73*	-0.22	39.89	-2.38	-1.03	4.18	0.76	-0.02	4.10	0.78*	-0.07	37.38	0.75	38.88*
T12	37.05	3.35	-0.05	51.80	1.80	8.46*	5.26	1.61	0.05	4.66	1.46	-0.02	34.65	0.84	65.22*
T13	36.43	1.47	0.02	46.60	4.91	108.95*	5.18	1.34*	-0.08	4.61	1.32*	-0.07	38.61	0.69	-0.75
T14	35.73	4.47	8.24*	39.30	1.42	-1.55	5.05	1.42*	-0.07	4.41	1.34	0.01	37.38	0.76	-1.27

* significant at 0.05%

Table 24b Estimates of stability parameters under shade condition (Eberhart and Russel model)

Genotypes	Length of pod (cm)			Test weight (g)			Yield per plant (g)			Protein content (%)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
T1	4.48	1.09	-0.03	4.16	0.22	0.05	12.36	1.24	-0.17	20.45	0.72	2.01*
T2	4.20	1.81	0.11	4.47	-0.61*	-0.04	13.26	1.30	0.45	19.68	-0.16	0.66*
T3	4.51	0.49	0.24*	4.44	-0.76	-0.02	14.04	1.37	-0.14	21.12	1.48	7.70*
T4	4.38	0.72	0.05	4.39	0.84	0.05	14.15	0.82	3.35*	20.17	2.11	2.33*
T5	4.27	1.69*	-0.03	4.72	1.79*	-0.05	14.02	0.89	0.41	22.14	2.04*	-0.01
T6	4.62	1.79	0.00	4.51	-0.74	0.05	15.45	1.11	0.11	20.67	1.02	6.54*
T7	4.41	1.09	-0.02	4.38	2.70	0.44*	13.58	1.50*	-0.18	21.82	3.08*	0.04
T8	4.32	0.88	-0.01	4.05	0.76	0.17*	13.32	1.14	0.55	20.97	-1.06	1.00*
T9	4.28	1.72	-0.03	4.40	0.79	0.04	13.88	0.61	3.29*	20.63	0.55	8.35*
T10	4.33	1.23	-0.01	4.31	-0.61	0.07	15.95	0.65*	-0.20	19.91	-0.79	4.82*
T11	3.85	1.17	-0.01	3.84	3.01	-0.02	12.45	1.07	0.39	19.37	-2.53*	0.26*
T12	3.83	-0.10	0.06	3.97	1.85	0.27*	11.90	0.88	0.77*	18.71	2.22	7.25*
T13	3.95	-0.66*	-0.02	3.96	2.80	-0.04	11.58	0.76	-0.18	19.10	2.47	0.41*
T14	4.21	1.02	-0.03	3.87	1.96	0.01	12.12	0.59	0.16	19.25	2.83	1.14*

* significant at 0.05%

4.2.4 Estimation of stability pooled over six environments

After estimating the stability parameters under open and shade condition stability parameters were estimated based on the data pooled over six environments.

4.2.4.1 Analysis of variance pooled over six environments

Analysis of variance pooled over six environments is presented in the Table 25. It shows that the environment was significant for all the traits. Effect of genotype was significant in days to flowering, length of pods, test weight and yield per plant. Genotype x environment interaction was significant in plant height, branch number, number of pod bearing branches, number of pods and test weight.

Table 25. Analysis of variance for pooled data over six environments

Source of variation	df	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches per plant	Number of pods per plant	Length of pods (cm)	Number of seeds per pod	Test weight (g)	Protein content (%)	Yield per plant (g)
Environment	5	14.97*	18.72	54.83*	49.29*	1675.13*	1.94*	1.78*	0.26*	18.38*	48.23*
Genotypes	13	2.72*	23.65	0.44	0.14	56.01	0.20*	0.32	0.59*	4.13	11.64*
Genotypes x Environment	65	1.07	28.30*	0.38*	0.30*	11.01*	0.06	0.17	0.06*	2.34	1.41
Error	78	0.49	3.23	0.04	0.03	3.20	0.03	0.16	0.03	0.94	0.09

4.2.4.2 Analysis of variance for stability for different traits under six environments

The analysis of variance for stability is presented in Table 26. Effect of genotype was significant for days to flowering, length of pods, test weight and yield per plant. Effect of environment was significant for all the traits studied. Genotype x environment interaction was significant for number of branches, number of pod bearing branches, number of pods, test weight and yield per plant.

Table 26. Analysis of variance for stability for different traits under six environments

Source	df	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches	Number of pods per plant	Length of pods (cm)	Number of seeds per pod	Test weight (g)	Yield per plant (g)	Protein content (%)
Genotype	13	2.73*	23.66	0.45	0.42	56.01	0.21*	0.32	0.59*	11.64*	4.13
Environment (linear)	1	74.85*	93.62*	274.20*	246.48*	8375.70*	9.72*	8.93*	1.30*	241.15*	91.91*
Genotype x Environment (linear)	13	0.87	24.49	1.24*	0.72*	23.92*	0.05	0.23	0.11*	1.71	1.16
Pooled deviation (non linear)	56	1.05	27.17	0.16	0.18	7.23	0.06	0.14	0.04	1.24	2.34
Error	78	0.50	3.23	0.043	0.04	3.20	0.03	0.16	0.03	0.09	0.94
Non linear : linear		1.20 :1	1.09:1	0.12:1	0.25:1	0.30:1	1.20:1	0.60:1	0.36:1	0.72:1	2.01:1

4.2.4.3 Stability parameters of black gram genotypes under six environments

The character wise estimate of stability parameters are presented in Table 27a and 27b.

4.2.4.3.1 Days to flowering

For days to flowering mean value ranged between 34.80 of T6 to 36.78 of T14. All genotypes were having non-significant bi values but S^2di was significant for T4, T11 and T12.

4.2.4.3.2 Plant height

Mean value for plant height ranged between 38.02 cm of T14 and 45.47 cm of T 8. All treatments were having non-significant bi values. S^2di was significant in T1, T3, T4, T6, T10, T11, T12 and T13.

4.2.4.3.3 Number of branches per plant

Mean value for number of branches per plant ranged between 4.66 of T2 and 5.67 of T12. All genotypes were having non-significant bi values. T2, T3, T4, T7, T10, T12 and T13 had significant S^2di values.

4.2.4.3.4 Number of pod bearing branches per plant

For number of pod bearing branches per plant mean value ranged between 4.34 of T11 and 5.25 of T12. All treatments were having non-significant bi values. T2, T3, T4, T5, T7, T8, T9, T13 and T14 had significant S^2di values.

4.2.4.3.5 Number of pods per plant

For number of pods per plant mean value ranged between 33.15 of T11 and 43.04 of T8. All treatments were having non-significant bi values. Treatments T3, T8, T9, T12 and T13 had significant S^2di values.

4.2.4.3.6 Length of pod

Mean values for length of pod ranged between 4.09 cm of T11 and 4.85 cm of T6. None of genotypes had significant bi values. However, T12 and T13 had significant S^2di values.

4.2.4.3.7 Number of seeds per pod

For the number of seeds per pod mean values ranged between 4.56 of T14 and 5.11 of T6. Significant bi values were showed by T4 and T13. None of genotype had significant S^2di values.

4.2.4.3.8 Test weight

The test weight had mean value ranging between 3.75 g of T8 and 4.72 g of T6. Significant bi values was showed by T3 only. T1, T11 and T12 had significant S^2di values.

4.2.4.3.9 Yield per plant

For yield per plant mean value ranged from 11.99 g of T13 and 16.35 g of T6. Significant bi values were showed by only two genotype T7 and T13. However, all genotypes was significant. Non-significant S^2di values showed by genotype T7 and T11.

4.2.4.3.10 Protein content

Mean value of protein content ranged from 18.64 per cent of T12 and 21.60 per cent of T5. None of treatments showed significant bi values. However, T8, T9, T11 and T12 had significant S^2di values.

Table 27a Estimates of stability parameter for different traits under six environments (Eberhart and Russell model)

Genotypes	Days to flowering			Plant height (cm)			Number of branches per plant			Number of pod bearing branches per plant			Number of pods per plant		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
T1	36.58	1.99	0.25	45.21	3.68	106.27*	4.76	0.83	0.03	4.45	0.79	0.01	34.83	1.07	-2.97
T2	34.89	1.55	0.11	40.74	3.68	2.36	4.66	0.95	0.23*	4.47	0.93	0.11*	37.40	1.07	1.68
T3	35.85	0.93	0.20	41.92	2.68	18.00*	4.85	0.84	0.13*	4.54	0.85	0.17*	40.12	0.78	9.03*
T4	35.66	0.49	1.31*	44.01	1.01	37.42*	4.88	0.92	0.31*	4.69	1.04	0.45*	35.61	1.15	4.05
T5	36.24	1.35	0.14	42.41	1.09	3.03	4.90	0.65	0.04	4.46	0.70	0.13*	40.91	1.09	1.00
T6	34.80	0.65	-0.10	44.35	3.44	5.11*	4.98	1.03	-0.03	4.91	1.03	0.80*	38.85	0.94	-2.64
T7	35.56	0.70	0.03	43.88	-1.44	4.56	4.98	1.07	0.24*	4.82	1.02	0.08	41.66	1.08	3.25
T8	36.22	0.98	0.69	45.47	-1.08	-0.02	5.03	1.00	0.01	4.53	0.97	0.11*	43.04	0.98	11.79*
T9	35.45	0.79	0.03	42.03	-1.23	4.65	5.14	0.94	0.06	4.86	0.88	0.08*	38.72	1.29	6.67*
T10	34.93	1.11	-036	42.45	-0.04	16.14*	5.17	0.90	0.26*	4.73	0.93	0.09*	37.10	1.38	1.44
T11	35.00	0.75	1.75*	43.75	2.42	45.65*	4.75	0.71	-0.02	4.34	0.90	0.01	33.15	0.98	-0.47
T12	36.05	0.85	3.11*	43.78	1.18	69.36*	5.67	1.65	0.13*	5.25	1.50	-0.01	34.49	0.75	15.35*
T13	36.51	0.72	0.09	41.18	-0.47	23.94*	5.32	1.16	0.17*	4.81	1.17	0.41*	36.14	0.66	8.38*
T14	36.78	1.08	0.06	38.02	-0.93	-1.90	5.31	1.29	0.65	5.07	1.24	0.24*	34.18	0.84	0.35

* Significant at 0.05%

Table 27b Estimates of stability parameter for different traits under six environments (Eberhart and Russel model)

Genotypes	Length of pod (cm)			Number of Seeds per pod			Test weight (g)			Yield per plant (g)			Protein content (%)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
T1	4.43	0.82	-0.02	5.10	2.40	0.06	4.05	0.51	0.05*	12.74	1.08	0.81*	20.05	0.81	-0.16
T2	4.52	0.56	-0.01	4.96	0.15	0.04	4.38	0.59	-0.09	13.69	1.29	0.44*	19.69	0.38	-0.01
T3	4.51	0.73	0.03	5.26	1.10	0.16	4.46	-0.58*	-0.02	14.67	1.18	4.40*	20.98	1.56	0.87
T4	4.42	0.69	-0.03	4.89	1.76*	-0.13	4.47	0.85	-0.07	14.30	0.66	1.47*	19.90	1.44	-0.71
T5	4.26	1.27	-0.08	5.09	0.99	0.16	4.67	1.54	-0.02	14.54	0.87	0.15*	21.60	1.31	-0.89
T6	4.85	1.12	-0.01	5.11	0.80	-0.08	4.72	-1.16	0.05	16.35	1.35	2.68*	20.44	1.61	1.13
T7	4.38	1.31	-0.03	4.85	0.93	-0.13	4.57	1.34	-0.47	14.40	1.52*	-0.01	20.93	1.84	0.97
T8	4.46	1.19	-0.01	4.97	1.28	-0.13	3.75	1.76	-0.03	14.39	1.26	1.13*	21.13	1.01	2.71*
T9	4.40	1.01	0.01	5.04	0.99	-0.01	4.42	1.00	-0.01	14.09	0.69	0.97*	20.07	0.39	2.43*
T10	4.24	1.37	-0.18	4.79	0.76	-0.06	4.36	-0.14	-0.05	15.92	0.57	2.32*	20.33	0.88	1.48
T11	4.09	0.78	-0.02	4.56	1.29	0.16	4.20	2.10	0.07*	12.19	1.14	0.06	19.94	0.41	3.39*
T12	4.22	1.05	0.20*	4.49	0.94	-0.11	3.94	1.47	0.07*	12.37	1.07	0.49*	18.64	0.42	2.19*
T13	4.27	0.74	0.15*	4.79	0.05*	-0.11	3.97	2.98	0.01	11.99	0.60*	0.25*	19.14	0.78	0.17
T14	4.22	1.30	-0.03	4.56	0.50	-0.07	3.85	1.69	-0.01	12.12	0.65	0.90*	19.23	1.11	1.45

* significant at 0.05%

4.3. Stability analysis (AMMI model)

4.3.1 Analysis of variance for AMMI analysis

The analysis of variance for AMMI is presented in Table 28. The effect by genotypes were significant for the traits, days to flowering, number of pod bearing branches, number of pods, length of pods, test weight and yield per plant. Environmental effect was significant for all the traits except plant height. Genotype x environmental interaction which is partitioned in to IPCA 1 and IPCA 2 were significant for all the traits.

Table 28 Analysis of variance for AMMI for different traits

Source of variations	df	Days to flowering	Plant height (cm)	Number of branches per plant	Number of pod bearing branches	Number of pods per plant	Length of pods (cm)	Number of seeds per pod	Test weight (g)	Protein content (%)	Yield per plant (g)
Genotypes	13	2.72*	23.65	0.44	0.41*	56.01*	0.20*	0.32	0.59*	4.13	11.64*
Environments	5	14.97*	18.72	54.83*	49.29*	1675.14*	1.94*	1.78*	0.26*	18.38*	48.23*
G x E Interaction	65	1.07	28.30	0.38	0.30	11.01	0.06	0.17	0.06	2.34	1.41
IPCA1	17	1.91*	52.32*	1.10*	0.64*	30.73*	0.14*	0.32*	0.11*	3.33*	3.91*
IPCA2	15	1.37*	30.31*	0.22*	0.36*	8.62*	0.06*	0.22*	0.07*	2.60*	0.92*
Residual	20	0.38	8.17	0.02	0.04	0.65	0.01	0.02	0.02	1.02	0.25

4.3.2 Estimates of stability parameters (AMMI model)

Genotype x environmental interaction is partitioned in to IPCA 1 and 2. The results of various stability parameters under AMMI model for the different traits are presented in Table 29a, 29b and 29c

4.3.2.1 Days to flowering

Mean values of days to flowering for treatments ranged between 34.89 of T2 and 36.79 of T14 (Table 29a). Range for environmental mean for days to flowering was broader varying between 33.79 to 36.79. Positive values for IPCA 1was showed by T2, T6, T9, T10, T11, T12, T13 and environments E1. IPCA2 values were positive in T4, T7, T8, T10, T11, T12, T13 and T14 and environments E1 and E2.

4.3.2.2 Plant height

Mean values of plant height for genotypes ranged between 38.02 cm of T14 and 45.48 cm of T8 (Table 29a). Plant height more than 45 cm was observed in T1 and T8. Range for environmental mean for plant height was narrow varying between 40.75 cm to 44.20 cm. Positive values for IPCA1 were showed by T1, T2, T5, T9 and environments E1, E2 and E3. IPCA2 values were positive in T1, T2, T3, T4, T5, T6, T11 and environments E1 and 2.

4.3.2.3 Number of branches per plant

For number of branches per plant, mean values of treatments ranged between 4.67 of T2 and 5.67 of T12 (Table 29a). Range for environmental mean for branch number was broader varying between 3.45 to 7.82. Positive values for IPCA1 was showed by T2, T6, T7, T8, T10, T11, T12, T13, T14 and environments E1 and E2. IPCA2 values were positive in T4, T5, T6, T7, T10, T12 and environments E1, E3 and E4.

4.3.2.4 Number of pod bearing branches per plant

Mean values of treatments for number of branches per plant, ranged between 4.34 of T11 and 5.25 of T12 (Table 29b). Range for environmental mean for pod bearing branches number was broader varying between 2.96 to 7.26. Positive values for IPCA 1was showed by T6, T7, T8, T12, T13 and T14 and none of environments had positive IPCA1. IPCA2 values were positive in T4, T7, T9, T10, T11, T12 and environment E4.

4.3.2.5 Number of pods per plant

For number of pods per plant mean values of treatments ranged between 34.19 of T14 and 43.04 of T8 (Table 29b). Range for environmental mean for pod number was broader varying between 29.71 to 51.57. Positive values for IPCA 1was showed by T3, T5, T6, T7, T8, T9 and environments E1 and E2. IPCA2 values were positive in T2, T4, T6, T8, T11, T12 and environments E1.

4.3.2.6 Length of pods

For length of pods, mean values of treatments ranged between 4.10 cm of T11 and 4.85 cm of T6 (Table 29b). Range for environmental mean for branch number was broader varying between 4.15 to 5.04. Positive values for IPCA 1 was showed by T6, T7, T12, T13 and environments E1 and E4. IPCA2 values were positive in T2, T4, T8, T11, T12, T13 and environments E4 and E5.

4.3.2.7 Number of seeds per pod

For number of seeds per pod, mean values of Ts ranged between 4.50 of genotype 12 and 5.27 of T 3 (Table 29c). Range for environmental mean for number of seed per pod was broader varying between 4.60 to 5.57. Positive values for IPCA 1 was showed by T1, T2, T3, T5, T7 and environments E1, E2 and E6. IPCA2 values were positive in T1, T4, T5, T6, T8, T9, T11, T12 and environments E1.

4.3.2.8 Test weight

Mean values of genotypes for test weight, ranged between 3.76 g of T8 and 4.68 g of T5 (Table 29c). Range for environmental mean for test weight was narrower varying between 4.10 to 4.50. Positive values for IPCA 1 were showed by T1, T2, T3, T4, T6, T9, T10, T11 and environments E3, E4 and E5. IPCA2 values were positive in T1, T4, T5, T10, T11 and environments E2, E3, E4 and E5.

4.3.2.9 Yield per plant

Mean values of genotypes for yield per plant, ranged between 11.99 g of T13 and 16.36 g of T6 (Table 29c). Range for environmental mean for test weight was narrower varying between12.09 to 15.96. Positive values for IPCA1 were showed by T2, T3, T6, T7, T8 and environment E3. IPCA2 values were positive in T3, T4, T6, T9, T13, T14 and environments E3, E4 and E6.

4.3.2.10 Protein content

Mean values of treatments for protein content ranged between 18.65 per cent of T12 and 21.60 per cent of T5 (Table 29c). Range for environmental mean for test weight was varying between18.36 to 21.43. Positive values for IPCA 1 were showed by T1, T2, T5, T6, T7, T8, T9 and environments E4, E5 and E6. IPCA2 values were positive in T1, T2, T8, T10, T11 and environments E4, E5 and E6.

Table 29a Mean and IPCA scores of different genotypes and environments

Genotypes	Days to flowering			Plant height (cm)			Number of branches per plant		
	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2
T1	36.58	-0.49	-1.01	45.22	3.80	1.58	4.77	-0.42	-0.47
T2	34.89	0.62	-0.45	40.75	0.25	0.92	4.67	0.12	-0.61
T3	35.85	-0.05	-0.68	41.92	-0.64	0.40	4.85	-0.42	-0.25
T4	35.66	-0.94	0.60	44.01	-1.39	1.19	4.89	-0.27	0.79
T5	36.24	-0.67	-0.38	42.42	0.07	1.16	4.90	-0.78	0.04
T6	34.80	0.20	-0.17	44.35	-0.56	1.68	4.98	0.08	0.07
T7	35.57	-0.52	0.30	43.89	-0.71	-0.86	4.98	0.27	0.27
T8	36.22	-0.64	0.19	45.48	0.42	-0.73	5.03	0.08	-0.34
T9	35.45	0.24	-0.47	42.03	0.79	-1.30	5.14	-0.18	-0.02
T10	34.94	0.16	0.00	42.45	-0.65	-1.49	5.17	0.39	0.38
T11	35.00	0.37	1.29	43.76	-2.01	1.27	4.76	0.62	-0.07
T12	36.06	1.60	0.07	43.79	2.22	-1.59	5.67	1.42	0.37
T13	36.52	0.39	0.18	41.18	-1.41	-1.56	5.32	0.45	-0.53
T14	36.79	-0.29	0.52	38.02	-0.19	-0.67	5.31	0.08	-0.07
E1	36.11	2.12	0.23	40.75	2.01	1.30	7.82	0.10	1.04
E2	36.29	-0.87	1.16	42.49	0.46	3.29	7.17	1.34	-0.83
E3	33.79	-0.27	1.06	44.20	3.38	-2.67	4.18	-0.78	0.04
E4	35.79	-0.24	-0.84	43.27	-2.63	-0.91	3.45	-0.49	0.090
E5	36.79	-0.50	-0.78	42.85	-0.58	-0.10	3.56	-0.49	-0.18
E6	35.78	-0.24	-0.83	43.27	-2.63	-0.91	3.48	-0.61	-0.15

Table 29b Mean and IPCA scores of different genotypes and environments

Genotypes	Number of pod bearing branches			Number of pods per plant			Length of pods (cm)		
	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2
T1	4.45	-0.49	-0.16	34.83	0.00	-0.18	4.43	-0.18	-0.04
T2	4.48	-0.10	-0.52	37.40	-0.82	0.37	4.53	-0.15	0.48
T3	4.54	-0.51	-0.13	40.13	1.22	-1.84	4.52	-0.20	-0.02
T4	4.70	-0.04	0.91	35.61	-1.98	0.56	4.42	-0.11	0.46
T5	4.47	-0.82	-0.10	40.91	3.32	-0.13	4.27	-0.26	-0.28
T6	4.92	0.06	-0.34	38.86	1.27	0.25	4.85	0.16	-0.26
T7	4.83	0.01	0.29	41.66	4.07	-0.62	4.38	0.07	-0.33
T8	4.53	0.14	-0.12	43.04	5.45	1.97	4.46	-0.07	0.15
T9	4.87	-0.35	0.11	38.72	1.13	-0.08	4.40	-0.34	-0.09
T10	4.73	-0.05	0.26	37.10	-0.49	-0.04	4.25	-0.29	-0.16
T11	4.34	-0.24	0.23	33.15	-4.44	0.47	4.10	-0.07	0.37
T12	5.25	1.01	0.53	34.50	-3.09	0.97	4.22	0.79	0.04
T13	4.82	0.61	-0.69	36.14	-1.45	-0.34	4.28	0.72	0.01
T14	5.08	0.74	-0.29	34.19	-3.40	-1.37	4.23	-0.06	-0.32
E1	7.26	0.97	1.12	51.57	3.29	1.92	5.04	-0.41	-0.43
E2	6.76	1.09	-0.98	51.70	1.07	-0.99	4.62	0.81	-0.30
E3	4.63	-0.72	0.14	32.73	-3.21	1.98	4.14	-0.75	-0.21
E4	3.53	-0.47	0.08	29.71	-0.51	-0.96	4.15	-0.03	0.56
E5	3.15	-0.25	-0.27	29.71	-0.51	-0.96	4.15	-0.03	0.56
E6	2.96	-0.63	-0.9	30.12	-0.13	-0.98	4.19	0.40	-0.17

Table 29c Mean and IPCA scores of different genotypes and environments

Genotypes	Number of seeds per pod			Test weight (g)			Yield per plant (g)			Protein content (%)		
	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2
T1	5.11	0.57	0.87	4.01	0.05	0.41	12.74	-0.47	-0.64	20.05	0.39	0.07
T2	4.96	0.52	-0.50	4.39	0.05	0	13.69	0.62	-0.23	19.69	0.59	0.43
T3	5.27	0.53	-0.31	4.47	0.43	-0.03	14.67	1.39	0.55	20.98	-1.06	-0.04
T4	4.90	-0.10	0.37	4.48	0.13	0.12	14.30	-0.88	0.51	19.90	-0.51	-0.24
T5	5.10	0.68	0.09	4.68	-0.22	0.02	14.54	-0.20	-0.19	21.60	0.04	-0.44
T6	5.11	-0.10	0.04	4.73	0.59	-0.52	16.36	1.21	0.30	20.44	1.07	-0.07
T7	4.85	0.14	-0.13	4.57	-0.11	-0.16	14.41	0.47	-0.71	20.93	0.36	-0.96
T8	4.97	-0.17	0.20	3.76	-0.22	-0.08	14.40	0.78	-0.37	21.14	0.30	1.09
T9	5.05	-0.50	0.05	4.43	0.07	0	14.10	-0.09	1.17	20.07	1.35	-0.23
T10	4.80	-0.04	-0.34	4.36	0.41	0.07	15.92	-1.25	-0.01	20.33	-0.97	0.61
T11	4.56	-0.66	0.30	4.20	0.06	0.63	12.19	-0.07	-015	19.95	-0.07	1.49
T12	4.50	-0.17	-0.09	3.95	-0.40	-0.44	12.37	-0.20	-0.65	18.65	-1.20	-0.41
T13	4.80	-0.30	-0.53	3.98	-0.57	0	11.99	-0.49	0.15	19.14	-0.13	-0.61
T14	4.56	-0.40	0	3.85	-0.29	0	12.12	-0.82	0.27	19.23	-0.15	-0.71
E1	5.57	0.47	1.13	4.21	-0.61	-0.40	15.85	-0.49	-1.05	18.36	-1.39	-1.39
E2	4.95	0.03	-0.38	4.21	-0.56	0.76	15.96	0.35	-0.47	20.31	-0.57	-0.57
E3	4.90	-0.81	-0.17	4.50	0.75	0.10	14.64	2.45	0.27	21.43	-0.76	-0.76
E4	4.68	-0.40	0	4.31	0.27	0.06	12.32	-0.67	0.06	21.07	0.95	0.95
E5	4.68	-0.40	0	4.31	0.27	0.06	12.20	-0.84	-0.31	20.45	1.49	1.49
E6	4.60	1.08	-0.60	4.10	-0.12	-0.57	12.09	-0.81	1.49	19.28	0.29	0.29

Discussion

5. DISCUSSION

Pulses are important in our daily diet as they are a good source of protein. Pulses are high in fiber, have low fat, no cholesterol, high protein, low glycemic index and high nutrient foods. Pulses are the sole source of protein for the vegetarian population. Mung bean and blackgram have been the major pulses in Asia since ancient times (Paroda and Thomas 1987). Blackgram has been identified as a high yielding pulse in many Asian countries (Smartt, 1990).

In India, Black gram (*Vigna mungo* L.), is one of the important pulse crop, grown throughout the country. The pulse 'Black gram' plays an important role in Indian diet, as it contains vegetable protein and supplement to cereal based diet. Black gram is a rich protein food, consumed in the form of split pulse as well as whole pulse, which is an essential supplement of cereal based diet. The combination of dal-chawal (pulse-rice) or dal-roti (pulse-wheat bread) is an important ingredient in the average Indian diet. The biological value improves greatly, when wheat or rice is combined with black gram because of the complementary relationship of the essential amino acids such as arginine, leucine, lysine, isoleucine, valine, phenylalanine etc.

Black gram also plays an important role in sustaining soil fertility by improving soil physical properties and fixing atmospheric nitrogen. Being a drought resistant crop, it is suitable for dryland farming and predominantly used as an intercrop with other crops. It can be raised as a catch crop after the harvest of the main crop which can come up well in residual soil moisture.

Black gram, one of the most important grain legumes of Kerala, is cultivated in uplands during *rabi* season and in summer rice fallows during the third crop season. However, the trend of cultivating blackgram got decreased in the recent past due to many factors. One of the major factor is lack of high yielding varieties stable over environments with determinate plant habit, which can tolerate weed growth.

The present work has been formulated with the objective of identifying the genotype x environment interaction of stable blackgram cultures developed in the Department of Plant breeding and Genetics by hybridization followed by selection. The identified cultures were having higher yield and good plant habit with medium plant height and more number of branches which can tolerate weeds.

The experiment was conducted with 10 blackgram cultures and four check varieties under three dates of sowing. Two varieties released by KAU, namely, Syama and Sumanjana and two varieties T9 and TAU 1 which were found to be superior by the previous studies in the Department were used as check varieties. The trials were undertaken under open condition to find out cultures which will be performing better under open condition to raise as sole crop in paddy lands as a summer crop. The second trial was conducted as an intercrop in coconut garden to find out a suitable culture to be used as an inter crop in coconut garden. The results of the study are discussed below.

5.1 Performance of blackgram genotypes under each environment

Black gram is cultivated in different seasons in India in *kharif* (rainy season) as a mixed crop with cereals and pigeon pea and *rabi* and *zabi* (spring and summer) as pure culture (Bhareti *et al.*, 2011). In Kerala it is cultivated as an intercrop in uplands during *kharif* and *rabi* season and as a pure crop during *rabi* and summer in rice fallows. Hence, the present study was undertaken during three seasons under both light and shaded condition.

5.1.1 Performance of blackgram genotypes under environment 1.

Black gram cultures showed wide variability in yield and other traits except days to flowering, number of pod bearing branches and number of seeds per pod in the first environment. Ghafoor *et al.* (1998), reported that pod length and seeds per pod do not exhibit much variation. According to Ghafoor *et al.* (2001), medium to high variance was observed for days to flowering, maturity, number of branches and pods, pod length, biomass and grain yield. Studies by Priti *et al.* (2006) indicated existence of variability for characters except pod length, number of seeds per pod, 100 seed weight and protein content in blackgram. Razvi *et al.* (2011), observed high variability for days to flowering, number of pods per plant, pod length, seeds per pod, seed yield and protein content. Existence of high variability for plant height, inflorescence number, pods per plant and yield per plant and moderate diversity for pod length and seeds per pod was observed by Majumder *et al.* (2011).

PCV and GCV values were classified as low (< 10%) moderate (10-20%) and high (>20%) by Sivasubramanian and Madhavamenon (1973). Genetic advance as per cent of mean was classified as low (< 10%) moderate (10-20%) and high (>20%) by Johnson *et al.* (1955).

The traits, number of pod bearing branches, length of pods, yield per plant and protein content showed low phenotypic (PCV) and genotypic (GCV) coefficient of variation. These traits were having low genetic advance also. Moderate PCV, low GCV and moderate GA as per cent of mean was observed for number of seeds per pod. All other traits showed moderate PCV, GCV and high GA.

Gandhi *et al.* (2012), observed high PCV, GCV and heritability for plant height, number of branches per plant, days taken for first flowering, clusters per plant, pods per plant, seeds per pod, seed yield per plant, 100-seed weight, protein and amino acid content.

Johnson *et al.* (1955), categorized heritability values as low (30%), medium (30-60%) and high (>60%). As per this classification all the traits except protein content exhibited high heritability. High heritability accompanied with high GA indicates that the heritability is due to additive gene effects and selection may be effective for these traits (Nadarajan and Gunasekharan, 2008). As per this criteria the traits, days to flowering, plant height, number of branches, number of pods and test weight were under the influence of additive gene action and selection can improve these traits. Priti *et al.*

(2006), observed high heritability and genetic advance for number of branches per plant, pods per plant and yield per plant.

High heritability coupled with high genetic advance as per cent mean was observed for plant height, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant by Reddy *et al.* (2011). However, Gandhi *et al.* (2012), observed low heritability for plant height and yield per plant. In the present study high heritability accompanied by moderate or low GA was observed for number of pod bearing branches, length of pod, number of seeds per pod and yield per plant. This indicate the prevalence of non additive gene action and ineffectiveness of selection to improve the traits. Low heritability accompanied by low genetic advance observed in protein content shows the prominent effect of environment on these traits.

5.1.2 Performance of blackgram genotypes under environment 2

Variability available with the tested genotypes were significant for all the traits in the second environment. Panigrahi *et al.* (2014), observed a wide range of variation for ten yield attributing characters in blackgram. However, studies by Ghafoor *et al.* (2001) observed lesser variance for seeds per pod and 100 seed weight. Priti *et al.* (2006), observed less variability for pod length, number of seeds per pod, test weight and protein content. Days to flowering, plant height, number of branches and test weight showed moderate PCV and GCV. Low PCV and GCV values were exhibited by number of pod bearing branches, number of pods, length of pod, number of seeds per pod, yield per plant and protein content. Reddy *et al.* (2011), reported that heritability in broad sense was high for all the characters except for number of seeds per pod and pod length. High heritability coupled with high genetic advance as per cent mean was observed for plant height, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant.

Selection can be attempted for the improvement of characters like, days to flowering, plant height, number of branches and test weight where, the traits exhibited high values for genetic advance as well as heritability. For other traits heritability was high, however, the GA value was moderate or low indicating the effect of non additive gene action.

5.1.3 Performance of blackgram genotypes under environment 3

The characters days to flowering, number of pods, number of seeds per pod and test weight showed no variability under the third environment. Ghafoor *et al.* (1998), observed a range of 64 days to 115 days for days to maturity. Ramya *et al.* (2014), observed high variance for primary branches per plant, number of pods per plant and single plant yield. Moderate PCV and GCV were showed by the traits plant height, number of pods per plant and yield per plant. Gandhi *et al.* (2012), observed high PCV and GCV for characters plant height, number of branches per plant, days to first flowering, clusters per plant, pods per plant, seeds per pod, seed yield per plant, 100-seed weight, protein and amino acid content. In the present study none of the traits showed high PCV and GCV. Moderate PCV and low GCV was showed by traits days to flowering and number of branches per plant. Both PCV and GCV were low for the traits number of pod bearing branches, length of pod, number of seeds per pod, test weight and protein content.

Additive gene action can be attributed to traits plant height, number of branches per plant, number of pods per plant and yield per plant which were having high heritability and high genetic advance. Reddy *et al.* (2011), also observed high heritability coupled with high genetic advance for plant height, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant. Days to flowering had moderate genetic advance and high heritability. All other traits except number of pod bearing branches were having low genetic advance and high heritability indicating influence of non additive gene action. Number of pod bearing branches had low genetic advance and moderate heritability indicating the influence of environment on this character.

5.1.4 Performance of blackgram genotypes under environment 4

Days to flowering, plant height, number of pod bearing branches, number of pods, length of pods, number of seeds per pod, yield per plant and protein content showed variation under fourth environment. Low values of PCV and GCV were exhibited by most of the traits. Plant height and yield per plant had medium values for PCV and GCV while number of pods per plant had moderate PCV and low GCV. Characters which are amenable for selection were plant height and yield per plant where the GA and heritability values were high. Non additive gene action had influence over the traits, days to flowering, number of branches, length of pod, number of seeds per pod and test weight. High environmental influence was noticed for traits like number of pod bearing branches and length of pod. Majumder *et al.* (2011), observed moderate heritability and genetic advance for pod number, plant height and yield per plant.

5.1.5 Performance of blackgram genotypes under environment 5

Under environment five, number of branches, number of pod bearing branches, length of pods and number of seeds per pod were not showing any variation. Moderate PCV and GCV were showed by traits like plant height and yield per plant. Number of pods had moderate PCV and low GCV. All other traits showed low values for PCV and GCV. High heritability and high GA were observed for the traits plant height and yield per plant indicating the importance of additive gene action and possibility of exerting selection in the population to improve the traits.

Ramya *et al.* (2014), observed high heritability per cent and high genetic advance as percentage of mean for number of primary branches and seed yield per plant. In the present study, number of pod bearing branches, number of seeds per pod and test weight recorded low genetic advance and high heritability indicating the importance of non additive gene action in determining these traits.

Sowmini and Jayamani (2013), observed high genetic advance as per cent of mean for plant height, number of clusters per plant, number of pods per plant, single plant yield and hundred seed weight. High heritability coupled with high genetic advance as per cent of mean was observed for hundred seed weight only. Low genetic advance and moderate heritability was observed for days to flowering and length of pod indicating the influence of environment for these traits.

5.1.6. Performance of blackgram genotypes under environment 6

All the traits except number of branches and number of seeds per pod showed wide variability in the tested environment. Moderate PCV and GCV were exhibited by the traits plant height, yield per plant and protein content. Days to flowering, number of branches per plant number of pod bearing braches, length of pod and test weight showed low values for both PCV and GCV. Other traits had moderate PCV and low GCV. As per this study, improvement through selection is possible only in traits plant height and yield per plant where high values of both heritability and genetic advance were observed. Days to flowering, number of branches and length of pod showed predominance of non additive gene action which is evident from low values of genetic advance and high heritability.

5.2 Genotype x environment interactions

5.2.1 Comparison of genotypes over seasons

Comparison of blackgram genotypes for important traits in different seasons showed that there is variation of the performance of individual genotypes under different environments.

5.2.1.1. Days to flowering

The comparison of days to flowering of genotypes of blackgram are presented in Figure 1. Days to flowering of the genotypes varied between different environments. Most of the genotypes showed early flowering during the environment 3 and late flowering in environment 5. Both the environments were under open condition indicating that there is no effect of light intensity on flowering of the genotypes.

According to Joseph *et al.* (unpublished) when the varieties get an accumulated photothermic index (PTI) of 250 and above the plants enter in to reproductive phase. Hence, it can be inferred that the genotypes might have received this PTI early during the rabi season and late during the summer season. According to Mavi and Tupper (2005), temperature stress intensity is severe under late sowing, causing reduction in the duration of later growth phases, leading to acquisition of lesser days to mature. In the present study this explanation can not hold good as early flowering was observed during rabi season where temperature stress is less and late flowering during summer season where temperature stress can be high. Agrawal *et al.* (2004), reported that agroclimatic indices for various phenological stages are known to be influenced by sowing dates in summer blackgram.

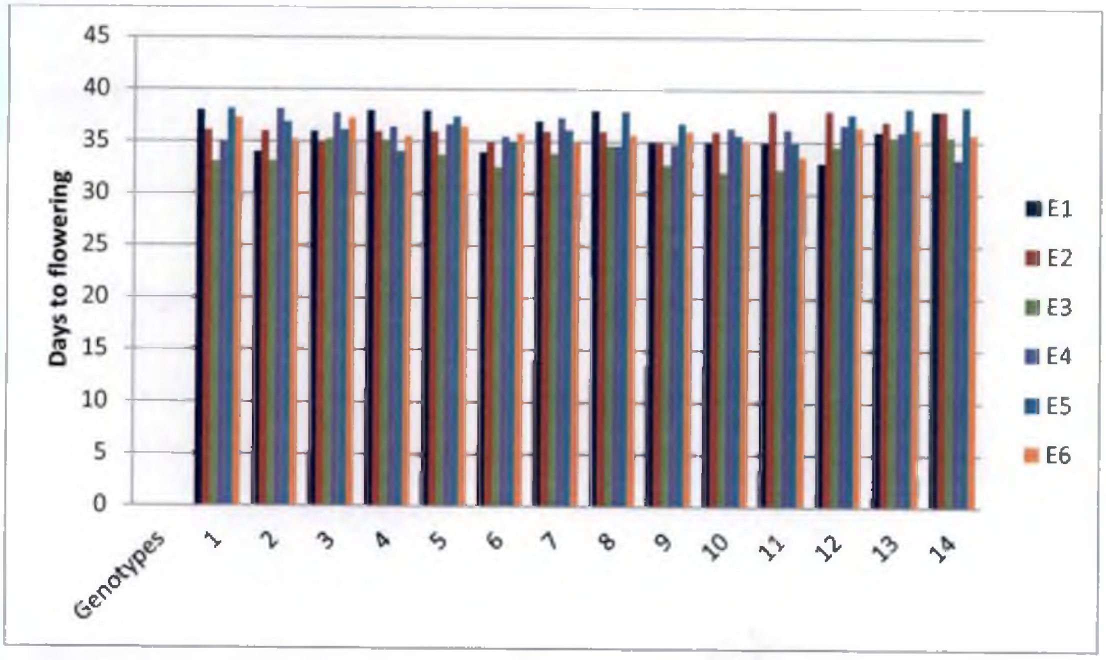

Figure 1. Comparison of days to flowering under different environments

5.2.1.2. Comparison of plant height under different environments

Comparison of plant height under different environments are presented in Figure 2. It shows that there was no specific pattern for the expression of plant height. Six of the genotypes were taller under the environment 4 which is shaded condition under rabi season and four genotypes were taller under E3 which is again *rabi* season under open condition. Hence, it can be inferred that during *rabi* season plants should have received more favorable condition for plant growth. As per the study by Singh *et al.* (2013) by raising the blackgram crop under four dates (10th March, 15th March, 20th March and 25th March) of sowing for three consecutive years, at Punjab Agricultural University, Ludhiana, maximum plant height was recorded in plants sown on 20th March which was significantly higher than the other sowing dates. This also indicate the effect of date of sowing on determining the plant height. Studies by Vijayalaxmi, (2013), showed that genotypes showed reduction in plant height under late sowing during first week of January where the normal sowing was done during second week of November. However, the rate of reduction in plant height was depended on genotype.

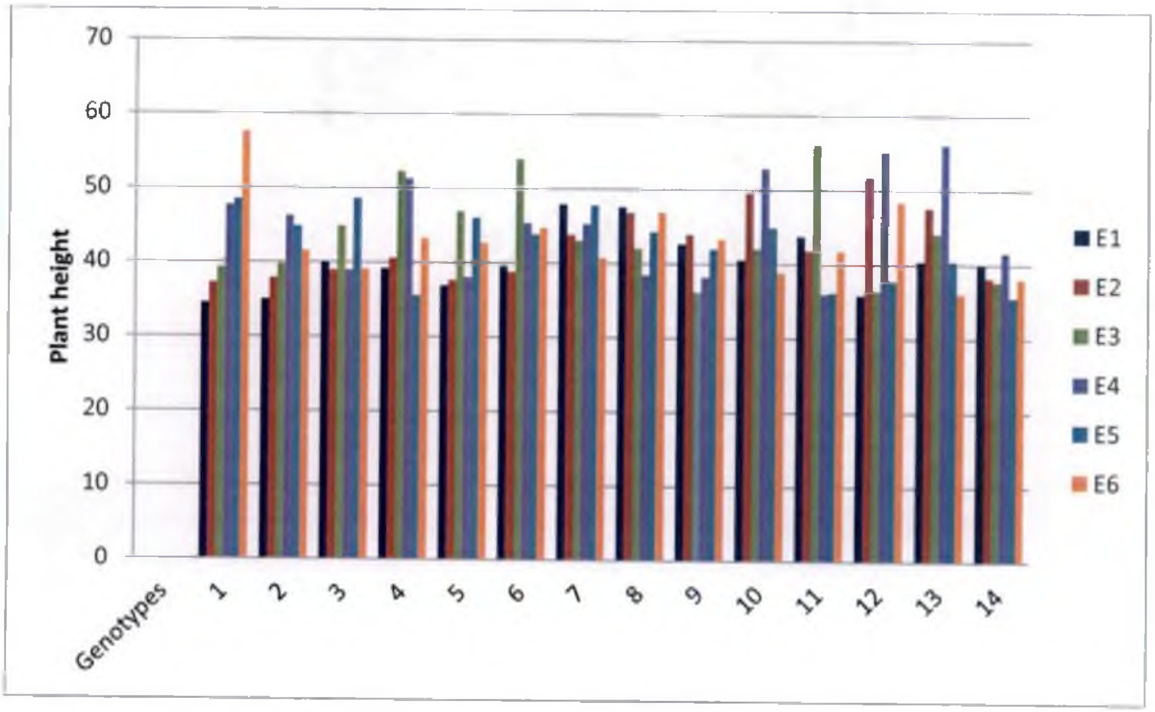

Figure 2. Comparison of plant height under different environments

5.2.1.3. Comparison of number of branches under different environments

Comparison of total number of branches produced by different genotypes under six environments is presented in Fig. 3. It showed that eleven genotypes were having maximum number of branches under environment one. The environment represented open condition during *kharif* season. The remaining three genotypes were having maximum number of branches under environment two that is shaded condition during *kharif* season. This also indicate that the availability of adequate soil moisture might have resulted in good plant growth and development. Singh *et al.* (2013), by raising the blackgram crop under four dates of sowing for three consecutive years reported maximum branches per plant was recorded in 15th March sowing which was, at par with 10th and 20th March sowings, all these three being significantly higher than 25th March sowing. This report also indicate the influence of planting date on number of branches per plant.

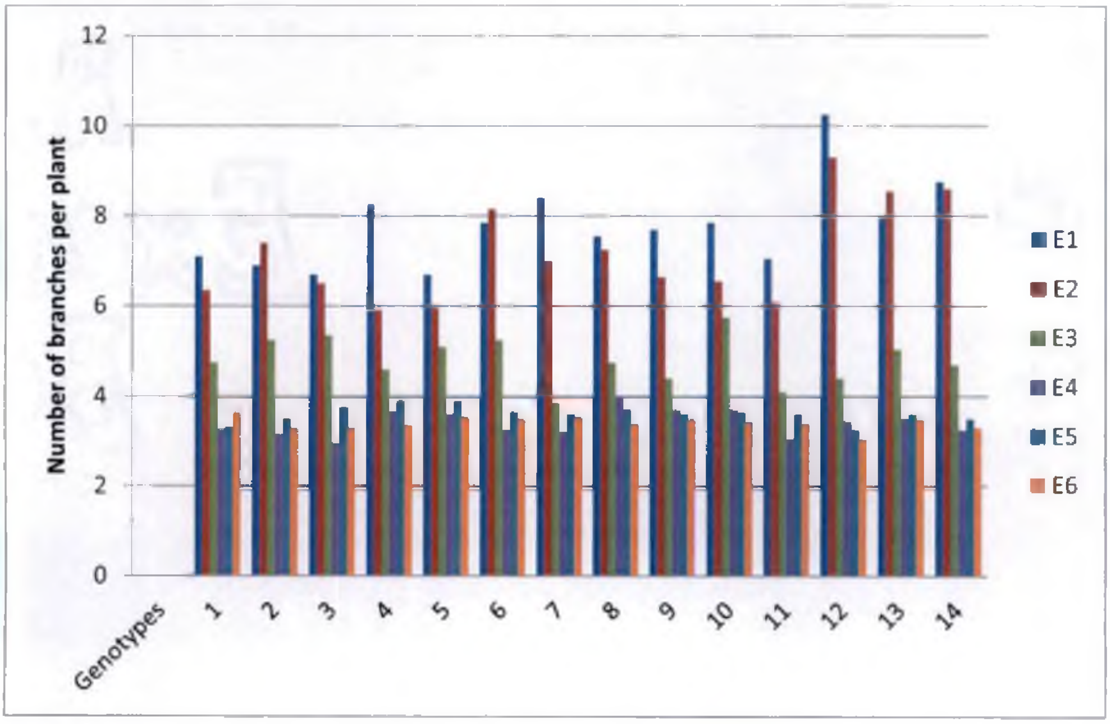

Figure 3. Comparison of number of branches under different environments

5.2.1.4 Comparison of number of pod bearing branches under different environments

Comparison of number of pod bearing branches produced by different genotypes under six environments are presented in Figure 4. It showed that eleven genotypes were having maximum number of pod bearing branches under environment one. The environment represented open condition during *kharif* season. The remaining three genotypes were having maximum number of pod bearing branches under environment two that is shaded condition during *kharif* season. This also indicate that the availability of adequate soil moisture might have resulted in good plant growth and development of the total number of branches as well as number of pod bearing branches.

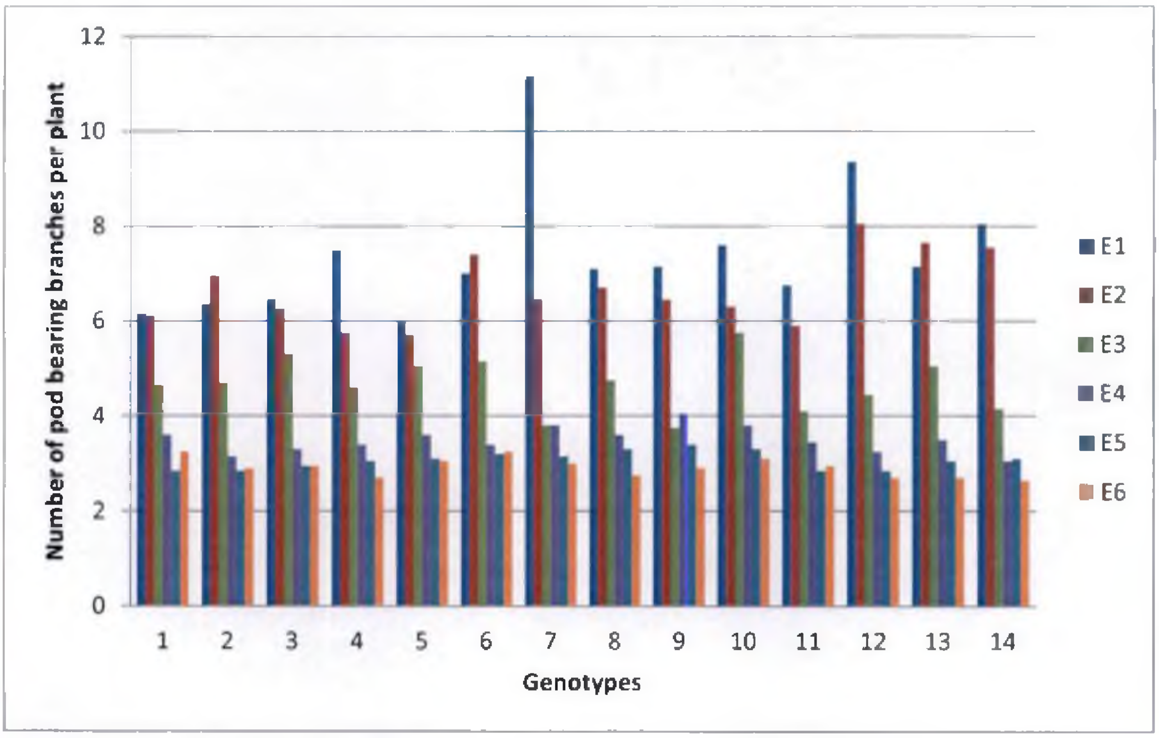

Figure 4. Comparison of number of pod bearing branches per plant under different environments

5.2.1.5. Comparison of number of pods per plant under different environments

Comparison of number of pods produced by different genotypes under six environments are presented in Figure 5. It showed that seven genotypes were having maximum number of pods under environment one. The environment represented open condition during *kharif* season. The remaining seven genotypes were having maximum number of pod bearing branches under environment two that is shaded condition during *kharif* season. This indicate that the development of pods also might have depend on availability of adequate soil moisture during the *kharif* season rather than the intensity of light. This might have resulted in good plant growth and development of the total number of branches as well as number of pods. Singh *et al.* (2013), by raising the blackgram crop under four dates during March for three consecutive years reported that 20[th] March sowing recorded the maximum pods per plant (21.1), which was significantly higher than all other dates of sowing. Kumar *et al.* (2008), reported that the maximum number of pods per plant was recorded under 20[th] March sown summer greengram indicating the effect of planting dates on the development of pods in pulses.

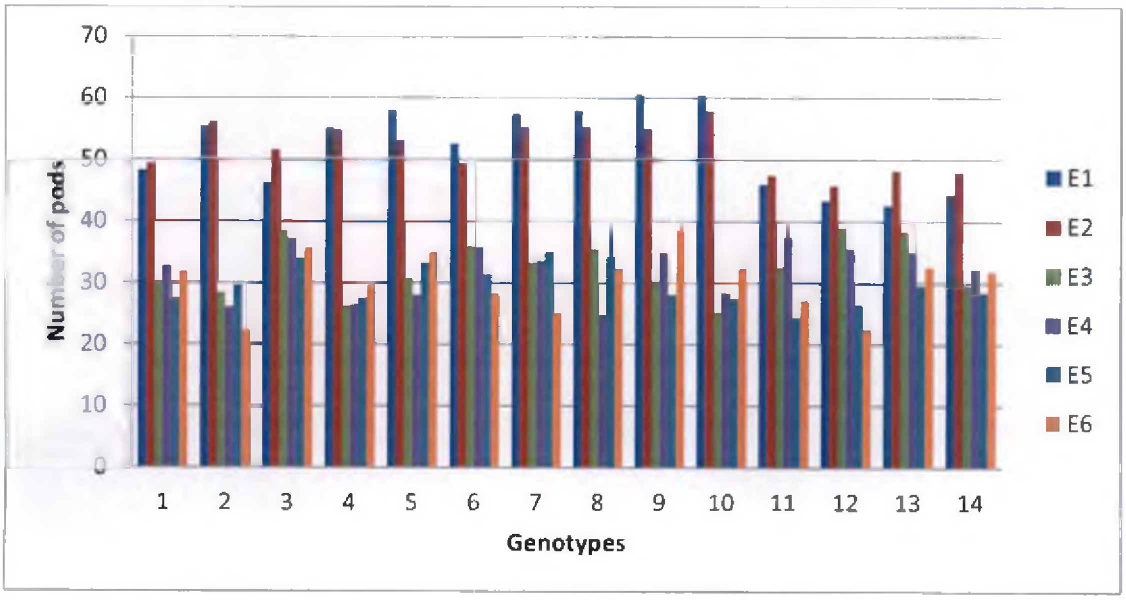

Figure 5. Comparison of number of pods per plant under different environments

5.2.1.6 Comparison of length of pods under different environments

Comparison of length of pods produced by different genotypes under six environments are presented in Figure 6. It showed that thirteen genotypes were having maximum pod length under environment one which represented open condition during *kharif* season. One genotype had long pods under environment three that is open condition during *rabi* season. This also indicate the size of pods might be depending on availability of adequate soil moisture as well as intensity of light.

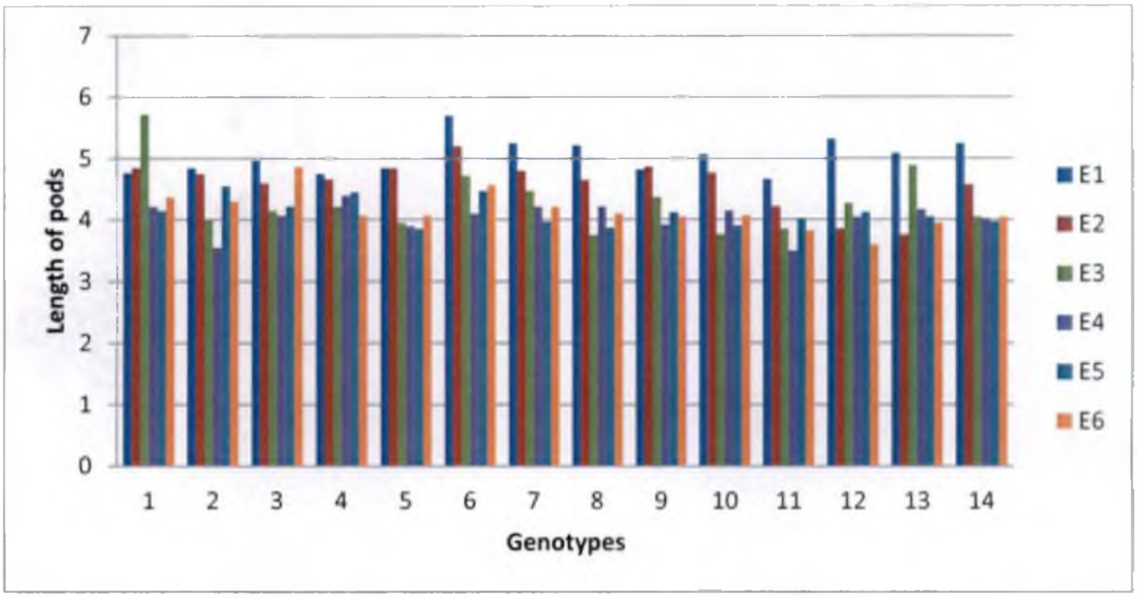

Figure 6. Comparison of length of pods under different environments

5.2.1.7 Comparison of number of seeds per pod under different environments

Comparison of number of seeds per pod over environments are presented in Figure 7. It indicated that high number of seeds per pod are seen in nine genotypes under environment one which is open condition during *kharif* season and three genotypes had high number of seeds under environment four that is shaded condition under *rabi* season. This suggests that even though the sowing date is having effect on the development of seeds in blackgram the effect of light intensity is negligible. Singh *et al.* (2013), by raising the blackgram crop under four dates of sowing for three consecutive years reported that seeds per pod was at par in 10[th], 15[th] and 20[th] March sowings, which was significantly higher than 25[th] March sowing. Kumar *et al.* (2008), also reported that the maximum number of grains per pod were recorded under 20[th] March sown summer greengram.

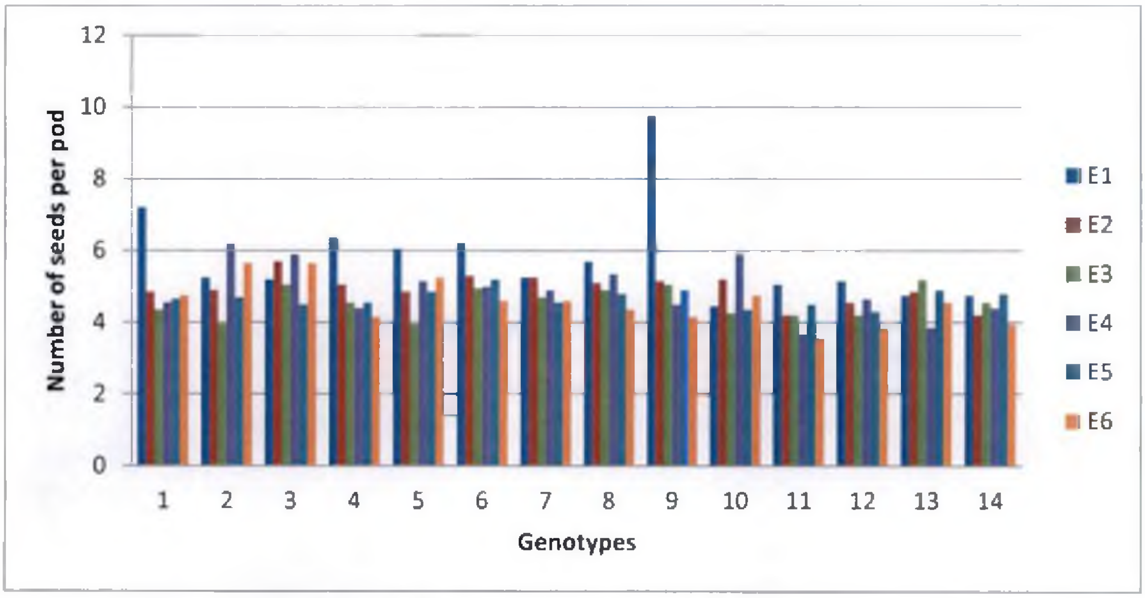

Figure 7. Comparison of number of seeds per pod under different environments

5.2.1.8 Comparison of test weight under different environments

Comparison of test weight over environments are presented in Figure 8. It indicated that high test weight was showed by six genotypes under environment four which is shade condition during *rabi* season and four genotypes had high test weight under environment two that is shaded condition under *kharif* season. Two genotypes had high test weight under environment one that is open condition under *kharif* season. The effect of season or intensity of light can not properly explain the development of heavier seeds in blackgram under the present study. Singh *et al.* (2013), by raising the blackgram crop under four dates of sowing for three consecutive years reported the 100-seed weight was higher in 10[th] and 15[th] March sowings than in 20[th] and 25[th] March sowings. Kumar *et al.* (2008), reported that the maximum number of pods per plant, number of grains per pod and 100-grain weight were recorded under 20[th] March sown summer greengram.

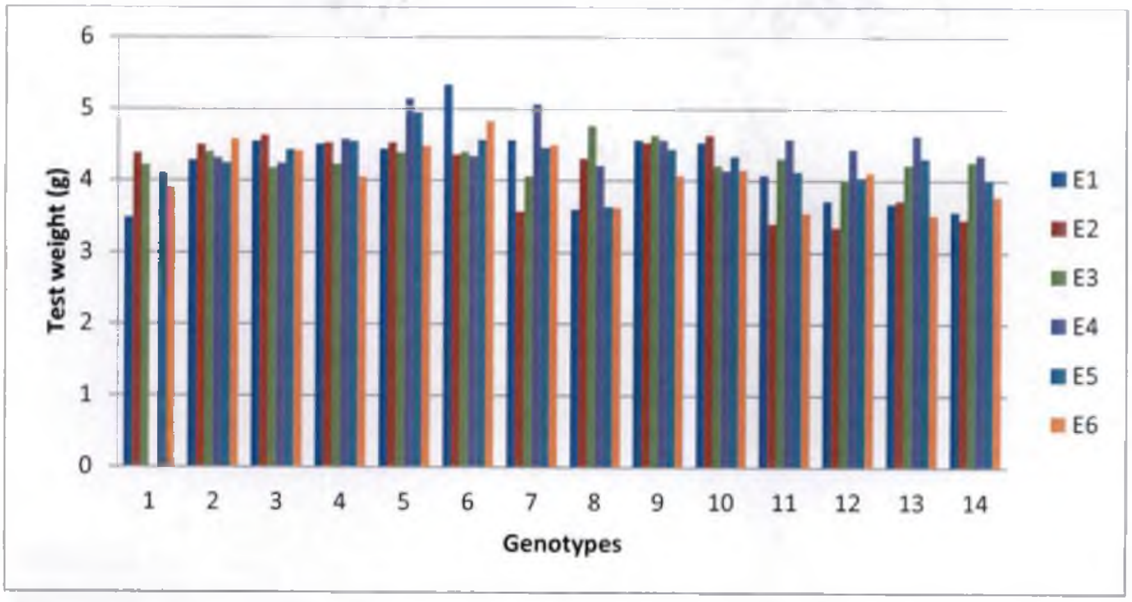

Figure 8. Comparison of test weight under different environments

5.2.1.9. Comparison of yield per plant under different environments

Comparison of yield per plant under different environments are presented in Figure 9. It showed that eight genotypes showed high yield under environment one which is representing open condition during *kharif* season. Six genotypes were having higher yield under environment 2 (shade condition under *kharif* season). Irrespective of the light intensity, season have more effect on yield. Assured soil moisture due to rains during the season can be the reason for high yield of the genotypes during *kharif* season.

Singh *et al.* (2013), by raising the blackgram crop under four dates of sowing for three consecutive years reported the grain yield was highest in 20th March sown crop, which was significantly higher than in other sowing dates. Similar findings have been reported by Kumar *et al.* (2007), in spring blackgram. Blackgram sown on 20[th] March registered 17.2, 3.2 and 4.5 per cent higher grain yield over 10[th], 15[th] and 25[th] March sowings, respectively. Studies by Vijayalaxmi (2013), observed variations for seed yield between genotypes under normal and late sowing conditions. Seed yield ranged between 4.46 g per plant to17.58 g per plant under normal sowing done during second week of November. However, the yield of genotypes ranged between 1.42 g per plant and 5.06 g per plant under late sowing during first week of January. Reduction in yield per plant during late sown crop was depended on genotype. High temperature during the grain filling stage of the crop affected seed development and reduced seed size and seed number per plant.

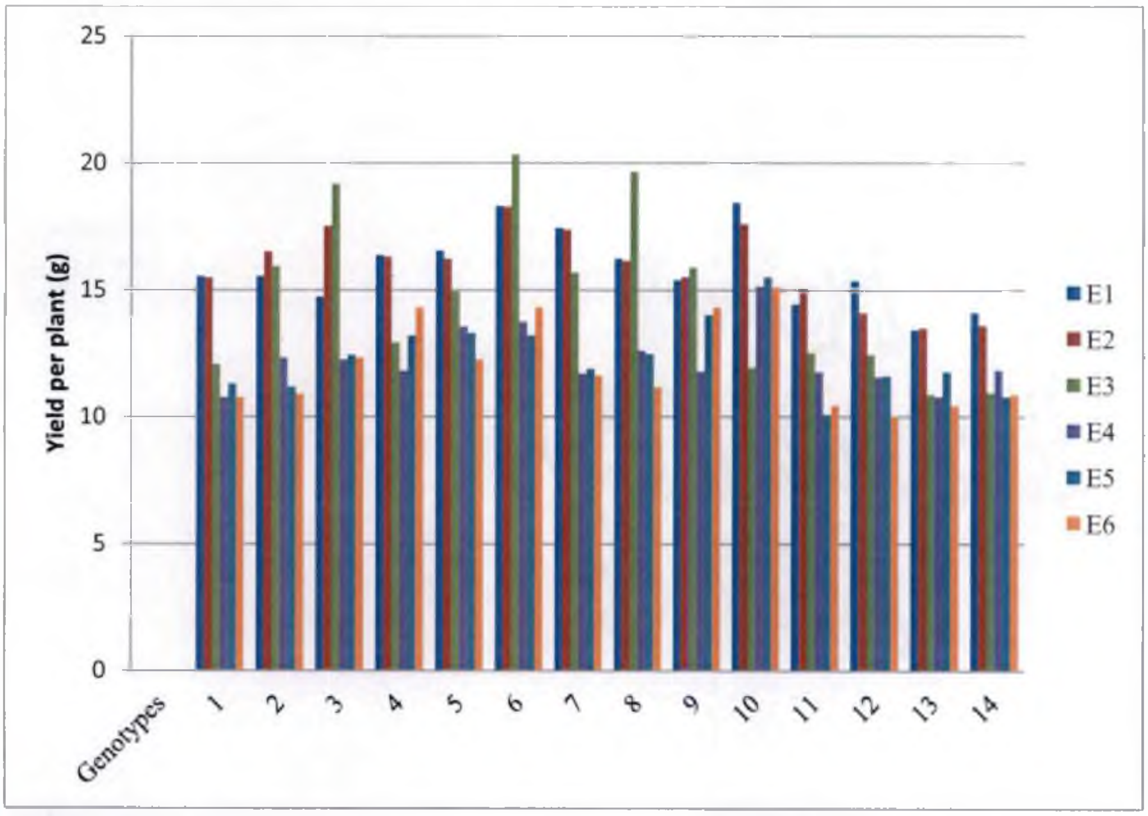

Figure 9. Comparison of yield per plant under different environments

5.2.1.10. Comparison of protein content under different environments

Comparison of protein content under different environments are presented in Figure 10. It shows that seven genotypes were showing high protein content under environment 4 (shade condition during *rabi* season) and five genotypes with high protein content under environment 3 (open condition during *rabi* season). It is evident that season is having more effect on protein content than the light intensity.

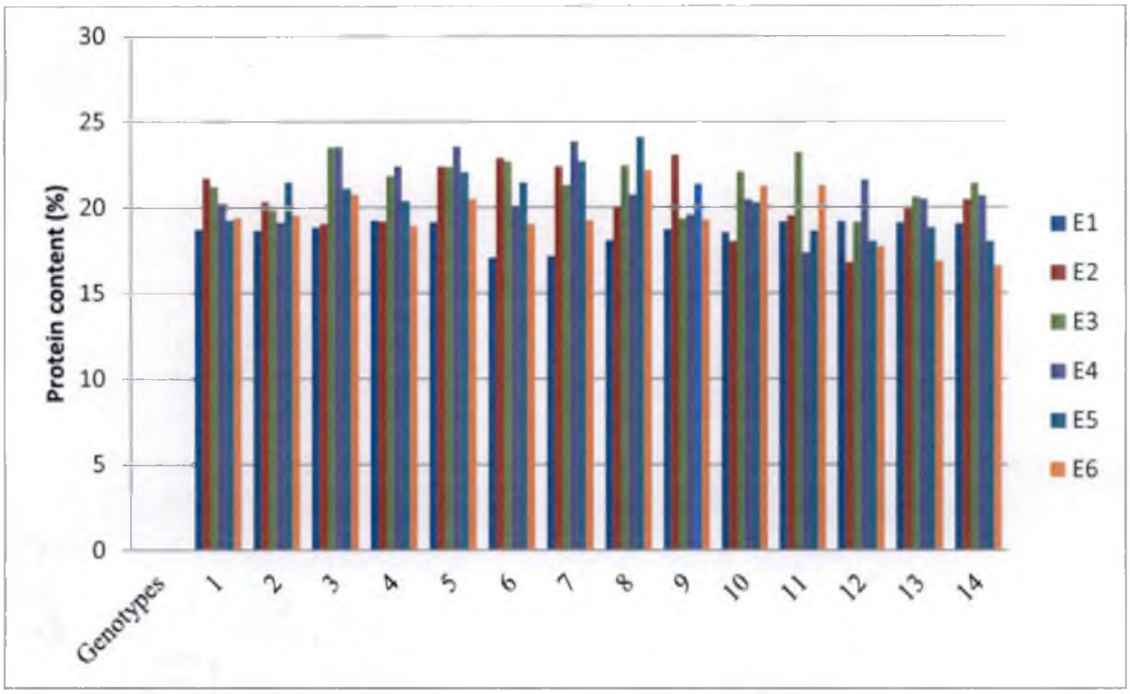

Figure10. Comparison of protein content under different environments

Comparison of performance of genotypes under six environments showed that plants early flower during *rabi* season. Most of the genotypes were showing better performances during *kharif* season indicating that the soil moisture available during the season is helping for good plant growth and yield.

5.2.2. Comparison of genetic components over seasons.

The present study conducted over six environments showed that genotypes differed with respect to many characters and the magnitude of variability differed between seasons. Phenotypic and genotypic variation observed in black gram genotypes under six environments showed that the traits were showing either medium or low phenotypic and genotypic coefficient of variation. Parameswarappa (1989), observed wide range of variability in blackgram genotypes and the magnitude of variability differed in different seasons.

Additive gene action expressed by high heritability and high genetic advance was observed for days to flowering, plant height, number of branches, number of pods and test weight under environment one while, days to flowering, plant height, number of branches and test weight showed additive gene action under second environment. Plant height, number of branches, number of pods and yield were having additive gene action under third environment. Under environment four, five and six, plant height and yield per plant were the only traits controlled by additive gene action. Based on the observation over all the environments, plant height was found to be controlled by additive gene action and hence, selection can improve the trait. Seed yield showed additive gene action under four environments suggesting possible improvement of seed yield by selection.

Non additive gene action was found to be influencing the traits, number of pod bearing branches, length of pod and seed yield under environment one. While, number of pod bearing branches, number of pods, length of pod, seeds per pod and yield per plant was influenced by non additive gene action under the second environment. Days to flowering, pod length, seeds per pod and test weight showed non additive gene action under third environment. Days to flowering, number of branches per plant, number of pods, length of pods, seeds per pod and test were under the influence of non additive gene action under fourth environment. Number of pod bearing branches, number of pods, seeds per pod, test weight and protein content were influenced by non additive gene action under fifth environment and days to flowering, number of branches, number of pods, length of pod, test weight and protein content under environment six. Length of pod was influenced by non additive gene action under five environments and test weight under four environments indicating the predominance of non additive gene action in determining the traits.

The traits protein content, number of pod bearing braches, days to flowering, length of pods and seeds per pod showed greater influence of environment in one or two environments.

5.3. Stability parameters

One of the major objective in any plant breeding programmes is the selection of genotypes that are consistently high yielding over a range of environments. This selection is often ineffcient due to genotype x environment interactions and the failure of genotypes to have the same relative performance in different environments. Genotype x environment interaction is important for plant breeding because it affects the genetic gain and recommendation and selection of cultivars with wide adaptability (Deitos *et al.*, 2006 and Souza *et al.*, 2009).

Environment is the sum total of physical, chemical and biological factors. G x E interactions have major importance to plant breeder in developing improved varieties. According to Nath and Dasgupta (2013), low levels of interactions are useful for some characters so as to maximize the stable performance over a number of environments and for some situation high interactions are beneficial and can be explored.

5.3.1 Stability parameters (Eberhart and Russel model)

The process of identification of stable genotype is difficult because of G x E interaction. Various attempts have been made to characterize the behaviors of genotypes in response to varying environments. Statistical approach by Finlay and Wilkinson (1963) has proved to be useful to measure the phenotypic stability in the performance of genotype. This regression analysis was improved by Eberhart and Russell (1966). They introduced deviation from regression (S^2di) which accounts for unpredictable irregularities in the response of genotypes to varying environments.

Eberhart and Russell (1966) defined a stable genotype as one which showed high mean yield, regression coefficient around unity and deviation from regression near to zero. Later Breese (1969); Samuel *et al.* (1970); Crossa *et al.* (1977) and Chaudhary

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Eberhart and Russell (1966) defined a stable genotype as one which showed high mean yield, regression coefficient around unity and deviation from regression near to zero. Later Breese (1969); Samuel *et al.* (1970); Crossa *et al.* (1977) and Chaudhary and Paroda (1980), advocated that linear regression could simply regarded as measure of response of a particular genotype, where the deviation from regression as a measure of stability.

5.3.1.1 Stability parameters (Eberhart and Russel model) pooled over open conditions

The data was collected from blackgram genotypes grown under open and shaded condition under three dates of sowing to identify a suitable genotype for open condition and shade condition. Pooled ANOVA over three open conditions were significant for all the characters indicating the effect of genotype and environment in determining the character. Hence, the phenotypic stability analysis of blackgram was done for each character and discussed character wise.

5.3.1.1.1 Days to flowering

Days to flowering did not show any variation between the dates of planting under open condition indicating that the character is highly stable. However, studies by Senthilkumar and Chinna, (2012); Sowmini and Jayamani, (2013) and Singh *et al.* (2013), reported significant variations between days to flowering in blackgram genotypes. Senthilkumar and Chinna, (2012), also observed non significant mean squares for pooled deviation for days to flowering in blackgram genotypes. Raturi *et al.* (2012), observed significant G x E interaction for days to flowering in greengram.

5.3.1.1.2 Plant height

For plant height, even though the mean values ranged between 36.65 cm of T12 and 46.27 cm of T7, only T8 had significant bi value. However, significant S^2di values was showed by many genotypes and T5, T7, T9, T13 and T14 were stable. As the height of the plant has effect on canopy coverage and hence tolerance to weed infestation, genotypes having tall plant stature is a desirable trait. However, tall plants may have indeterminate growth resulting in difficulty in harvest. Hence, a medium height of 40-50 cm is preferred in the present study. Based on all these criteria, stable genotypes T5, T7, T9 and T13 with good plant height and non significant bi and S^2di values can be identified. Senthilkumar and Chinna (2012) observed highly significant differences for plant height over three diverse environments. Out of thirty five genotypes they tested only three genotype showed high mean value and stable performance for plant height. Bais *et al.* (2007), observed significant G x E interaction for plant height in mungbean.

5.3.1.1.3. Number of branches per plant

None of the genotypes had significant bi value. However, five genotypes had significant S^2di values and hence, nine genotypes were stable for branches per plant. Senthilkumar and Chinna (2012), observed highly significant differences for number of branches per plant for thirty five blackgram genotypes over three diverse environments. Out of thirty five genotypes they tested only two genotype showed high mean value and stable performance for number of branches per plant indicating the influence of environment in determining the trait in blackgram. Raman and Sinhamahapatra (2012), observed stable performance for number of branches per plant in blackgram when four genotypes were tested in six environments. Raturi *et al.* (2012), reported significant G x E interaction for primary branches per plant in greengram. They could identify eight stable genotypes for number of primary branches. Katiyar and Sarial (1987), observed that the G x E interaction for branches per plant was non significant in pigeon pea.

5.3.1.1.4. Number of pod bearing branches per plant

Significant bi value was showed by T8 and significant S^2di value was showed by T7. All other genotypes were showing stability for number of pod bearing branches per plant. Among these stable genotypes having high number of pod bearing branches per plant can be considered as superior. Rasul *et al.* (2012), suggested that branching is basically a genetic factor but environmental conditions may also influence the number of pod bearing branches per plant and play an important role in enhancing seed yield.

5.3.1.1.5. Number of pods per plant

For the character, number of pods per plant significant bi value was showed by T1, T9 and T14. While, significant S^2di values were showed by T12. The genotypes T5, T7 and T8 with non significant bi and S^2di value and pods more than 40 per plant can be considered as superior. Senthilkumar and Chinna (2012), observed the genotypes HG 157 and LBG 623 were having high mean value and were stable over three environments for the character number of pods per plant. Manivannan *et al.* (1998), observed good stability for pods per plant in three genotypes in greengram. Nath and Dasgupta (2013), identified nine genotypes with high number of pods and bi value close to zero in greengram.

5.3.1.1.6. Length of pod

Length of pod did not show any variation between the three dates of sowing under open condition. However, studies in greengram by Nath and Dasgupta (2013) reported highly significant differences between genotypes and environment for length of pod. Significant G x E inereaction for pod length in blackgram was reported by Sirohi and Singh, (2013).

5.3.1.1.7. Number of seeds per pod

Number of seeds per pod did not show any variation between the dates of planting under open condition indicating that the character is highly stable. Senthilkumar and Chinna (2012), reported three stable genotypes for the character number of seeds per pod. Nath and Dasgupta (2013), based on their studies in green gram identified seven genotypes exhibiting average stability for seeds per pod having bi value close to one. Bais *et al.* (2007), reported significant G x E interaction for seeds per pod in greengram.

5.3.1.1.7. Test weight

For test weight, significant bi values were showed by T1 and T6 while significant S^2di was showed by T5, T8 and T12. Among the stable genotypes, T9 can be identified as having high mean value with more than 4.5 g. Senthilkumar and Chinna (2012), observed non significant mean squares for pooled deviation for test weight in blackgram genotypes. They identified four genotypes having stable performance for test weight, tested over three environments. Significant G x E interaction for test weight in blackgram was reported by Sirohi and Singh, (2013).

5.3.1.1.8. Yield per plant

Yield being the most important criteria for selection in any breeding programme identification of genotype with high mean value and non significant bi and S^2di value is essential. However, most of the genotypes were having significant bi and S^2di values indicating the effect of environment on the expression of the character. Most of the genotypes having high yield were not stable. Among the stable genotypes, the genotype, 5 and 9 had yield per plant of more than 14g. Shanthi *et al.* (2007), studied twenty blackgram genotypes for stability under three environments and identified four genotypes with high yield potential and stability over environments. Senthilkumar and Chinna (2012), could identify four genotypes stable over three environments with high mean yield per plant. Abraham *et al.* (2013), identified five genotypes of blackgram showing high yield and stability over two environments selected from sixty one germplasm collection from Andhrapradesh. Sirohi and Singh (2013), observed significant G x E inereaction for yield per plant in blackgram.

5.3.1.1.9. Protein content

Protein content in blackgram genotypes varied between 18.77 and 21.54 per cent. None of the genotypes had significant bi values. However, Chaudhary and Paroda (1980), advocated that linear regression could simply regarded as measure of response of a particular genotype, where the deviation from regression as a measure of stability.

In the study all the genotypes were showing significant S^2di indicating that the genotypes were not stable for protein content. Chaudhari *et al.* (2013), based on their study on 36 genotypes of cowpea under four seasons observed that magnitude of genotype x environment linear and pooled deviation from linearity was high for protein content.

The present study revealed that no genotype was stable for all the traits studied. Senthilkumar and Chinna (2012), also could not identify any single variety stable for all the traits. According to Eberhart and Russell model a good genotype is the one with high mean value and non significant bi and S^2di values. Considering yield and major yield contributing traits the genotypes were ranked as suggested by Arunachalam and Bandyapadhyay (1984). For stable genotypes rank 1 was given and for unstable rank 2. For plant height, as the optimum height preferred was 40 - 50 cm, genotypes falling in this category was given rank 1and others rank 2. The genotypes were raked from 1 to 14 for the major traits namely, number of pods per plant, number of seeds per pod, test weight and yield per plant. Based on the ranks scoring was done for the genotypes as given in Table 30. The genotype with lowest score was given rank one followed by other lower scores. The genotypes T6, was the best followed by T9 and T5 suitable for cultivation under open condition (Plate 3 and Plate 4).

Plate 3. Promising genotypes at harvest in open condition

Genotype T6

Genotype T9

Genotype T5

Plate 4. Grains of stable and promising genotypes of blackgram

Genotype T6

Genotype T9

Genotype T5

Table 30. Total scores and ranks of genotypes under open condition

Genotypes	Plant height (cm)	Stability	Number of pods per plant	Stability	Number of seeds per pod	Stability	Test weight (g)	Stability	Yield per plant (g)	Stability	Total score	Rank
T1	1	2	12	2	5	1	13	2	11	2	51	11
T2	2	2	7	1	10	1	8	1	8	2	42	9
T3	1	2	6	1	7	1	5	1	3	2	29	5
T4	1	2	10	1	4	1	4	1	9	2	35	7
T5	1	1	3	1	6	1	2	1	7	1	24	3
T6	1	2	4	1	2	1	1	2	1	2	17	1
T7	1	1	2	1	8	1	6	2	6	2	30	6
T8	1	2	1	1	5	1	11	2	2	2	28	4
T9	1	1	5	2	1	1	3	1	5	1	21	2
T10	1	2	8	1	13	1	7	1	4	2	40	8
T11	1	2	13	1	11	1	9	1	12	1	52	12
T12	2	2	11	2	12	1	14	2	10	1	57	13
T13	1	1	9	1	6	1	10	1	13	2	45	10
T14	2	1	14	2	9	1	12	1	14	2	58	14

5.3.1.2. Stability parameters (Eberhart and Russel model) pooled over shade conditions

Cultivation of blackgram can be undertaken in different seasons and as a sole crop in paddy lands after the harvest of paddy in *rabi* and summer. During *kharif* and *rabi* season it can be cultivated in uplands as an inter crop in the main crop. This will give the farmer an additional income as well as improve soil nutritional status for the main crop.

Singh *et al.* (1986), based on their experiments for comparing the effects of different legume intercrops on available soil nitrogen, bacterial activity and the yield of maize over two years showed that soyabean and blackgram were more suitable for intercropping than groundnut. This combination was substantially increasing NO_3 and NH_4 concentrations and population of active bacteria in the maize rhizosphere. This increased maize yield by 15-20 per cent and grain protein content by 20 per cent.

Midya *et al.* (2005), studied the effect of staggered seeding of blackgram in rice field as a cereal-legume intercropping system and reported, that deferred seeding of blackgram in rice (30 cm) after one weeding was most remunerative system and registered maximum rice-equivalent yield (2711 kg ha^{-1}). Rice blackgram (20 cm) intercropping system was very effective for weed smothering among unweeded intercropping treatments. They concluded that deferred seeding of blackgram in rice field (30 cm) with one weeding may be recommended for better yield, weed suppression and better economics.

Harisudan *et al.* (2009), suggested intercropping of blackgram was an important aspect for biological farming systems not only for weed control, but also reducing the leaching of nutrients, control of pests and soil erosion. They reported that inclusion of legumes as intercrop in cotton play a multi beneficiary role by providing grains and simultaneously it improves nitrogen status of soil through fixation of atmospheric nitrogen.

In Kerala, blackgram was cultivated in coconut garden and as inter crop during *kharif* and *rabi* season which was useful for soil enrichment, cover crop and control of weeds along with the pulse yield. Hence, study was attempted with the ten blackgram cultures raised along with four check varieties for three seasons in coconut garden to find out a suitable genotype for intercropping in coconut garden. The results of the study are discussed below.

5.3.1.2.1. Days to flowering

Days to flowering showed variation between the seasons under shade condition. Genotypes 6 and 11 had significant bi value and genotypes T1, T2, T3, T7 and T14 had significant S^2di. Among the stable genotypes, the genotypes T8, T9 and T10 with flowering duration of 35 days can be suggested for cultivation. Patil and Narkhede (1992),reported significant genotype, environments and G x E interaction in greengram indicating considerable influence of differential environments on days to flowering. However, Senthilkumar and Chinna (2012), observed non significant mean squares for pooled deviation for days to flowering in blackgram genotypes. Raturi *et al.* (2012), observed significant G x E interaction for days to flowering in greengram. Razvi *et al.* (2011), observed significant G x E interaction for days to flowering in common bean.

5.3.1.2.2. Plant height

For plant height T3, T4, and T9 had significant bi values and T1, T5, T10, T12 and T13 had significant S^2di value. Among the stable genotypes the genotypes having plants of medium height of 40cm-50cm can be suggested for cultivation. They were T2, T6, T7 and T8. Pervin *et al.* (2007), reported significant effect of environment on plant height in blackgram genotypes. Senthilkumar and Chinna (2012), observed highly significant differences for plant height over three diverse environments. Out of thirty five genotypes they tested only three genotype showed high mean value and stable performance for plant height. Bais *et al.* (2007), observed significant G x E interaction for plant height in mungbean.

5.3.1.2.3. Number of branches per plant

Plants having more number of branches per plant will cover the land more effectively. Hence, from the stable genotypes the genotypes having more number of branches namely, T2, T6, T7, T8, T9, T10 and T12 with more than 4.5 branches per plant can be suggested for cultivation. Raman and Sinhamahapatra (2012), reported the genotypes VK 1 and VK3 were having stable performance for number of branches in blackgram. Katiyar and Sarial (1987), observed high G x E interaction for branch number in pigeon pea.

5.3.1.2.4. Number of pod bearing branches per plant

For number of pod bearing branches per plant none of the genotypes were having significant S^2di values. According to Chaudhary and Paroda (1980), linear regression could simply regarded as measure of response of a particular genotype, where the deviation from regression as a measure of stability. Considering this argument all the genotypes can be considered as stable for number of pod bearing branches. Genotypes with more than 4.5 number of pod bearing branches namely, genotype T6 and T12 can be selected. Rasul *et al.* (2012), suggested that branching is basically a genetic factor but environmental conditions may also influence the number of pod bearing branches per plant and play an important role in enhancing seed yield.

5.3.1.2.5. Number of pods per plant

Number of pods in the genotypes showed that there is variation between different seasons for the genotypes. The T13 and T14 with non significant bi value and S^2di value were stable over seasons for number of pods per plant. So these were the only genotypes stable over seasons under shade condition. Reports by Manivannan *et al.* (1998), showed good stability for pods per plant in three genotypes in greengram. Nath and Dasgupta (2013), reported nine genotypes with high number of pods and bi value close to zero in greengram.

5.3.1.2.6. Length of pod

For length of pods the T5 and T13 had significant bi value and T3 had significant S^2di. Of the eleven stable genotypes T1, T6 and T7 with longer pods can be selected. Nath and Dasgupta (2013), reported highly significant differences between genotypes and environment for length of pod. Significant G x E inereaction for pod length in blackgram was reported by Sirohi and Singh (2013).

5.3.1.2.7. Number of seeds per pod

The number of seeds per pod did not show any variation between seasons under shade condition indicating that all the genotypes were stable under these conditions. Babu *et al.* (2009), observed significant G x E interaction for number of seeds per pod in blackgram. Nath and Dasgupta (2013), based on their studies in green gram identified seven genotypes exhibiting average stability for seeds per pod having bi value close to one.

5.3.1.2.8. Test weight

Nine genotypes had stability for test weight. Of these stable genotypes T3, T6 and T9 with high test weight can be identified as superior. Senthilkumar and Chinna (2012) could identify four genotypes having stable performance for test weight tested over three environments. Babu *et al.* (2009), observed non significant G x E interaction for test weight based on their studies in 12 blackgram genotypes under six environments. Significant G x E inereaction for test weight in blackgram was reported by Sirohi and Singh (2013).

5.3.1.2.9. Yield per plant

For yield per plant T7 and T10 had significant bi values and T4, T9 and T12 had significant S^2di. Of the stable genotypes T3, T5 and T6 with yield per plant more than 14 g can be identified as superior. Senthilkumar and Chinna (2012) could identify four genotypes stable over three environments with high mean yield per plant. Abraham *et al.* (2013) identified five genotypes of blackgram showing high yield and stability over two environments selected from sixty one germplasm collection from Andhrapradesh. Babu *et al.* (2009) and Sirohi and Singh (2013), observed significant G x E interaction for yield per plant in blackgram.

5.3.1.2.10. Protein content

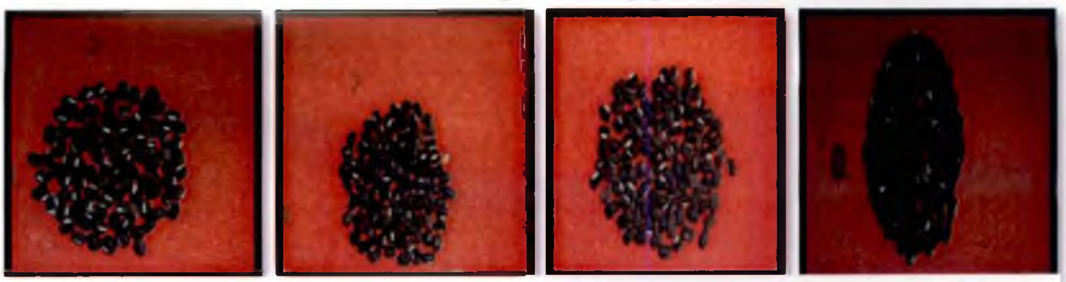
For protein content all the tested genotypes had significant values for S^2di indicating that none of the genotypes were stable under shade condition for protein content. This shows that the environment plays a major effect on determining protein content of blackgram genotypes. Same result was obtained under open condition also indicating that the protein content in blackgram genotypes is determined by the environment under which they are grown, irrespective of light intensity. Babu *et al.* (2009), observed non significant G x E interaction for protein content. Chaudhari *et al.* (2013), based on their study on 36 genotypes of cowpea under four seasons observed that magnitude of genotype x environment linear and pooled deviation from linearity was high for protein content.

Similar to the studies conducted under open condition no genotype was stable for all the traits studied. Scores were constructed based on stability and ranks for yield and major yield contributing characters as done under data an open condition and it is presented in Table 31. Based on the ranks T3 had the lowest score of 20 while T5, T6 and T10 had score of 24 (Plate 5 and Plate 6). These genotypes can be identified as suitable for cultivation as an intercrop in coconut garden.

Plate 5. Promising genotypes at harvest in shade condition

Genotype T3 Genotype T5 Genotype T6 Genotype T10

Plate 6. Grains of stable and promising genotype of blackgram



Genotype T3 Genotype T5 Genotype T6 Genotype T10

Table 31 Total scores and ranks of genotypes under shaded condition

Genotypes	Plant height (cm)	Stability	Number of pods per plant	Stability	Number of seeds per pod	Stability	Test weight (g)	Stability	Yield per plant (g)	Stability	Total score	Rank
T1	1	2	6	2	8	1	9	1	11	1	42	8
T2	1	1	12	2	2	1	3	2	9	1	34	4
T3	2	2	2	2	1	1	4	1	4	1	20	1
T4	1	2	11	2	10	1	6	1	3	2	39	6
T5	2	2	4	2	4	1	1	2	5	1	24	2
T6	1	1	8	2	5	1	2	1	2	1	24	2
T7	1	1	7	2	7	1	7	2	7	2	37	5
T8	1	1	9	2	6	1	10	2	8	1	41	7
T9	1	1	1	2	9	1	5	1	6	2	29	3
T10	1	2	3	2	3	1	8	1	1	2	24	2
T11	2	1	10	2	14	1	14	1	10	1	56	11
T12	2	2	13	2	12	1	11	2	13	2	60	12
T13	1	2	5	1	11	1	12	1	14	1	49	9
T14	2	1	10	1	13	1	13	1	12	1	55	10

5.3.1.3. Stability analysis pooled over six environments

Stability analysis of fourteen genotypes pooled over six environments showed significant effect of environment on expression of all the characters.

5.3.1.3.1. Days to flowering

Except T4, T11 and T12 having significant S^2di values all other genotypes were for days to flowering. Among these the genotypes with low flowering duration namely, T2, T6 and T10 having first flowering in less than 35 days can be considered as superior. However, studies by Senthilkumar and Chinna (2012), observed non significant mean squares for pooled deviation for days to flowering in blackgram genotypes. Raturi *et al.* (2012), observed significant G x E interaction for days to flowering in greengram.

5.3.1.3.2. Plant height

For plant height significant bi values and significant S^2di values were showed by eight genotypes. This indicate that only four genotypes namely T2, T5, T7 and T9 were stable when six environments were considered. These genotypes were having an average plant height of 40-50 cm and hence, can be selected. Senthilkumar and Chinna (2012) observed highly significant differences for plant height over three diverse environments. Out of thirty five genotypes they tested only three genotype showed high mean value and stable performance for plant height. Significant G x E interaction for plant height in mungbean was observed by Bais *et al.* (2007).

5.3.1.3.3. Number of branches per plant

Genotypes T2, T3, T4, T7, T10, T12 and T13 had significant S^2di values. Among the stable genotypes T8 and T9 had high mean value for number of branches per plant. Raman and Sinhamahapatra (2012), could identify only two genotypes stable for number of branches in blackgram.

5.3.1.3.4. Number of pod bearing branches per plant

Significant S^2di values were showed by 10 genotypes. The genotype T12 was stable and had high mean value for number of pod bearing branches per plant.

5.3.1.3.5. Number of pods per plant

Genotypes T3, T8, T9, T12 and T13 had significant S^2di values. Senthilkumar and Chinna (2012), observed the genotypes HG 157 and LBG 623 were having high mean value and were stable over three environments for the character number of pods per plant. Manivannan *et al.* (1998), observed good stability for pods per plant in three genotypes in greengram. Nath and Dasgupta (2013), identified nine genotypes with high number of pods and bi value close to zero in greengram. Stable genotypes T5 and T7 were bearing more than 40 pods per plant can be selected.

5.3.1.3.6. Length of pod

Most of the genotypes with non significant bi values and S^2di values were stable for length of pod except T12 and T13 with significant S^2di values. Among the stable genotypes T2, T3 and T6 had high mean value. Significant G x E interaction for pod length in blackgram was reported by Sirohi and Singh (2013).

5.3.1.3.7. Number of seed per pod

For number of seeds per pod bi values were non significant S^2di values. Hence, all the genotypes can be considered as stable. Out of the stable genotypes, T1, T3, T5 and T6 with high mean value of more than 5 seeds per pod can be identified as superior. However, the studies by Senthilkumar and Chinna (2012), in blackgram; Bais *et al.* (2007), and Nath and Dasgupta (2013), in green gram reported significant G x E interaction for seeds per pod.

5.3.1.3.8. Test weight

The trait, test weight had significant bi values for T3 and significant S^2di values for T1, T11 and T12. The genotypes T5, T6 and T7 with high mean value of more than 4.5 g for test weight can be selected for high seed weight. Senthilkumar and Chinna (2012) identified four genotypes having stable performance for test weight tested over three environments. Significant G x E interaction for test weight in blackgram was repored by Sirohi and Singh (2013).

5.3.1.3.9. Yield per plant

For yield per plant none of the genotype had non significant bi and S^2di value indicating the major influence of environment on the expression of yield. Senthilkumar and Chinna (2012), could identify four genotypes stable over three environments with high mean yield per plant. Abraham *et al.* (2013), identified five genotypes of blackgram showing high yield and stability over two environments selected from sixty one germplasm collection from Andhrapradesh. Sirohi and Singh (2013), observed significant G x E inereaction for yield per plant in blackgram.

5.3.1.3.10. Protein content

For protein content, T8, T9, T11 and T12 had significant S^2di values. This was in contrast to the result of protein content under open and shade condition where, none of the genotype had stability. The stable genotype T5 with more than 21 per cent protein can be selected. Chaudhari *et al.* (2013), based on their study on 36 genotypes of cowpea under four seasons observed that magnitude of genotype x environment linear and pooled deviation from linearity was high for protein content. Evaluation of genotypes for stability during three seasons under open and shade condition showed that no genotype was stable for all the traits studied. Scoring was done by considering stability and rank of genotypes for yield and major yield contributing traits Table 32. T6 had the lowest total score followed by T5 and T3 (Plate 7 and Plate 8). This indicates the suitability of this genotype for cultivation under both condition and seasons

Plate 7. Promising genotypes at harvest in pooled over six environments

Genotype T6

Genotype T5

Genotype T3

Plate 8. Grains of stable and promising genotype of blackgram

Genotype T6

Genotype T5

Genotype T3

Table 32 Total scores and ranks of genotypes under six environments

Genotypes	Plant height (cm)	Stability	Number of pods per plant	Stability	Number of seeds per pod	Stability	Test weight (g)	Stability	Yield per plant (g)	Stability	Total score	Rank
T1	1	2	3	1	3	1	10	2	10	2	43	9
T2	1	1	7	1	7	1	7	1	9	2	37	8
T3	1	2	4	2	1	1	5	2	3	2	23	3
T4	1	2	10	1	8	1	4	1	7	2	37	8
T5	1	1	3	1	4	1	2	1	4	2	20	2
T6	1	2	5	1	2	1	1	1	1	2	17	1
T7	1	1	2	1	9	1	3	1	5	2	26	4
T8	1	1	1	2	6	1	14	1	6	2	35	6
T9	1	1	6	2	5	1	6	1	8	2	33	5
T10	1	2	8	1	10	1	8	1	2	2	36	7
T11	1	2	14	1	11	1	9	2	12	1	54	11
T12	1	2	12	2	12	1	12	2	11	2	57	12
T13	1	2	9	2	10	1	11	1	14	2	53	10
T14	2	1	13	1	11	1	13	1	13	2	58	13

5.3.2 Stability analysis (AMMI model)

Relative performance of crop varieties are generally different in different environments which is difficult to explain by variance component method. The regression models can adequately describe the behavior of genotypes over different environments only when the genotypic response is fairly linear. Non linear G x E interactions is a complex phenomenon resulting from various genetical, physiological and other reasons characteristic of different genotypes in relation to different environmental conditions (Varghese *et al.*, 2006). Stability analysis by Eberhart and Russells model showed that for certain traits the G x E linear were not significant as given in the ANOVA. Non significant G x E linear may not always interpret the stability parameters. As an alternative to additive ANOVA model which identifies the interaction as a source but does not analyse it multiplicative formulations may be chosen to quantify the varieties contribution to G x E interaction. These multiplicative formulations permit the interpretation of interaction as differential genotypic sensitivity to environmental variables (Varghese *et al.*, 2006).

The AMMI model is a hybrid analysis that incorporates both the additive and multiplicative components of the two-way data structure. AMMI biplot analysis is considered to be an effective tool to diagnose G x E patterns graphically. The principal component analysis (PCA), which provides a multiplicative model, is applied to analyze the interaction effect from the additive ANOVA model. The biplot display of PCA scores plotted against each other provides visual inspection and interpretation of G x E interaction components. The integration of biplot display and genotypic stability statistics enables genotypes to be grouped on the basis of similarity in performance across diverse environments (Mukherjee *et al.*, 2013). Hence, in order to get a better picture about the stability of the fourteen genotypes tested under six environments the data was analysed using AMMI model and the results are discussed here.

5.3.2.1. Days to flowering

Mean values of days to flowering for the genotypes ranged between 34.89 of T2 and 36.79 of T14. Positive values for IPCA 1 was showed by T2, T6, T9, T10, T11, T12, T13 and environment E1. IPCA2 values were positive in T4, T7, T8, T11, T12, T13 and T14 and environments E1 and E2. Based on the biplot1 (Fig.11) T10 and T11 had similar main effects while, T6, T9 and T10 and T7 and T1 had similar interaction effects. The T6 and T8 had similar main effects and interaction effects. The T3 placed near to zero in biplot 1 is stable for the trait. Based on Biplot 2 (Fig.12). The environment 1 that is *kharif* season under open condition which was having a long spoke exerted strong interactive forces on the genotype. The environments 4 and 6 that is shade condition under *rabi* and summer season exerted lesser interaction on the genotype. T6 and T10 which are present near to the origin were non sensitive to interactive patterns. These genotypes were having early flowering also. Hence, these genotypes can be selected for days to flowering.

5.3.2.2 Plant height

Mean values of plant height for the genotypes ranged between 38.02 cm of T14 and 45.48 cm of T8. Positive values for IPCA 1 was showed by T1, T2, T5, T9 and environments E1, E2 and E3. IPCA2 values were positive in T1, T2, T3, T4, T5, T6, T11 and environments E1 and 2. Based on the biplot1 (Fig.13) T5 and T10, T3 and T9 and T4 and 7, had similar main effects. T3, T10 and T7 and T13 and T4 had similar interaction effects. Based on Biplot 2 (Fig.14) the environments 3 and 6 that is open condition under *rabi* season and shade condition under smmer season exerted strong interactive forces to the genotypes. The environment 5 that is open condition under summer season exerted least interactive forces to the genotype. The T3, T7, T8 and T14 were lesser sensitive to environmental interactive forces. Among these, the T8 and T7 with plant height 40-50cm can be selected for plant height. Babu *et al.* (2009), studied the phenotypic stability in blackgram using AMMI model and identified two genotypes as stable for plant height as situated close to centre of IPCA axis in biplot 2.

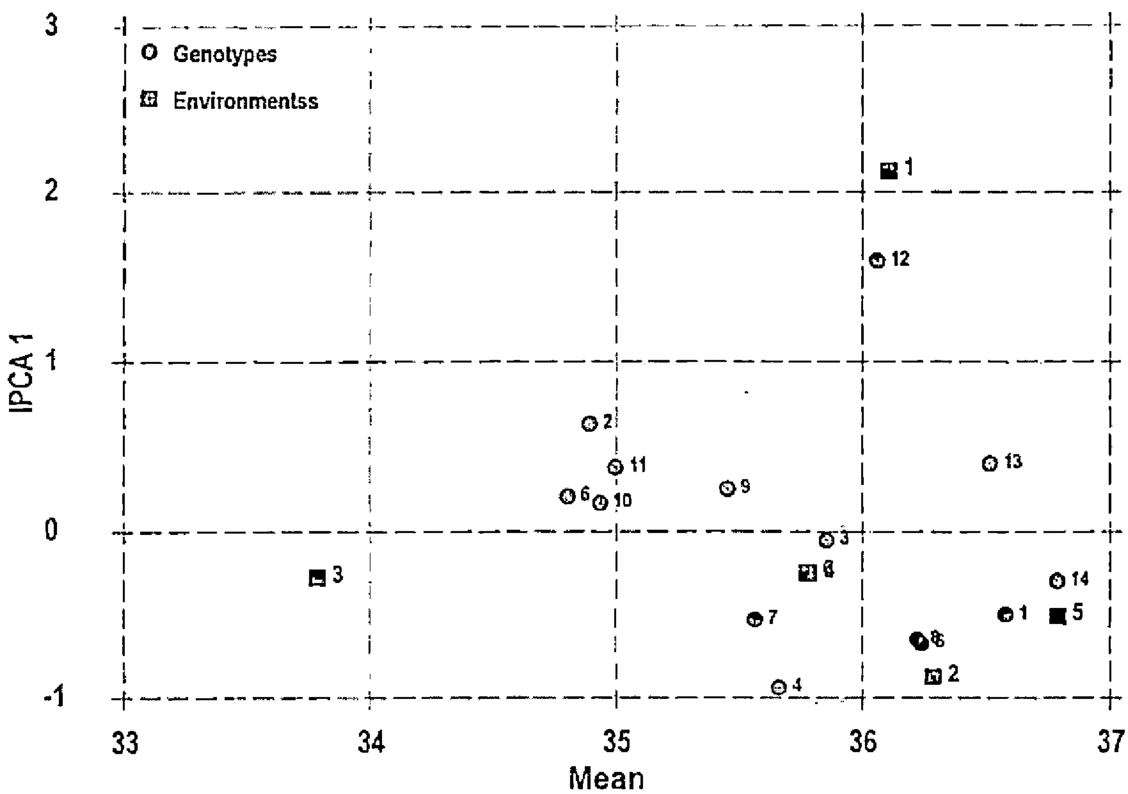


Fig.11. Biplot (AMMI 1) for days to flowering

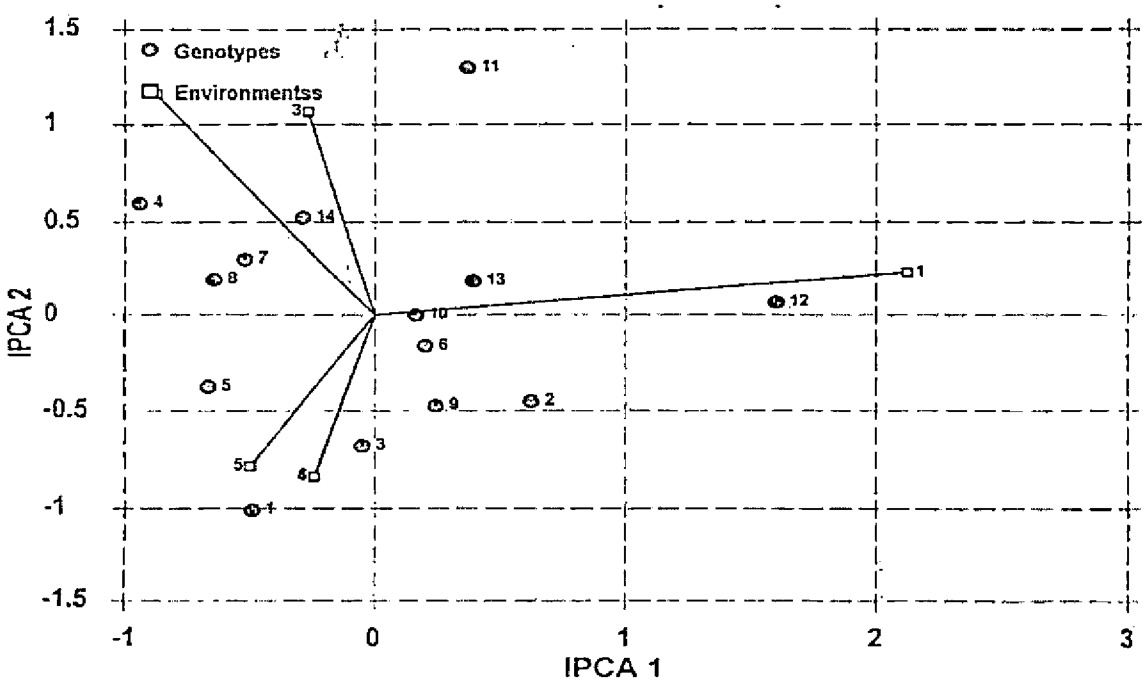


Fig.12. Interaction biplot (AMMI 2) for days to flowering

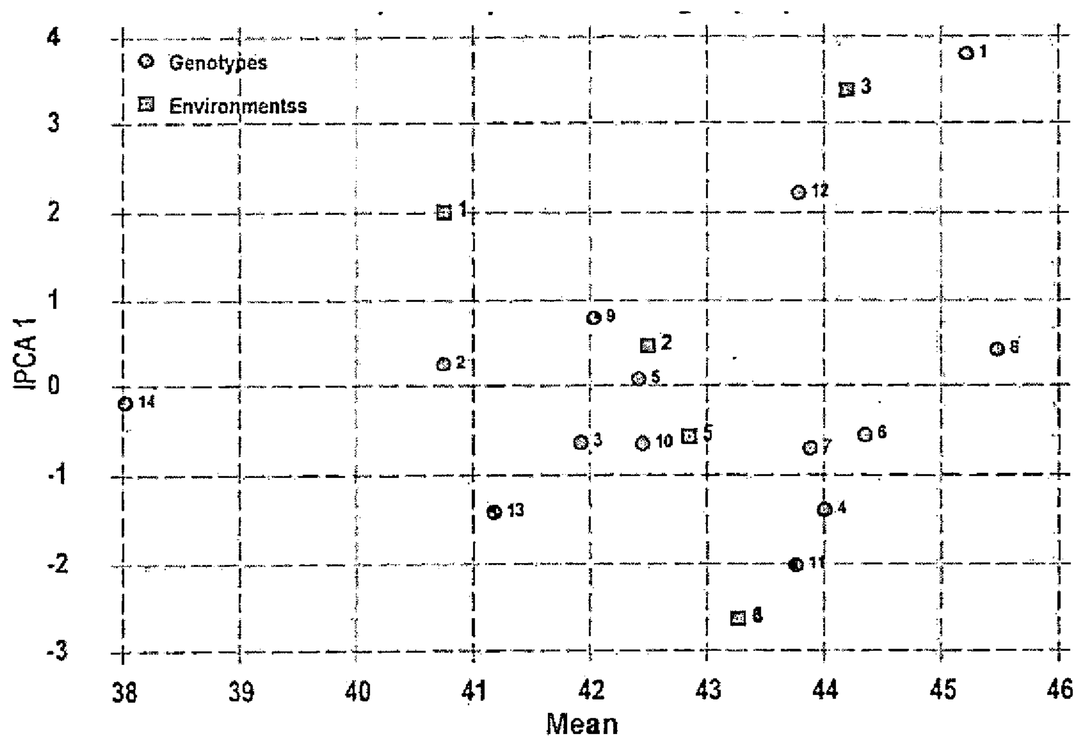


Fig. 13.Biplot (AMMI 1) for plant height in blackgram

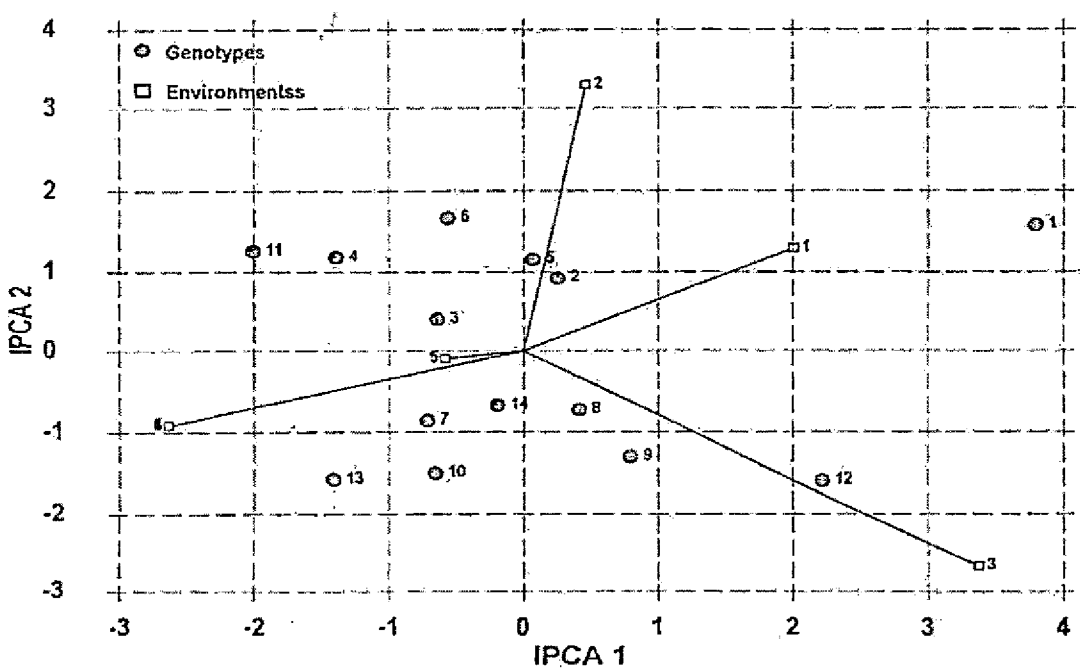


Fig. 14.Interaction Biplot (AMMI 2) for plant height in blackgram

5.3.2.3 Number of branches per plant

For number of branches per plant, mean values of the genotypes ranged between 4.67 of T2 and 5.67 of T12. Positive values for IPCA 1 was showed by T2, T6, T7, T8, T10, T11, T12, T13, T14 and environments E1 and E2. IPCA2 values were positive in T4, T5, T6, T7, T10, T12 and environments E1, E3 and E4. Based on the biplot 1 (Fig.15) the T1, T3 and T10 had similar interaction effects while, the T9, T10, T13 and T14 had similar main effects. T1 and T3 had similar main and interaction effects. T1, T3 and T11 had similar interactive patterns as seen in biplot 2 (Fig.16). Environment 1 and 2 that is open and shade condition under *kharif* season exerted strong interactive forces on the genotypes for branch number. The environments 4 and 6 that is shade condition under *rabi* and summer season exerted less interactive forces to the genotype. T6 and T9 were found to be non sensitive to environmental interactive forces. Both these genotypes were having moderately high branch number and hence, can be selected.

4.3.2.4 Number of pod bearing branches per plant

Mean values of the genotypes for number of pod bearing branches per plant, ranged between 4.3 of T11 and 5.25 of T12. Positive values for IPCA 1 was showed by T6, T7, T8, T12, T13 and T14 and none of environments had positive IPCA1(Fig.17). IPCA2 values were positive in T4, T7, T9, T10, T11, T12 and environment E4. T5, T1, T11, T2, and T8 had similar main effects as shown in Biplot 1 (Fig.18). T1 and T3 and T2, T4, T6, T7, T8 and T10 exhibited similar main and interaction effects. The environments 1 and 2 open and shade condition under *kharif* season exerted strong interactive forces while the environments 4 and 5 shade condition under *rabi* season and open condition under summer season exerted lesser interactive effect. T6 and T8 were comparatively non sensitive to environment. Hence, T6 with high number of pod bearing branches can be selected.

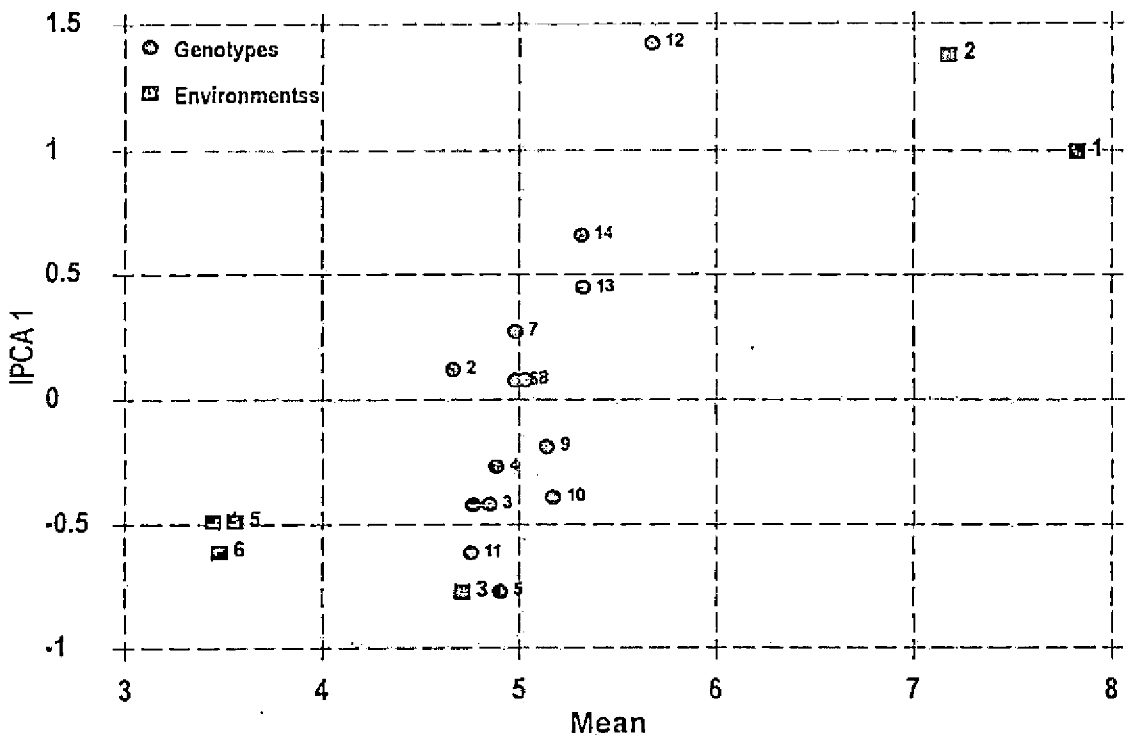


Fig.15. Biplot (AMMI 1) for number of branches per plant

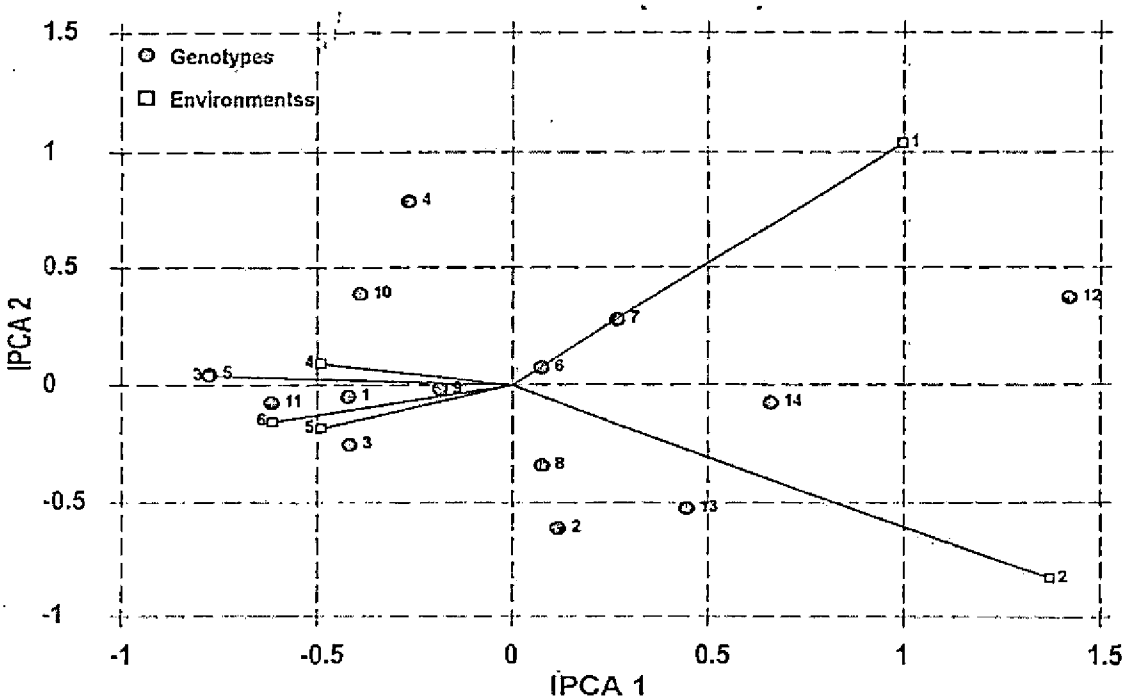


Fig.16. Interaction biplot (AMMI 2) for number of branches per plant

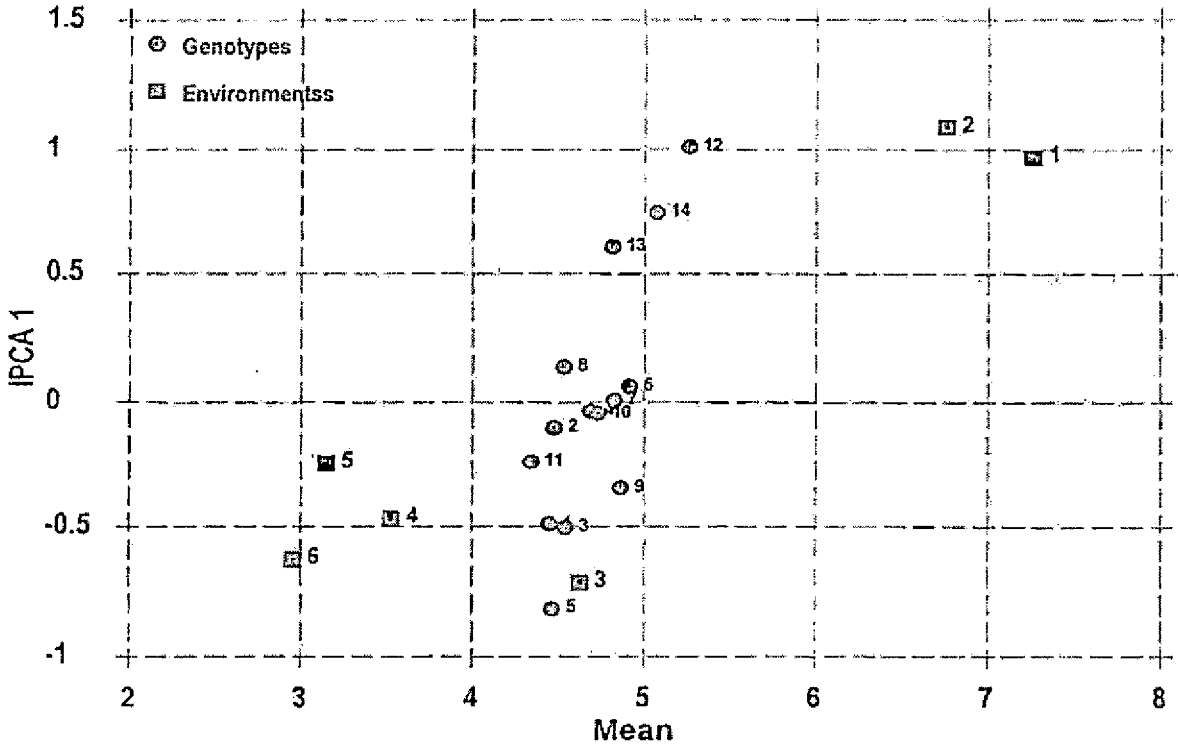


Fig.17. Biplot (AMMI 1) for number of pod bearing branches per plant

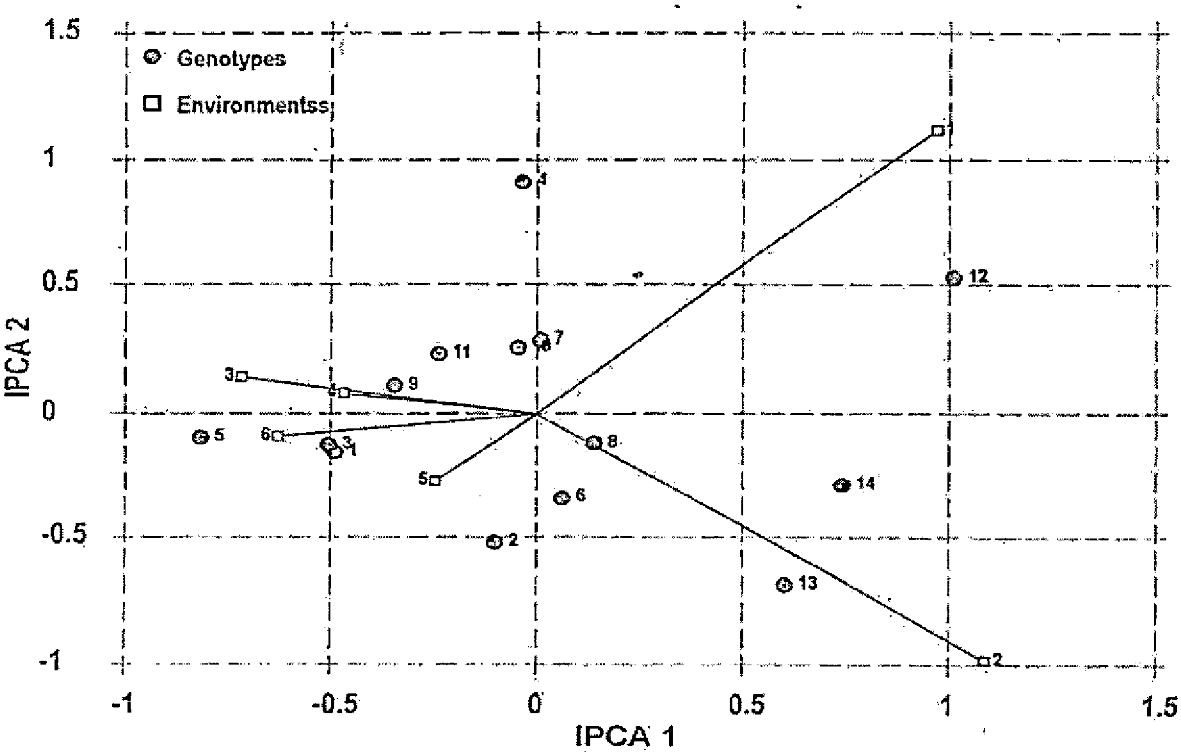


Fig.18. Interaction Biplot (AMMI 2) for number of pod bearing branches per plant

5.3.2.5 Number of pods per plant

For number of pods per plant, mean values of the genotypes ranged between 34.19 of T14 and 43.04 of T8. Positive values for IPCA 1 was showed by T3, T5, T6, T7, T8, T9 and environments E1 and E2. IPCA2 values were positive in T2, T4, T6, T8, T11, T12 and environments E1. Similar main effects were observed in T14 and T12, T4 and T13, T10 and T2 and T9 and T6 as expressed in Biplot 1(Fig.19). Similar interaction effects were observed in T2, T5 and T7, T11 and T14, T9 and 10 and T1 and T6. Similar mean and interaction effects were observed in T5 and T7. From the biplot 2 (Fig.20), it can be observed that T9 and T10 and T4 and T2 had similar interactive patterns. The environment 1 and 3 that is open condition during *kharif* and *rabi* exhibited strong interactive forces on the genotype while, environment 5 and 6 that is open and shade condition during summer exhibited least interactive forces on the genotypes. T1 and T6 were found to be non sensitive to environmental interactive forces. Of this two genotypes, genotype 6 with high number of pods per plant can be selected. Babu *et al.* (2009) studied the phenotypic stability in blackgram using AMMI model and identified four genotypes as stable as situated close to centre of IPCA axis in biplot 2. Stability studies using AMMI model by Pratap *et al.* (2009), in green gram indicated that seven genotypes out of 12 were stable for number of pods per plant.

5.3.2.6. Length of pods

For length of pods, mean values of the genotypes ranged between 4.10 of T11 and 4.85 of the T6. Positive values for IPCA 1 was showed by T6, T7, T12, T13 and environments E1 and E4. IPCA2 values were positive in T2, T4, T8, T11, T12, T13 and environments E4 and E5. As per the biplot 1(Fig.21) the T14 and T12 and T5 and T13 had similar main effects. T11, T14 and T8 and T1 and T3 had similar interaction effects. T10 and T5, T1, T4, and T8 had similar mean and interaction effects. According to the biplot 2 (Fig.22), T2 and T4 and T13 and T12 had similar interactive patterns. The environments 2 and 5 that is shade condition under *kharif* season and open condition under summer season exerted strong interactive forces while the environment

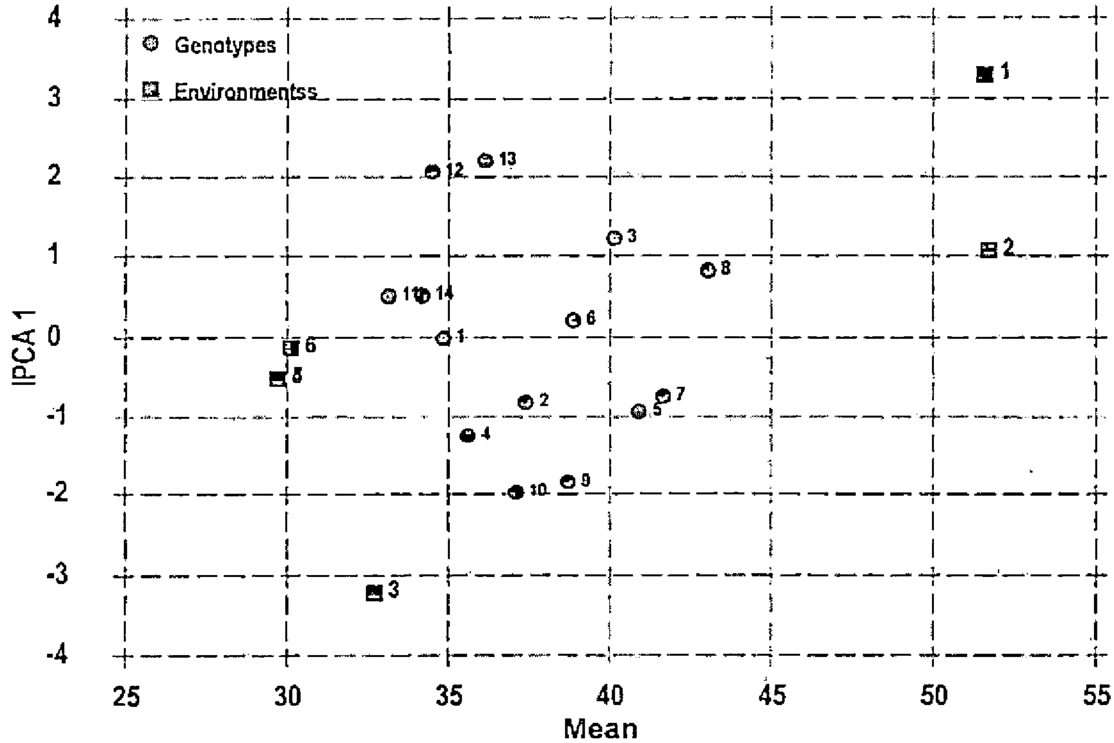


Fig. 19. Biplot (AMMI 1) for number of pods per plant

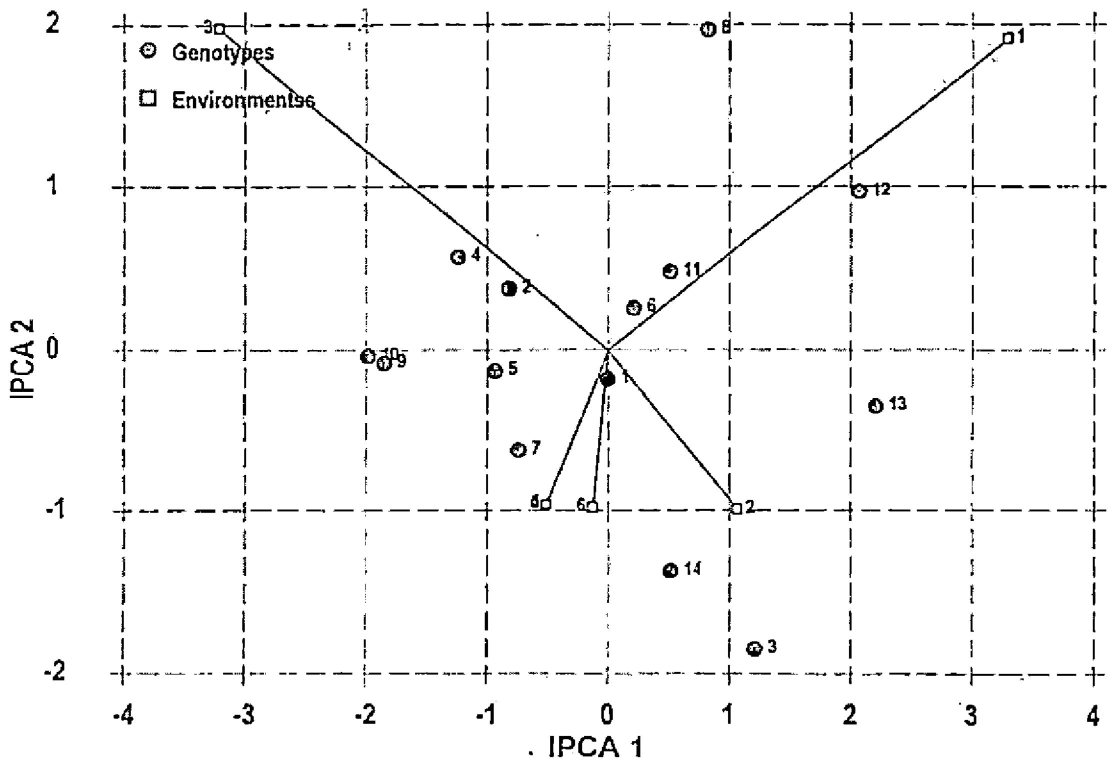


Fig. 20. Interaction Biplot (AMMI 2) for number of pods per plant

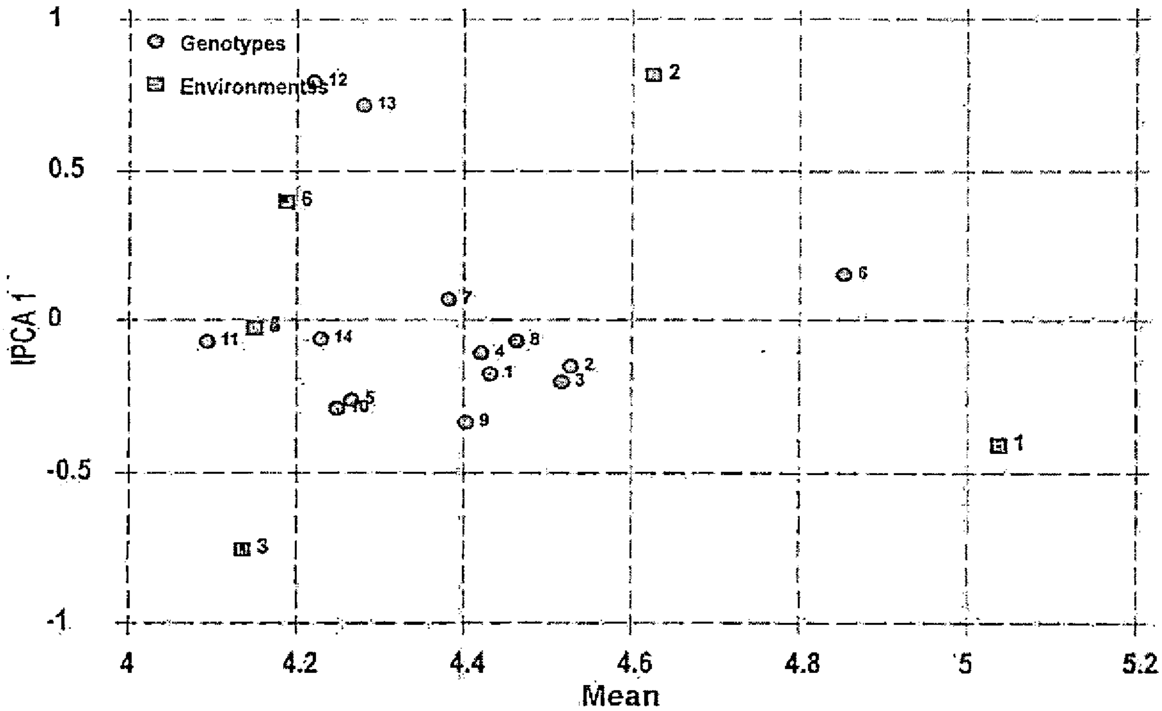


Fig. 21.Biplot (AMMI 1) for length of pods in blackgram

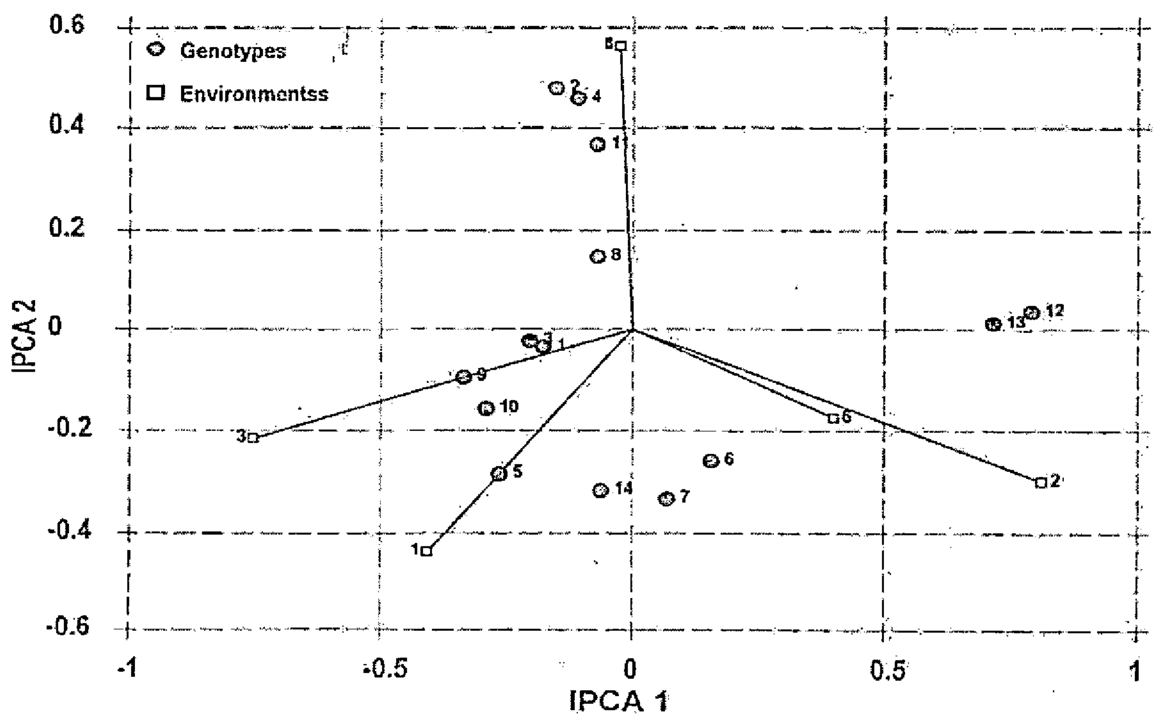


Fig. 22. Interaction Biplot (AMMI 2) for length of pods in blackgram

6 that is shade condition under summer season exerted less interactive forces on the genotypes. T1 and T3 were comparatively non sensitive to environmental interactive forces. Of this two genotypes, T3 having longer pods can be selected.

5.3.2.7 Number of seeds per pod

For number of seeds per pod, mean values of the genotypes ranged between 4.50 of T12 and 5.27 of T3. Positive values for IPCA 1 was showed by T1, T2, T3, T5, T7 and environments E1, E2 and E6. IPCA2 values were positive in T1, T4, T5, T6, T8, T9, T11, T12 and environments E1. As presented in Biplot 1(Fig. 23), T11 and T14 and T13 and T10 had similar main effects. T2 and T3 and T4 and T6 had similar interaction effects. T10 which had IPCA 1 value near to zero can be considered as stable. As shown in biplot 2 (Fig. 24) the environments 1 and 6 that is open condition under *kharif* season and shade condition under summer season exerted strong interaction. The environment 2 that is shade condition under *kharif* season exerted less interaction over the genotypes. Babu *et al.* (2009) studied the phenotypic stability in blackgram using AMMI model and identified three genotypes as stable across environments for seeds per pod.

5.3.2.8. Test weight

Mean values of the genotypes for test weight ranged between 4.67 of T2 and 5.67 of T12. Positive values for IPCA 1 were showed by T1, T2, T3, T4, T5, T9, T10, T11 and environments E3, E4 and E5. IPCA2 values were positive in T1, T4, T5, T10, T11 and environments E2, E3, E4 and E5. The main effects were similar in T13 and T1, T2 and T10 and T4 and T3 as presented in biplot 1 (Fig.25). Similar main effects were exhibited by the T1, T11, T2 and T9. T2, T4 and T9 had similar main and interaction effects. As per biplot 2 (Fig. 26), T5, T8 and T14 and T3 and T10 showed similar interaction pattern. Environment 2 and 3 shade condition under *kharif* season and open condition under *rabi* season exerted strong interaction while the environments 4 and 5 that is shade condition under *rabi* season and open condition under summer season exerted lesser interactive forces on the genotypes. T2 and T9 were non sensitive to

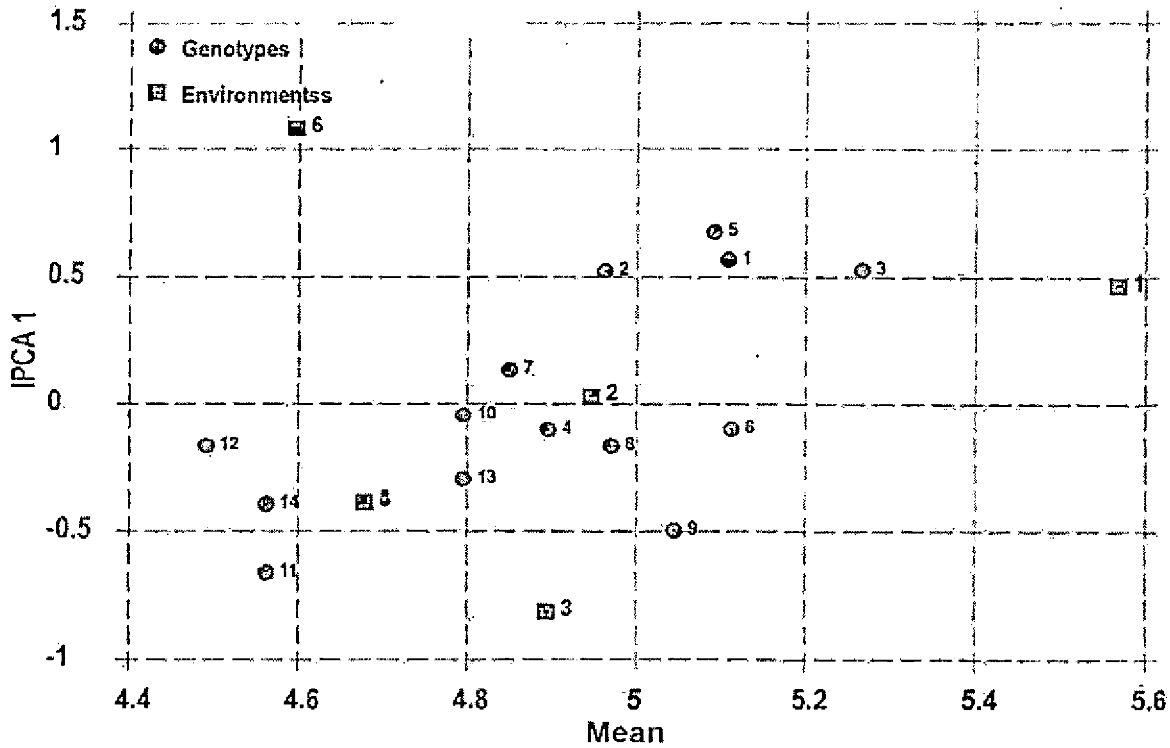


Fig.23. Biplot (AMMI 1) for number of seeds per pod in blackgram

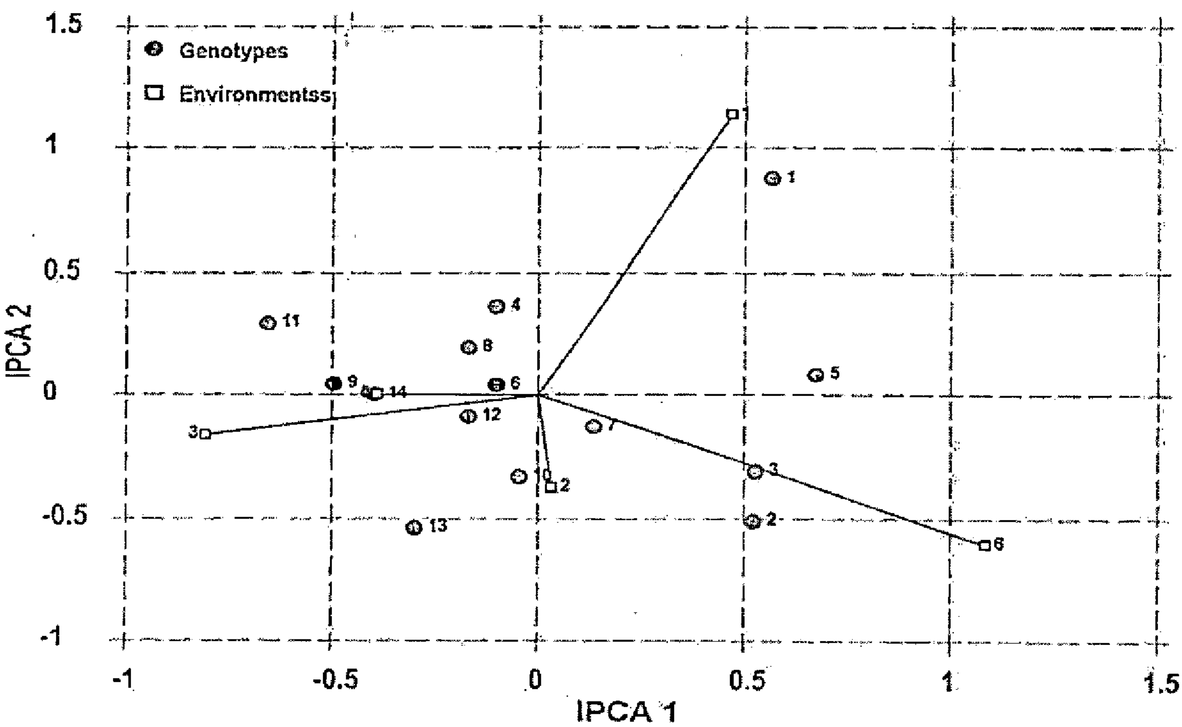


Fig.24. Interaction biplot (AMMI 2) number of seeds per pod in blackgram

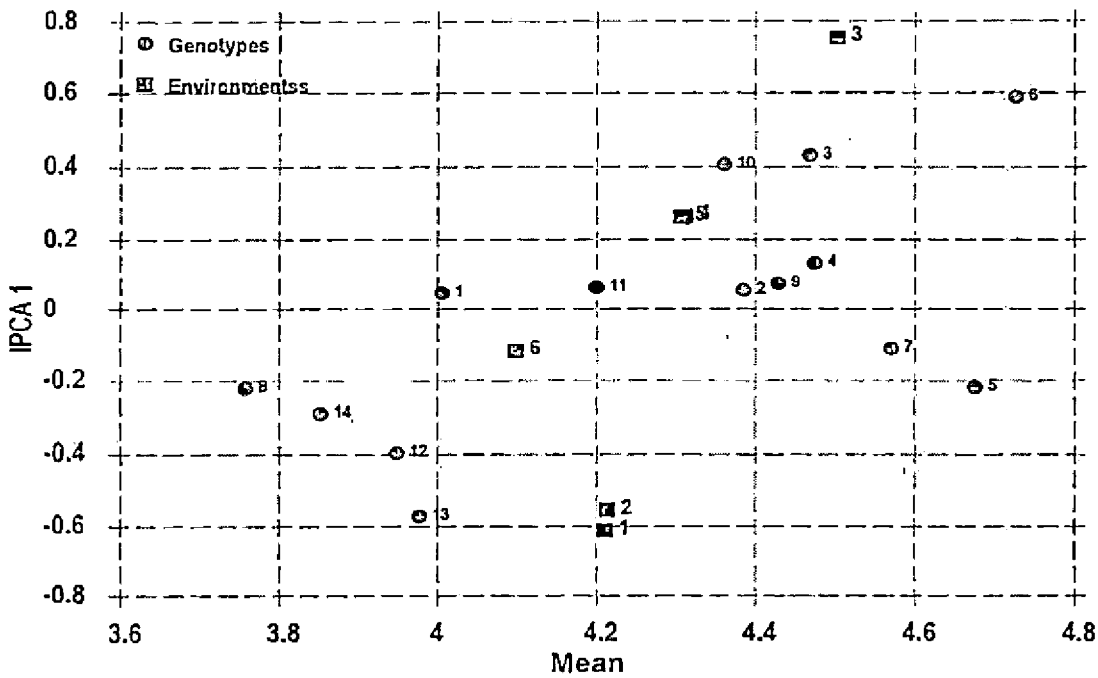


Fig. 25.Biplot (AMM1) for test weight (g)

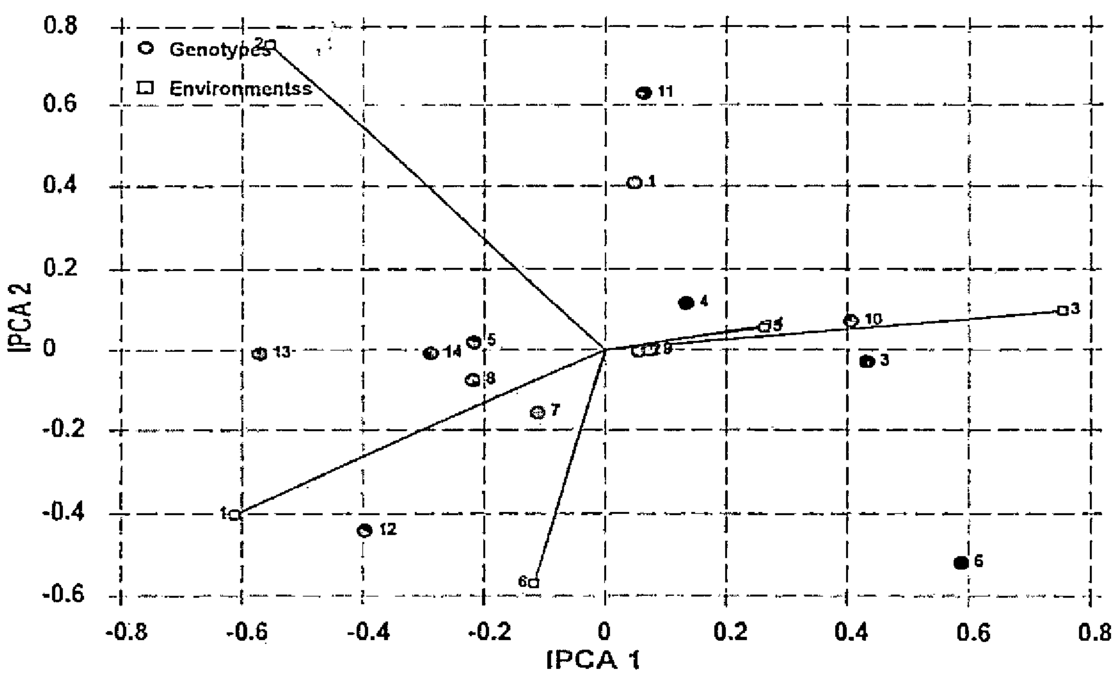


Fig. 26. Interaction Bioplot (AMMI 2) for test weight (g)

environmental interactive forces. Both the genotypes were having moderately high mean value indicating that these genotypes can be selected. Babu *et al.* (2009), studied the phenotypic stability in blackgram using AMMI model and identified three genotypes as stable across environments. Stability studies using AMMI model by Pratap *et al.* (2009), in green gram indicated that four genotypes out of 12 were stable for 100 seed weight.

5.3.2.9. Yield per plant

Mean values of the genotypes for yield per plant ranged between 11.99 of T13 and 16.36 of T6. Positive values for IPCA 1 were showed by T2, T3, T6, T7, T8 and environment E3. IPCA2 values were positive in T3, T4, T6, T9, T13, T14 and environments E3, E4 and E6. T4, T7 and T8, and T5 and T3 had similar main effects as shown in biplot1 (Fig.27). T12 and T9 were having similar interaction effects. T10 and T6 were having high main effects but were away from IPCA 1 axis indicating that even though they are high yielders, the performance can not be predicted. According to biplot 2 (Fig.28) T4, T14 and T13 and T2 and T8 which are placed closer in the biplot had similar interaction effects. The environments 6 and 3 that is shade condition under summer season and open condition under *rabi* season exerted strong interactive patterns and the environments 4 and 2 that is shade condition under *kharif* and *rabi* season exerted lesser interactive patterns on the genotype. T5 and T11 were nonsensitive to environment. Of this two genotypes T5 with high mean value can be selected. Babu *et al.* (2009), studied the phenotypic stability in blackgram using AMMI model and identified three genotypes as stable for yield per plant. Stability studies using AMMI model by Pratap *et al.* (2009), in green gram indicated that seven genotypes out of 12 were stable for seed yield per plant.

5.3.2.10. Protein content

Mean values of the genotypes for protein content ranged between 18.65 of T12 and 21.60 of T5. Positive values for IPCA 1 were showed by T1, T2, T5, T6, T7, T8, T9

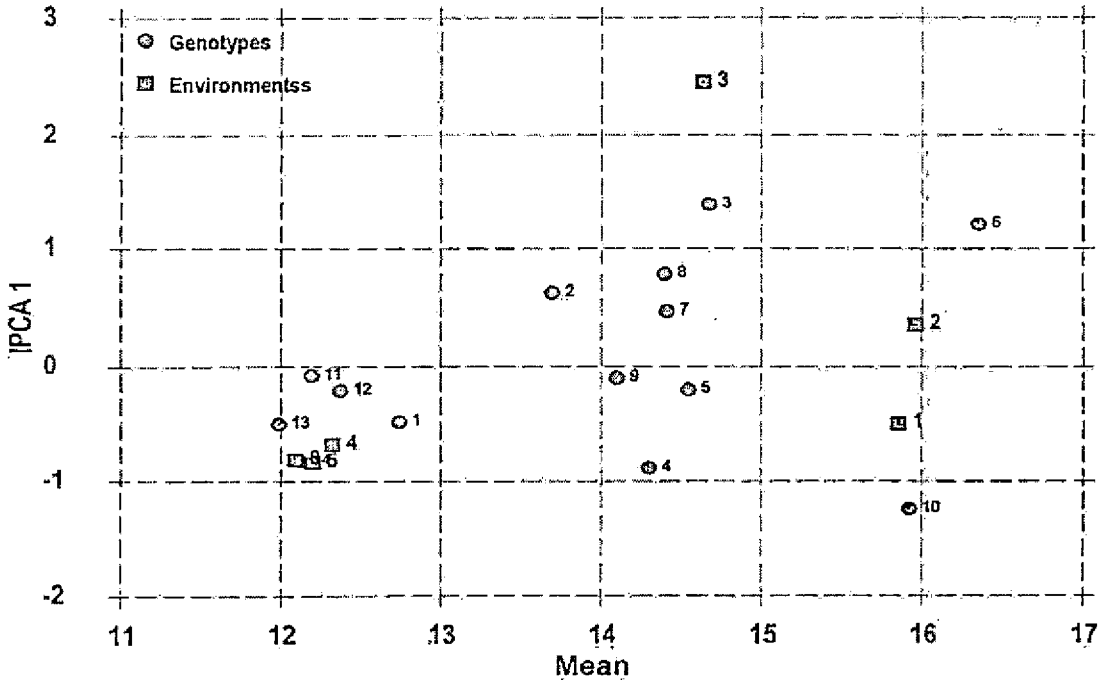


Fig. 27. Biplot (AMMI 1) for yield per plant (g) in blackgram

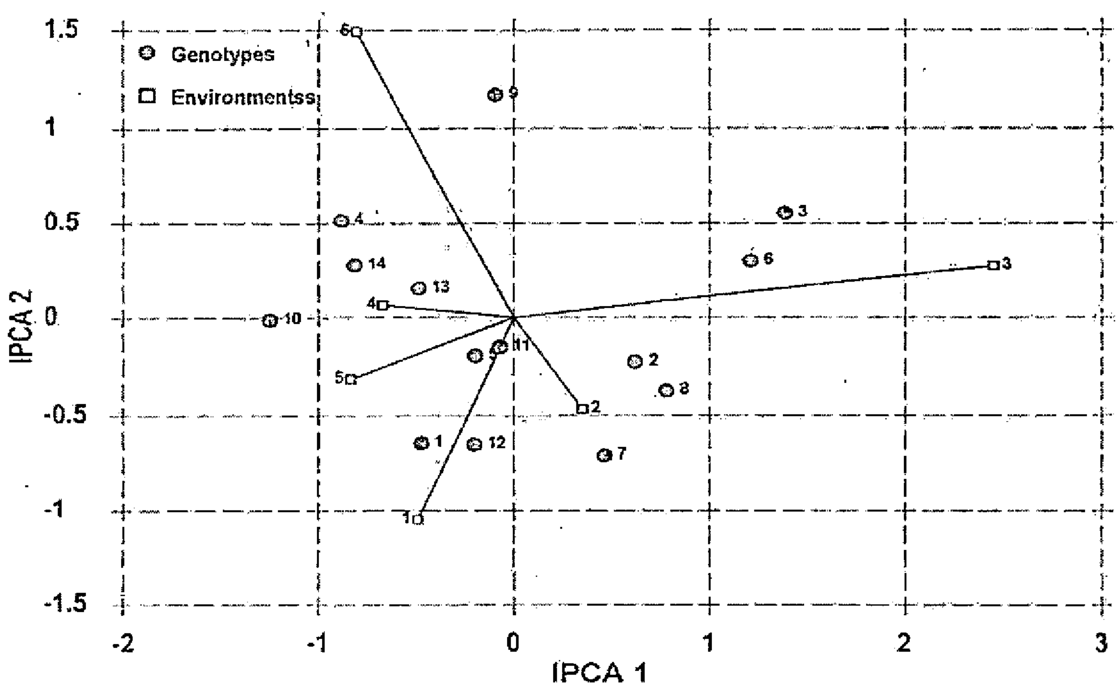


Fig. 28. Interaction Biplot (AMMI 2) for yield per plant (g)

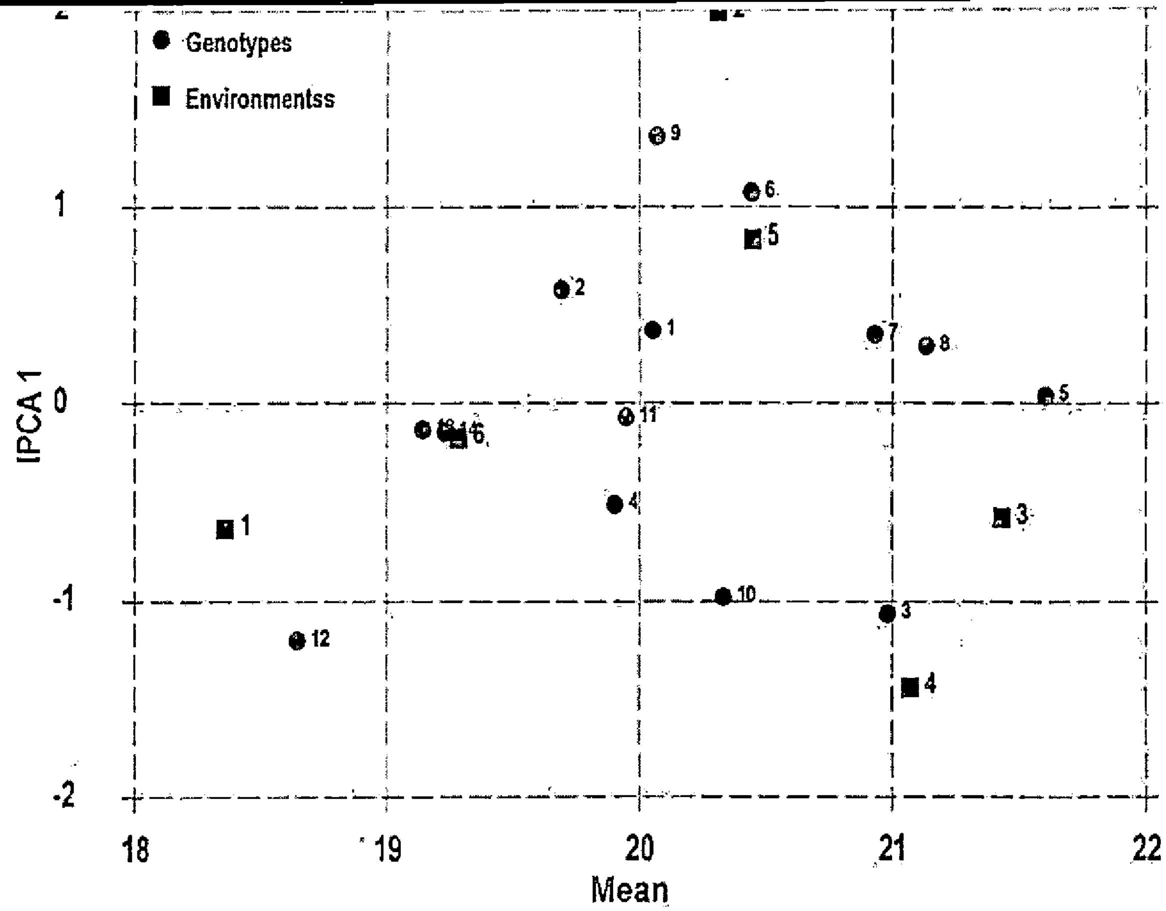


Fig.29. Biplot (AMMI 1) for Protein content in blackgram

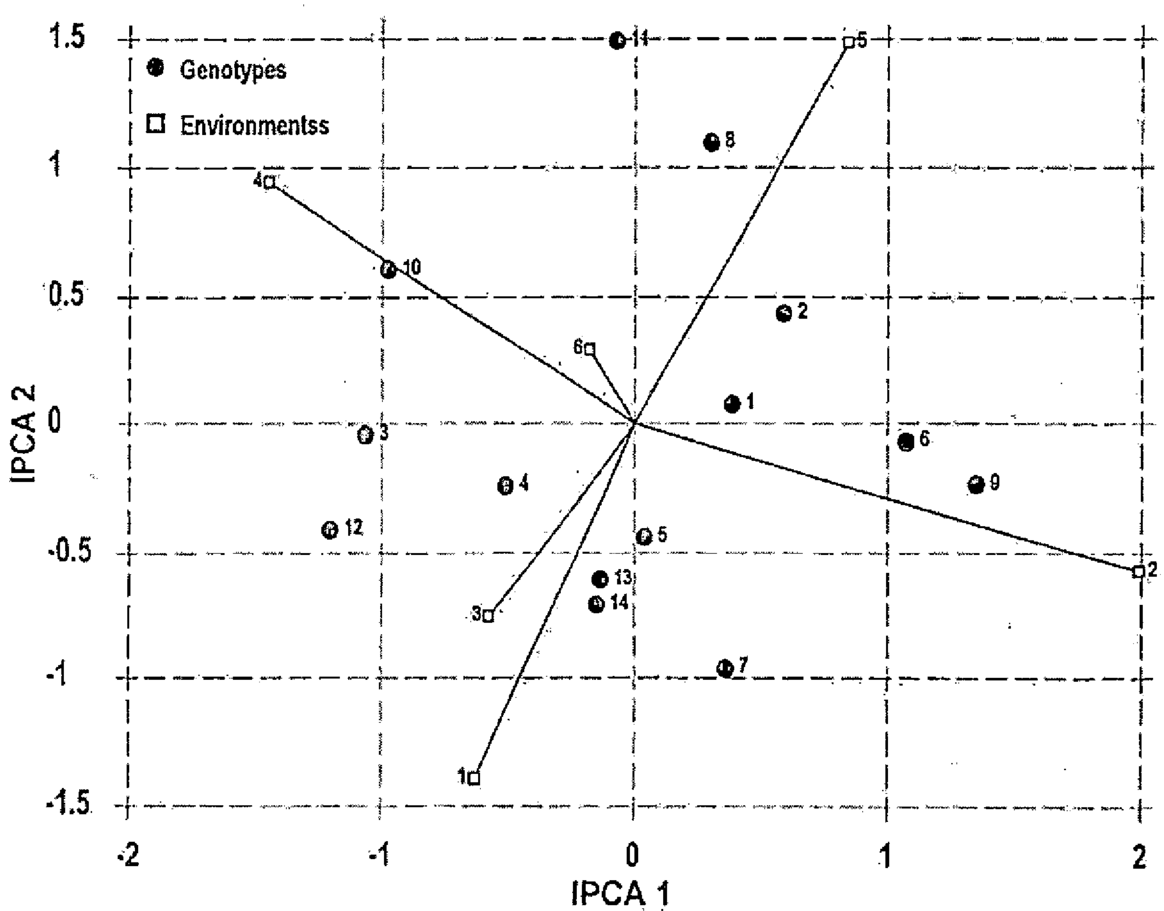


Fig.30. Interaction biplot (AMMI 2) for Protein content in blackgram

and environments E4, E5 and E6. IPCA2 values were positive in T1, T2, T8, T10, T11 and environments E4, E5 and E6. From the biplot 1 (Fig.29). It is clear that the T10 and T6 and T4 and T11 were having similar main effects. T1 and T7 were having similar interaction effects. T4, T5, T13 and T14 were having similar main and interaction effects. T10 with IPCA score near to zero was comparatively stable over environments. T13 and T14 were having similar interactive patterns as evident from biplot 2 (Fig.30). The environments 1, 2, 4 and 5 exerted strong interactive patterns while the environment 6 alone exerted lesser interactive patterns indicating the effect of environment in determining the trait protein content. T1, T4 and T5 were comparatively stable over environments. Of these, T5 with high mean value can be selected. Babu *et al.* (2009), studied the phenotypic stability in blackgram for protein content using AMMI model and identified three genotypes as stable. Stability studies using AMMI model by Pratap *et al.* (2009), in green gram indicated that four genotypes out of 12 were stable for protein content.

Scoring was done for yield and major yield contributing traits by AMMI model. The total score of the genotypes are given in Table 33. The genotype T6 was the best genotype with lowest total score fallowed by T5 and T3.

Comparison of result of stability estimates by Eberhart and Russell model and AMMI model showed that the stable and promising genotypes were the same by both the model. They are T6, T5 and T3.

Table 33 AMMI genotypes score pooled over six environments

Genotypes	Plant height (cm)	Stability	Number of pods per plant	Stability	Number of seeds per pod	Stability	Test weight (g)	Stability	Yield per plant (g)	Stability	Total score	Rank
T1	1	2	11	1	3	2	10	2	10	2	44	9
T2	1	1	7	2	7	2	7	2	9	2	40	8
T3	1	2	4	2	1	2	5	1	3	2	23	3
T4	1	2	10	2	8	2	4	2	7	2	40	8
T5	1	1	3	2	4	2	2	2	4	1	22	2
T6	1	2	5	1	2	1	1	2	1	2	18	1
T7	1	2	2	2	9	2	3	2	5	2	30	4
T8	1	2	1	2	6	2	14	2	6	2	38	6
T9	1	2	6	2	5	2	6	1	8	2	35	5
T10	1	2	8	2	10	2	8	2	2	2	39	7
T11	1	2	14	2	11	2	9	2	12	1	56	11
T12	1	2	12	2	12	1	12	2	11	2	57	12
T13	1	2	9	2	10	2	11	2	14	2	55	10
T14	2	2	13	2	11	2	13	2	13	2	62	13

Summary

6. SUMMARY

An experiment entitled "Genotype x environment interaction in blackgram *Vigna mungo* L. Hepper.)" was carried out at the Department of Plant Breeding and Genetics, College of Horticulture, KAU, Vellanikkara during August 2013 - December 2014. The objective of the study was to assess the genotype x environmental interaction in black gram cultures. The study was undertaken in three different seasons of sowing namely *kharif*, *rabi* and summer under two conditions open condition and as an inter crop in coconut garden. The study mainly focused on development of stable genotypes in black gram for cultivation as sole crop and inter crop for central zone of Kerala. The salient findings of the study are summerised below.

Performance of blackgram genotypes under environment 1.

- Black gram cultures showed wide variability in yield and other traits except days to flowering, number of pod bearing branches per plant and number of seeds per pod during *kharif* season under open condition.
- Low phenotypic (PCV) and genotypic (GCV) coeiffient of variation and low genetic advance was showed by number of pod bearing branches, length of pods, yield per plant and protein content.
- Moderate PCV, low GCV and moderate genetic advance (GA) as per cent of mean was observed for number of seeds per pod.
- Days to flowering, plant height, number of branches per plant and number of pod bearing branches per plant, number of pods per plant, test weight, yield per plant and protein content showed moderate PCV and GCV and high GA.
- All the traits except protein content exhibited high heritability.
- Additive gene action was observed for days to flowering, plant height, number of branches per plant, number of pods per plant and test weight.

- High heritability accompanied by moderate or low GA was observed for number of pod bearing branches per plant and length of pod, number of seeds per pod and yield per plant.
- Low heritability accompanied by low genetic advance observed in protein content shows the prominent effect of environment on these traits.

Performance of blackgram genotypes under environment 2

- Variability available with the tested genotypes were significant in all the traits during *kharif* season under shaded condition.
- Days to flowering, plant height, number of branches and test weight showed moderate PCV and GCV.
- Low PCV and GCV values were exhibited by number of pod bearing branches, number of pods, length of pod, number of seeds per pod, yield per plant and protein content.
- High heritability coupled with high GA was observed for plant height, number of clusters per plant, number of pods per plant, 100-seed weight and seed yield per plant.
- Selection can be attempted for the improvement of days to flowering, plant height, number of branches and test weight where, the traits exhibited high values for genetic advance as well as heritability.

Performance of blackgram genotypes under environment 3

- The characters days to flowering, number of pods, number of seeds per pod, and test weight showed no variability during *rabi* season under open condition
- None of the traits showed high PCV and GCV.
- Moderate PCV and low GCV was showed by traits days to flowering and number of branches per plant.
- Both PCV and GCV were low for number of pod bearing branches, length of pod, number of seeds per pod, test weight and protein content.

- Additive gene action was exhibited by plant height, number of branches per plant, number of pods per plant and yield per plant.
- Days to flowering had moderate genetic advance and high heritability. All other traits except number of pod bearing branches per plant were having low genetic advance and high heritability.
- Number of pod bearing branches per plant had low genetic advance and moderate heritability

Performance of blackgram genotypes under environment 4

- Days to flowering, plant height, number of pod bearing branches per plant, number of pods per plant, length of pods, number of seeds per pod, yield per plant and protein content showed variation during *rabi* season under shade condition.
- Low values of PCV and GCV were exhibited by most of the traits. Plant height and yield per plant had medium values for PCV and GCV while number of pods per plant had moderate PCV and low GCV.
- Plant height and yield per plant had high GA and heritability.
- Non additive gene action had influence on, days to flowering, number of branches per plant, length of pod, number of seeds per pod and test weight.
- High environmental influence was noticed for number of pod bearing branches per plant and length of pod.

Performance of blackgram genotypes under environment 5

- Number of branches per plant, number of pod bearing branches per plant, length of pods and number of seeds per pod were not showing any variation during summer season under open condition.

- Moderate PCV and GCV were showed by traits like plant height and yield per plant. Number of pods per plant had moderate PCV and low GCV. All other traits showed low values for PCV and GCV.

- High heritability and high GA were observed for plant height and yield per plant.

- Number of pod bearing branches per plant, number of seeds per pod and test weight recorded low genetic advance and high heritability.

- High heritability with high GA was observed for hundred seed weight. Low genetic advance and moderate heritability was observed for days to flowering and length of pod.

Performance of blackgram genotypes under environment 6

- All the traits except number of branches and number of seeds per pod showed wide variability during summer season under shade condition.

- Moderate PCV and GCV were exhibited by plant height, yield per plant and protein content.

- Days to flowering, number of branches per plant, number of pod bearing braches per plant, length of pod and test weight showed low values for both PCV and GCV.

- Days to flowering, number of branches per plant and length of pod showed predominance of non additive gene action.

Comparison of genotypes under different conditions

- Days to flowering of the genotypes varied between different environments. Most of the genotypes showed early flowering during *rabi* season under open condition and late flowering during summer season under open condition.

- Comparison of plant height under different environments showed that six of the genotypes were taller under during *rabi* season under shade condition and four genotypes were taller during *rabi* season under open condition.
- Eleven genotypes were having maximum number of branches per plant during *kharif* season under open condition.
- Eleven genotypes were having maximum number of pod bearing branches per plant during *kharif* season under open condition.
- Seven genotypes were having maximum number of pods per plant during *kharif* season under open condition.
- Thirteen genotypes were having maximum pod length under environment one which represented open condition during *kharif* season.
- High number of seeds per pod are seen in nine genotypes during *kharif* season under open condition.
- High test weight was showed by six genotypes under shade condition during *rabi* season and four genotypes had high test weight under shaded condition under *karif* season.
- Comparison of yield per plant under different environments showed that eight genotypes showed high yield during *kharif* season under open condition.
- Comparison of protein content under different environments showed that seven genotypes were showing high protein content under shade condition during *rabi* season and five genotypes with high protein content under open condition during *rabi* season.
- Phenotypic and genotypic variation observed in blackgram genotypes under six environments showed that the traits were showing either medium or low phenotypic and genotypic coifficient of variation.
- Based on the observation over all the environments plant height was found to be controlled by additive gene action and hence, selection can improve the trait.
- Seed yield showed additive gene action under four environments suggesting possible improvement of seed yield by selection.

- Length of pod was influenced by non additive gene action under five environments and test weight under four environments indicating the predominance of non additive gene action in determining the traits.
- The traits protein content, number of pod bearing braches per plant, days to flowering, length of pods and seeds per pod showed greater influence of environment in one or two environments.

Stability parameters pooled over open condition

- Days to flowering did not show any variation between the dates of planting under open condition indicating that the character is highly stable.
- For plant height, stable genotypes 4.5.8 and 4.5.9 with good plant height and non significant bi and S^2di values was identified.
- For number of branches per plant, the stable genotypes namely, 4.5.7, 4.5.9, 6.4.1, Sumanjana and Syama with high mean value of more than 5.5 can be considered as superior.
- The stable genotypes 4.5.7, 4.5.9, 6.4.1 and TAU-1 having high number of pod bearing branches per plant can be considered as superior.
- For the character number of pods per plant the genotypes 4.5.8, 4.5.9 and 4.5.18 with non significant bi and S^2di value and pods more than 40 per plant can be considered as superior.
- Length of pod did not show any variation between the three dates of sowing under open condition.
- Number of seeds per pod did not show any variation between the dates of planting under open condition indicating that the character is highly stable.
- For test weight, the genotype 4.5.9 can be identified as having high mean value with more than 4.5 g.
- Most of the genotypes having high yield were non stable. Among the stable genotypes, the genotypes 4.5.8 and 4.6.1 had yield per plant of more than 14g.
- None of the genotypes were stable for protein content.

- No genotype was stable for all the traits studied.
- Based on the total scores calculated from stability parameters and ranks of important traits the 4.5.9, 4.6.1 and 4.5.8 genotypes were identified as superior and suitable for cultivation under open conditions.

Stability parameters pooled over shaded condition

- Days to flowering showed variation between the seasons under shade condition. Among the stable genotypes, the genotypes 4.5.18, 4.6.1 and 6.4.1 with flowering duration of 35 days can be suggested for cultivation.

- For plant height, from the stable genotypes namely, 4.5.2, 4.5.9, 4.5.10 and 4.5.18 having plants of medium height of more than 40 cm can be suggested for cultivation.

- From the stable genotypes for number of branches per plant, the genotypes 4.5.2, 4.5.9, 4.5.10, 4.5.18, 4.6.1, 6.4.1 and T-9 with more than 4.5 branches per plant can be suggested for cultivation.
- For number of pod bearing branches per plant genotypes with more than 4.5 number of pod bearing branches per plant namely, genotype 4.5.9, TAU-1 and Sumanjana can be selected.

- The genotype Sumanjana and Syama with non significant bi value and S^2di value were stable over seasons for number of pods per plant.

- For length of pods the stable genotypes 4.1.1, 4.5.9 and 4.5.10 with longer pods can be selected.

- The number of seeds per pod did not show any variation between seasons under shade condition.

- Ten genotypes had stability for test weight. Of the ten stable genotypes the genotypes 4.5.3, 4.5.9 and 4.6.1 with high test weight can be identified as superior.

- For yield per plant the stable genotypes namely, 4.5.3, 4.5.8 and 4.5.9 with yield per plant more than 14g can be identified as superior with respect to stability and yield.
- For protein content none of the genotypes were stable under shade condition.
- Based on the total scores calculated from stability parameters and ranks of important traits the 4.5.8, 4.5.9 and 6.4.1 genotypes were identified as superior and suitable for cultivation under shaded conditions.

Stability parameters pooled over open and shaded condition

Stability analysis of fourteen genotypes pooled over six environments showed significant effect of environment on expression of all the characters. G x E interaction was significant only for plant height, branch number, number of pod bearing branches per plant and test weight.

- Except the genotypes 4.5.7, TAU-1 and T-9, all other genotypes were stable for days to flowering. Among these also the genotypes with low flowering duration namely, genotypes 4.5.2, 4.5.9 and 6.4.1 having first flowering in less than 35 days can be considered as superior.

- For plant height four genotypes namely genotype 4.5.2, 4.5.8, 4.5.9 and 4.6.1 were stable when six environments were considered. These genotypes were having an average plant height of more than 40 cm and hence can be selected.

- For number of branches per plant from the stable genotypes the genotype 4.1.1, 4.5.18, 4.6.1, and Syama had high mean value for number of branches per plant.

- The genotypes namely, 4.1.1, 4.5.9, TAU-1 and T-9 were stable and had high mean value for number of pod bearing branches per plant.
- For number of pods per plant genotypes 4.5.8 and 4.5.9 which were stable and having more than 40 pods per plant can be selected.
- Among the stable genotypes for length of pod the genotypes 4.5.2, 4.5.3, 4.5.9 and 4.6.1 had high mean value.
- Out of the stable genotypes for seeds per pod, genotypes 4.1.1, 4.5.3, 4.5.8 and 4.5.9 with high mean value of more than 5 seeds per pod can be identified as superior.
- The stable genotypes 4.5.8, 4.5.9 and 4.5.9 with high mean value of more than 4.5g for test weight can be selected for high seed weight.
- For yield per plant only the genotype TAU-1 was stable for yield per plant indicating the major influence of environment on the expression of yield.
- For protein content, the stable genotype 4.5.8 with more than 21 per cent protein can be selected.
- Evaluation of genotypes for stability during three seasons under open and shade condition showed that no genotype was stable for all the traits studied.
- Based on the total scores calculated from stability parameters and ranks of important traits the 4.5.9 had the lowest total score followed by 4.5.8 and 4.5.3 genotypes were identified as superior and suitable for cultivation under open and shaded conditions.

AMMI Analysis

- The genotypes 4.5.9 and 6.4.1 which are present near to the origin were non sensitive to interactive patterns. These genotypes were having early flowering also. Hence, these genotypes can be selected for days to flowering.

- The genotypes 4.5.3, 4.5.9, 4.5.18 and Syama were lesser sensitive to environmental interactive forces. Among these, the genotype 4.5.18 with high mean value and genotype 4.5.9 with plant height more than 44 cm can be selected for plant height.

- The genotypes 4.5.9 and 4.6.1 were found to be non sensitive to environmental interactive forces. Both these genotypes were having moderately high branch number and hence can be selected.

- The genotypes 4.5.9 and 4.5.18 were comparatively non sensitive to environment. Hence, the genotype 4.5.9 with high number of pod bearing branches per plant can be selected.

- The genotypes 4.1.1 and 4.5.9 were found to be non sensitive to environmental interactive forces. Of this two genotypes, genotype 4.5.18 with high number of pods per plant can be selected.

- The genotypes 4.1.1 and 4.5.9 were comparatively non sensitive to environmental interactive forces. Of this two genotypes, genotype 4.5.9 having longer pods can be selected.

- Genotype 6.4.1 which had IPCA 1 value near to zero can be considered as stable for seeds per pod.

- The genotypes 4.5.2 and 4.6.1 were non sensitive to environmental interactive forces and were having moderately high mean value indicating that these genotypes can be selected.

- For yield per plant, genotypes 6.4.1 and 4.5.9 were having high main effects but were away from IPCA 1 axis indicating that even though they are high yielders, the performance can not be predicted. The genotypes 4.5.8 and TAU-1 were non sensitive to environment. Of this two genotypes the genotype 4.5.8 with high mean value can be selected.

- For protein content, the genotypes 4.1.1, 4.5.8 and 4.5.7 were comparatively stable over environments. Of these, genotype 4.5.8 with high mean value can be selected.

- Based on the total scores calculated from AMMI model and ranks of important traits the 4.5.9, 4.5.8 and 4.5.3 genotypes were identified as superior and suitable for cultivation under open and shaded conditions.

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GENOTYPE X ENVIRONMENT INTERACTION IN BLACKGRAM (*Vigna mungo* L. Hepper)

by

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ABSTRACT OF THE THESIS

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ABSTRACT

Blackgram (*Vigna mungo* (L.) Hepper) is an important short duration pulse crop occupying unique position in Indian agriculture. Its seeds are highly nutritious and used in the preparation of many popular dishes. Pulses are part of the daily diet of vegetarians world over. They are rich in protein (20-30 %) and are an excellent source of dietary fiber, low molecular weight carbohydrates, essential aminoacids, poly unsaturated fatty acids and range of micronutrients. In recent years there has been an increase in consumption of pulses in several developed countries where they are increasingly considered as health food.

In Kerala, cultivation of pulses especially black gram as third crop i.e., in summer fallows in paddy growing areas was a common practice by the farmers. However, this trend has come down in the near past due to non availability of labourers for harvesting and low yield of traditional varieties. Raising blackgram in coconut gardens seems as a viable option to increase area of cultivation. In Kerala, high yielding varieties suited to both open and shaded conditions are not available.

The study on "Genotype x environment interaction in black gram" was an attempt to identify suitable cultures for cultivation under open condition as a sole crop in rice fallow lands and as an intercrop in coconut garden. Materials used for the study consisted of ten black gram cultures developed by pedigree breeding from four crosses in the stabilized generation at the Department of Plant Breeding and Genetics. The check varieties were TAU-1, T-9, Sumanjana and Syama. The crop was raised under open and shade condition during *kharif*, *rabi* and summer seasons of 2013-2014. The plants were raised in plots of five meter square with two replications. All the observations were recorded at harvest except days to flowering. The data was analyzed for stability by Eberhart and Russell's model as pooled over open condition, pooled over shade condition and pooled over all the six environments.

According to Eberhart and Russell's model of stability a good genotypes is the one having high mean value, non significant bi and S^2di value. Stability analysis by Eberhart and Russell's model pooled over open condition showed that there was no variation between genotypes under three seasons for days to flowering, length of pod and number of seeds per pod. Also none of the genotypes showed stability for protein content. Genotypes were ranked based on stability, yield and major yield contributing characters. The genotypes with least score were T6, T5 and T9. These can be recommended for cultivation under open condition.

Stability analysis by Eberhart and Russell's model pooled over shade condition showed that that there was no variation between genotypes under three seasons for number of seeds per pod. None of the genotype was stable for protein content. Ranking of genotypes showed that genotypes T3, T5, T6 and T10 can be recommended for cultivation as an inter crop in coconut garden.

Estimation of stability by Eberhart and Russell's model pooled over six environments showed that there was variation between genotypes under the environments for all the traits studied. Genotypes were ranked based on stability, yield and major yield contributing characters. The genotypes with least score were T6, T5 and T3. These can be recommended for cultivation under both the conditions.

Based on G x E analysis done by AMMI model also genotypes T5, T6 and T 3 were identified as suitable for planting under the six environments.

The identified genotypes suitable for each condition that is genotypes T3, T5, T6,T9 and T10 has be evaluated in large plots to confirm the results and the quality of these genotypes has to be assessed for developing as variety suitable for open condition and intercropping.