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Associations between pod yield and its contributing traits in advanced peanut lines as influenced by imposed moisture stress

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Abstract

Aim: Assessment of correlation between yield and its contributing traits in groundnut under terminal drought stress

Experimental Design: Randomized complete block design (RCBD) design replicated twice

Location and duration of the study: The College of horticulture, Hiriya during *rabi* 2016-17

Methodology: Forty genotypes of groundnut comprising advanced breeding lines and existed cultivars were subjected to field evaluation under irrigated and imposed end-of-season drought stress. The moisture stress was imposed at 90 DAS for 20 days by withholding irrigation to drought stress block. However, the irrigated trail was provided with regularly recommended irrigations. Observations on morphological, yield and its contributing traits were recorded on randomly sampled five plants per entry per replication in both the environments at different stages of the crop growth cycle. The resulted mean data was subjected to statistical analysis using Genstat 14.1 software.

Results: Results revealed that pod yield per plant showed a significant positive correlation with the number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index under imposed end-of-season drought stress.

Conclusion: It can be concluded that these traits should be given due importance while practicing selection for increasing yield under drought stress and also in development of high yielding drought tolerant genotypes in groundnut.

Keywords: Peanut, correlation, pod yield, drought tolerance

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the principal oilseed crops ranking fourth among the oil seed crops of the world (Cuc *et al.*, 2008 and Coulbaly, 2013) ^[6, 5], popularly called as groundnut, peanut, earthnut, wonder nut, monkey nut, panilla, manila nut *etc.* It is an important food legume cash crop having adaptability to a variable soil and climatic conditions. Groundnut is cultivated worldwide in tropical, sub-tropical and warm temperature areas located between 40° N to 40° S latitude (Coulbaly, 2013) ^[5]. Groundnut yield in rain fed areas has been limited by drought stress because pod yield and other growth parameters have been severely affected resulting the average yield loss of 17 to 70 per cent in grain yield due to drought stress (Mostafa, 2013) ^[19]. Mid and end-of-season droughts are critical as they affect the pod yield and quality parameters. The extremely variable nature of drought has made it difficult to define plant attributes required for improved performance under drought, consequently limiting plant-breeding efforts to enhance drought tolerance in groundnut. Genetic options for improvements in drought tolerance vary with most drought patterns experienced in a given environment (Suvarna *et al.*, 2004 and Gopinath *et al.*, 2008) ^[28, 11].

Yield is a complex trait and selection for this attribute based on heritability estimates only will not be rewarding for yield improvement. Pod yield is the effect of complex interrelationships between various component characters thus, understanding the relationship between these traits helps in achieving the improved yield. Information on the phenotypic and genotypic interrelationship of the pod yield with its components and also among the component characters themselves would be useful to the breeder in developing an appropriate selection

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strategy (John and Reddy (2015) ^[14]; Jayalakshmi and Nirmala (2015) ^[13]; Thakur *et al.* (2013b) ^[29]; Babariya and Dobariya (2012) ^[3]; Ravi and Sekhar (2012) ^[2]; Dandu *et al.* (2012) ^[7]; Zaman *et al.* (2011) ^[34]; Korat *et al.* (2010) ^[17]; Vaithiyalingan *et al.* (2010) ^[30].

It has been reported that primary yield components of groundnut *viz.*, pod size, sound mature kernels (Nandini and Savithramma 2012), shelling percentage (Venkataravana *et al.* (2000) ^[31]; Roy *et al.* (2003) ^[23]; John and Reddy (2015) ^[14], 100 kernel weight (Venkataravana *et al.* (2000) ^[31]; Roy *et al.* (2003) ^[23]; John and Reddy (2015) ^[14], kernel yield (Nandini and Savithramma (2012); John and Reddy (2015) ^[14]; Venkataravana *et al.* (2000) ^[31], 100 pod weight (Roy *et al.* (2003) ^[23], plant height (Venkataravana *et al.* (2000) ^[31], number of branches per plant and number of mature pods per plant (Venkataravana *et al.* (2000) ^[31], number of pods (Roy *et al.* (2003) ^[23]; De Costa and Nayakarathne 2001) ^[8], showed positive correlation with each other and with pod yield. Nandini and Savithramma (2012) reported that pod yield per plant was negatively correlated with days to shelling out turn percentage and days to 50 per cent flowering.

With this background, present study was undertaken with an objective of finding association between pod yield and its components traits in selected groundnut genotypes under both irrigated and imposed drought stress environments

Material and Methods

Plant material

Forty groundnut genotypes including advanced breeding lines and local checks were obtained from International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, National Bureau of Plant Genetic Resources (NBPGR), New Delhi and other institutes were included as genetic materials in this study. The details of the genotypes are presented in the table 1.

Crop management and experimental design

The research material employed in the present study consisted of forty genotypes which were screened under drought condition (moisture stress) and optimum moisture (non-stress) conditions at College of Horticulture, Hiriyur located in the Central Dry Zone (Zone-IV) of Karnataka at 13° 57' North latitude, 76° 40' East longitudes with an altitude of 630 meters above the mean sea level.

The experiment was laid out in a randomized complete block design (RCBD) in two replications. The experimental plot size per genotype was 0.6m length X 3m width which constitutes 1.87m². On the other hand plot to plot and replication to replication distance was 0.2 and 0.5 m respectively. Test materials were sown by hands in fields on 1st of October 2016. Seeds were sown in furrow at the depth of 4 cm approximately.

Seed treatment

A pinch (25-30 g) of trichoderma is dissolved in one litre of 10% jaggery solution and well shaken. Then seeds were treated with the solution and allowed to shade dry for half an hour. Later the seeds were treated with Chloropyrifos just before the sowing.

Seed sowing

Each of the 40 genotypes was sown in 3 meter rows with two rows per genotype per replication with spacing of 30 cm between rows and 10 cm between plants within a row. Care was taken to ensure uniform depth of sowing. Sound, mature

and good quality kernels were only used for sowing. All the plots were irrigated as per package of practices (once in 7-8 days) up to 90 days. For moisture stressed plots, moisture stress was imposed for 20 days starting from 90 days after sowing by withdrawing irrigation. However, regular irrigation was provided for the non-moisture stressed plots.

Observations and measurements

Observations on different morphological, and yield related traits were taken at different stages of crop growth in both moisture stressed and normal moisture plots.

Days to fifty per cent flowering

The number of days from sowing until the time when fifty per cent of the plants flowered in each genotype of each replication in both normal moisture and moisture stressed conditions was recorded.

Plant height at 30, 60 and 90 days after sowing and at harvest (cm)

Plant height was measured from the soil surface to the tip of the five randomly selected plants of each genotype from each replication in both moisture stressed and non-stressed plots with the help of scale at 30, 60 and 90 days after sowing and also at harvest. Finally average plant height was computed and expressed in centimeters.

Number of primary branches per plant at 60, 90 DAS and harvest

The number of primary branches arising from the main stem in each of the sampled plants were counted in both moisture stressed and non-stressed plots of all the genotypes at 60, 90 DAS and also at harvest. The mean number of primary branches for each genotype was computed.

Number of secondary branches per plant at 60, 90 DAS and harvest

The number of secondary branches arising from the main stem was counted in five randomly tagged plants from which number of primary branches were taken in both moisture stressed and non-stressed plots of all the genotypes at 60, 90 DAS and also at harvest and their average was computed for each genotype.

Number of days to maturity

The number of days from emergence to maturity of pod was recorded as days to maturity. Ninety days after sowing, one plant was harvested from each plot to determine the percentage of developed pods. The plots were harvested when at least 75 per cent of the developed pods were mature as determined by the blackening of the internal shell wall (Williams and Drexler, 1981) ^[33].

Number of pods per plant

Total number of pods of five randomly selected plants from each genotype in moisture stressed and non-stressed plots was counted and their average was taken as the number of pods per plant.

Number of mature pods per plant

Total number of mature pods was counted from five randomly selected plants from each genotype in moisture stressed and non-stressed plots and their average was taken as the number of mature pods per plant.

Number of immature pods per plant

It was calculated by deducting the total number of matured pods from the total number of pods of five randomly selected plants from each genotype in moisture stressed and non-stressed plots.

Pod yield per plant (g)

Pod yield was determined from pods harvested from five randomly selected plants from each genotype in moisture stressed and non-stressed plots after air drying to constant weight for two weeks and their average was taken as the pod yield per plant which was expressed in grams.

Pod yield per hectare (kg/ha)

The weight of pods in each plot was recorded, and then transformed to pod yield per hectare and expressed in kilograms.

Shelling percentage (%)

Randomly selected 100 g pods from each genotype in moisture stressed and non-stressed plots was weighed and recorded. Then the same pods were shelled with hand and kernels were separated. The weight of kernel and shell was weighted. The shelling percentage was calculated by using the following formula:

$$\text{Shelling out turn (\%)} = \frac{\text{Weight of kernels (g)}}{\text{Weight of pods (g)}} \times 100$$

Kernel yield per plant (g)

Kernel yield was calculated by using the following formula and expressed in grams as given by Bell *et al.*, 1991.

$$\text{Kernel yield} = \text{pod yield (g)} \times \text{shelling percentage (\%)}$$

Number of kernels per plant

Total number of kernels of five randomly selected plants from each genotype in moisture stressed and non-stressed plots were counted and their average was taken as the number of kernels per plant.

Test weight (hundred kernel weight) (g)

Randomly selected 100 well sun dried kernels/seeds from each genotype in moisture stressed and non-stressed plots separately were weighed and data was recorded in grams.

Sound mature kernel percentage (%)

This observation was made on the randomly selected 100 g of kernels of which mature sound and healthy seeds were separated, counted and recorded as sound mature kernel percentage according to the formula:

$$\text{Sound mature kernel (\%)} = \frac{\text{Number of mature sound kernels}}{\text{Total number of kernels}} \times 100$$

The sound mature kernel percentage was expressed as percentage.

Harvest Index (HI)

Harvest index was calculated by using the following formula and which was expressed as percentage (Girdthai *et al.*, 2010) [10].

$$\text{Harvest index (HI)} = \frac{\text{Total pod weight (g)}}{\text{Total Biomass weight (g)}} \times 100$$

Fresh weight of seedling (g)

Fresh weight of the five seedlings was measured using a precision balance after harvest and average seedling weight was computed and expressed in milligrams.

Total seedling length (cm)

It is the summation of total length of shoot and total length of root measured in centimetres. It was calculated by using the following formula

$$\text{Seedling length (cm)} = \text{Total length of shoot (cm)} + \text{Total length of root (cm)}.$$

Correlation coefficients

The correlation coefficients were calculated to determine the degree of association of different characters with yield and also among the different yield components.

Phenotypic correlation coefficients between all pairs of characters were determined by using variance and covariance components as suggested by Al-Jibouri *et al.*, (1958) [2]. The Correlation analysis was done by using the WINDOSTAT software.

$$r_{xy} = \text{cov (xy)} / \sqrt{v(x) \cdot v(y)}$$

Where,

r = Correlation coefficient

x,y = Variables

cov (x,y) = Covariance between x and y

V (x), v (y) = Variance of x and y variable

The calculated value of r was compared with 'r' table value with (n - 2) degrees of freedom at 5 and 1 per cent level of significance, where n refers to number of pairs of observation.

Results**Correlation of pod yield with yield component traits**

In case of normal moisture condition, the pod yield per plant recorded a highly positive significant association with number of mature pods per plant (0.8913), number of immature pods per plant (0.5849), number of pods per plant (0.8404), number of kernels per plant (0.8607), kernel yield per plant (0.8194), fresh weight of seedling (0.7245) and harvest index (0.8297). It had negative significant relation with plant height at harvest (0.2580). Further, it had a positive non-significant association with primary branches at harvest (0.0866), test weight (0.0646) and number of days to maturity (0.1295). A negative non-significant correlation of this trait was observed for secondary branches at harvest (0.1090), shelling percentage (0.1589), percentage of sound mature kernels (0.1803) and total seedling length (0.2068). However, under managed drought condition, it had highly positive significant association with number of mature pods per plant (0.5822), number of immature pods per plant (0.2485), number of pods per plant (0.5882), number of kernels per plant (0.5464), kernel yield per plant (0.5680), fresh weight of seedling (0.4618) and harvest index (0.2710). A negative non-significant correlation was observed for primary branches at harvest (0.0420), secondary branches at harvest (0.1890) and number of days to maturity (0.1749). It had a positive non-significant correlation with plant height at harvest (0.0485), shelling percentage (0.0399), percentage of sound mature kernels (0.1101), test weight (0.1573) and total seedling length (0.1042).

Association among the component traits**Plant height at harvest**

Under normal moisture condition, the plant height at harvest had positive significant association with shelling percentage

(0.4506), test weight (0.3260) and total seedling length (0.8765). It also had a negative significant association with number of mature pods (0.3367), number of immature pods (0.3367), number of pods per plant (0.3500), fresh weight of the seedling (0.2406), harvest index (0.3338) and number of days to mature. A positive non-significant association was observed for secondary branches at harvest (0.0976) and percentage of sound mature kernels (0.1412). It also had a negative non-significant correlation with primary branches at harvest (0.2100), number of kernels per plant (0.2178) and kernel yield per plant (0.2124).

Under moisture stress condition, plant height at harvest recorded a positive significant correlation with total seedling length (0.8496) and fresh weight of the seedlings (0.2314). It had a negative significant correlation with harvest index (0.2251). It also had a positive non-significant correlation with shelling percentage (0.1643), percentage of sound mature kernels (0.1199), test weight (0.0710) and number of days to maturity (0.0039). It had a negative non-significant correlation with primary branches at harvest (0.1189), secondary branches at harvest (0.0676), number of matured pods per plant (0.1186), number of immature pods per plant (0.1758), number of pods per plant (0.0880), number of kernels per plant (0.0787) and kernel yield per plant (0.0951).

Primary branches per plant at harvest

Under normal moisture, primary branches per plant at harvest had a positive non-significant association with fresh weight of seedling (0.2219), percentage of sound mature kernels (0.0806), number of mature pods per plant (0.1631), number of pods per plant (0.1633), number of kernels per plant (0.1212), kernel yield per plant (0.0250) and harvest index (0.1015). A negative significant correlation was recorded with shelling percentage (0.2436) and test weight (0.2377) besides having a negative non-significant association with secondary branches per plant at harvest (0.0972), number of immature pods per plant (0.0336), total seedling length (0.0921) and number of days to maturity (0.0679).

However, in moisture stressed condition, primary branches per plant at harvest had a negative significant association with shelling percentage (0.2497). The negative non-significant association for this trait was observed with secondary branches per plant at harvest (0.0796), percentage of sound mature kernels (0.0135), test weight (0.0012), number of mature pods per plant (0.0664), number of pods per plant (0.1524), number of immature pods per plant (0.0421), number of kernels per plant (0.0535) and total seedling length (0.1247). It had a positive non-significant association with kernel yield per plant (0.1291), fresh weight of seedling (0.0076), harvest index (0.0500) and number of days to maturity (0.0612).

Secondary branches per plant at harvest

Under normal moisture condition, secondary branches per plant at harvest had a positive significant association with number of days to maturity (0.2662) besides having a positive non-significant association with shelling percentage (0.0401), percentage of sound mature kernels (0.0614), test weight (0.0043) and total seedling length (0.0295). This trait had a negative non-significant association with number of mature pods per plant (0.1562), number of immature pods per plant (0.2130), number of pods per plant (0.1693), number of kernels per plant (0.1878), kernel yield per plant (0.1048), harvest index (0.1776) and fresh weight of seedling (0.0827).

However, in moisture stress condition, secondary branches per plant at harvest had a positive significant association with number of days to maturity (0.2877) and test weight (0.4862) but positive non-significant association with shelling percentage (0.0486), fresh weight of seedling (0.0732) and total seedling length (0.0097). It showed a negative significant correlation with number of immature pods per plant (0.2306) and number of pods per plant (0.2345) whereas negative non-significant correlation was observed with percentage of sound mature kernels (0.0411), number of kernels per plant (0.1705), kernel yield per plant (0.1247) and harvest index (0.0729).

Shelling percentage

Under normal moisture condition, the shelling percentage had a positive significant association with total seedling length (0.3006) and positively non-significant correlation with percentage of sound mature kernels (0.1106) and test weight (0.0592). Negative significant correlation with number of pods per plant (0.2276) and non-significant negative correlation with number of mature pods per plant (0.1898), number of immature pods per plant (0.1237), number of kernels per plant (0.0423), kernel yield per plant (0.0483), fresh weight of seedling (0.1551), number of days to maturity (0.0550) and harvest index (0.2175) was observed for this trait.

The shelling percentage under moisture stress exhibited a negative significant correlation with number of days to maturity (0.2766) whereas negative non-significant correlation was seen with percentage of sound mature kernels (0.0754), number of mature pods per plant (0.0843), number of immature pods per plant (0.2176) and number of pods per plant (0.0350). Positive non-significant correlation of this trait was observed with test weight (0.1129), number of kernels per plant (0.1141), kernel yield per plant (0.0590), fresh weight of seedling (0.1638), harvest index (0.0189) and total seedling length (0.1960).

Percentage of sound mature kernels

Under normal moisture condition, the percentage of sound mature kernels had positive non-significant relation with total seedling length (0.1535) and test weight (0.1685). This character had a negative non-significant correlation with number of pods per plant (0.1694), number of mature pods per plant (0.1474), number of immature pods per plant (0.2173), number of kernels per plant (0.1655), kernel yield per plant (0.1047), fresh weight of seedling (0.1582), number of days to maturity (0.0753) and harvest index (0.0940).

In moisture stressed condition, this trait had negative non-significant association with traits like test weight (0.1096), number of pods per plant (0.0110), number of mature pods per plant (0.0362), number of immature pods per plant (0.0880), number of kernels per plant (0.0143), kernel yield per plant (0.1949), number of days to maturity (0.1191) and harvest index (0.0292) except for fresh weight of seedling (0.1556) and total seedling length (0.1678) which had a positive non-significant correlation.

Test weight

For test weight under normal moisture condition, positive significant correlation was observed with total seedling length (0.2320) and positive non-significant correlation with harvest index (0.1141), kernel yield per plant (0.0081) and number of days to maturity (0.0091). Negative non-significant correlation was observed with number of pods per plant

(0.1855), number of mature pods per plant (0.1829), number of immature pods per plant (0.1244), number of kernels per plant (0.1031) and fresh weight of seedling (0.0038).

In moisture stressed condition, test weight has shown positive non-significant correlation with kernel yield per plant (0.0929), number of days to maturity (0.1633), fresh weight of seedling (0.0434) and total seedling length (0.1783). Negative non-significant association of this trait with number of pods per plant (0.1517), number of mature pods per plant (0.1129), number of immature pods per plant (0.1176), number of kernels per plant (0.0440) and harvest index (0.0912) was observed.

Number of mature pods per plant

Under normal moisture condition, a positive significant correlation of number of mature pods was observed with number of immature pods per plant (0.5124), number of pods per plant (0.9309), number of kernels per plant (0.8533), kernel yield per plant (0.7649), harvest index (0.7211) and fresh weight of seedling (0.6641). Further, it also recorded a positive non-significant correlation with number of days to maturity (0.0173) besides having a negative significant association with total seedling length (0.2771).

Number of mature pods per plant in moisture stressed condition exhibited a positive significant correlation with number of immature pods per plant (0.2505), number of pods per plant (0.6345), number of kernels per plant (0.5076), kernel yield per plant (0.4483) and harvest index (0.3925) besides having a positive non-significant association with fresh weight of seedling (0.1813) and total seedling length (0.0067). A negative non-significant correlation of this trait was seen with number of days to maturity (0.0827).

Number of immature pods per plant

Under normal moisture condition, number of immature pods per plant indicated a positive significant correlation with number of pods per plant (0.6038), number of kernels per plant (0.5125), kernel yield per plant (0.5142), harvest index (0.6076), fresh weight of seedling (0.5151) and number of days to maturity (0.2800) in addition to having a negative non-significant correlation with total seedling length (0.3405). For number of immature pods per plant in moisture stressed condition, positive significant correlation was observed with number of pods per plant (0.4954), number of kernels per plant (0.3528) and kernel yield per plant (0.4343) and positive non-significant correlation was recorded with harvest index (0.2505) and fresh weight of seedling (0.0277), respectively. It also had negative non-significant correlation with number of days to maturity (0.0919) and total seedling length (0.1972).

Number of pods per plant

Under normal moisture condition, number of pods per plant pointed a positive highly significant correlation with number of kernels per plant (0.7818), kernel yield per plant (0.7155), fresh weight of seedling (0.6536) and harvest index (0.7320) besides its non-significant positive correlation with number of days to maturity (0.0228). A negative significant association was observed with total seedling length (0.2848).

In moisture stressed condition, this trait had positive significant correlation with kernels per plant (0.3202), harvest index (0.3089) and kernel yield per plant (0.2658) in addition to its positive non-significant relation with fresh weight of seedling (0.1956). A negative non-significant correlation was observed with number of days to maturity (0.1271) and total seedling length (0.0116).

Number of kernels per plant

Under normal moisture condition, number of kernels per plant exhibited a positive significant correlation with kernel yield per plant (0.8594), fresh weight of seedling (0.5985) and harvest index (0.7092). A negative non-significant correlation was observed with number of days to maturity (0.0245) and total seedling length (0.1510).

For this trait under moisture stressed condition, positive significant correlation was observed with kernel yield per plant (0.5798), harvest index (0.3721) and fresh weight of seedling (0.2336). Further, it had a negative non-significant correlation with number of days to maturity (0.1661) and total seedling length (0.0856).

Kernel yield per plant

Under normal moisture condition, kernel yield per plant had positive significant correlation with fresh weight of seedling (0.5240) and harvest index (0.6764) besides showing a non-significant positive correlation with number of days to maturity (0.0702). There was a negative non-significant correlation of this trait with total seedling length (0.1886).

In moisture stressed condition, kernel yield per plant exhibited a positive significant correlation with fresh weight of seedling (0.3396) and harvest index (0.2729). It had a negative significant relation with number of days to maturity (0.2226) and negative non-significant association with total seedling length (0.0516).

Fresh weight of seedling

Under normal moisture condition, the fresh weight of seedling recorded a positive significant correlation with harvest index (0.5643) and non-significant positive correlation with number of days to maturity (0.1959). But a negative non-significant correlation was observed for this trait with total seedling length (0.1663).

In moisture stressed condition, positive significant correlation of fresh weight of seedling was observed with total seedling length (0.3071) and positive non-significant association with harvest index (0.0861). A negative non-significant relation was seen with number of days to maturity (0.1993) for this trait.

Harvest index

Under normal moisture condition, the harvest index exhibited a non-significant positive correlation with number of days to maturity (0.0885) and negative significant correlation with total seedling length (0.2389).

In moisture stressed condition, negative non-significant correlation was observed for harvest index with total seedling length (0.2204) and number of days to maturity (0.1260).

Number of days to maturity

For number of days to maturity under normal moisture condition, negative significant correlation was observed with total seedling length (0.2714). However, in moisture stressed condition, number of days to maturity had a negative non-significant relationship with total seedling length (0.1442).

Discussion

Association analysis

In normal moisture condition, the pod yield per plant recorded a highly positive significant association with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index. It

had negative significant relation with plant height at harvest. It had positive non-significant association with primary branches at harvest, test weight and number of days to maturity. A negative non-significant correlation was observed for secondary branches at harvest, shelling percentage, percentage of sound mature kernels and total seedling length. Similar trend was reported by Roy *et al.* (2003) [23]. However, in managed drought condition it had highly positive significant association with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index. A negative non-significant correlation was observed for primary branches at harvest, secondary branches at harvest and number of days to maturity. It had positive non-significant correlation with plant height at harvest, shelling percentage, percentage of sound mature kernels, test weight and total seedling length. Similar results were reported by Lakshmidhevamma *et al.* (2004) [18], Suneetha *et al.* (2005) [27], Venkateswarlu *et al.* (2007) [32], Vaithiyalingan *et al.* (2010) [30] and John and Reddy, (2015) [14].

Among the yield component traits, different types of correlations were observed and are discussed briefly here under:

Under normal moisture, number of primary branches per plant at harvest had a positive significant association with fresh weight of seedling while it had a negative significant correlation with shelling percentage and test weight. It has recorded a positive non-significant association with percentage of sound mature kernels, number of mature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant and harvest index. Also this trait had a negative non-significant association with secondary branches per plant at harvest, number of immature pods per plant, total seedling length and number of days to maturity. However, in moisture stress condition, number of primary branches per plant at harvest had a negative significant association with shelling percentage. The negative non-significant association for this trait was observed with secondary branches per plant at harvest, percentage of sound mature kernels, test weight, number of mature pods per plant, number of pods per plant, number of immature pods per plant, number of kernels per plant and total seedling length. It had a positive non-significant association with kernel yield per plant, fresh weight of seedling, harvest index and number of days to maturity. Similar findings were reported by Venkataravana *et al.* (2000) [31].

Under normal moisture condition, number of secondary branches per plant at harvest had a positive significant association with number of days to maturity and also positive non-significant association with shelling percentage, percentage of sound mature kernels, test weight and total seedling length. This trait had a negative non-significant association with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, harvest index and fresh weight of seedling. However, in moisture stress condition, number of secondary branches per plant at harvest had a positive significant association with number of days to maturity and test weight but positive non-significant association with shelling percentage, fresh weight of seedling and total seedling length. It showed negative significant correlation with number of immature pods per plant and number of pods per plant whereas negative non-significant correlation was observed with percentage of sound mature

kernels, number of kernels per plant, kernel yield per plant and harvest index.

The shelling percentage under normal moisture had a positive significant association with total seedling length and positively non-significant correlation with percentage of sound mature kernels and test weight. Negative significant correlation of this trait was observed with number of pods per plant and non-significant negative correlation with number of mature pods per plant, number of immature pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling, number of days to maturity and harvest index. However, under moisture stress condition, negative significant correlation was observed with number of days to maturity whereas negative non-significant correlation was seen with percentage of sound mature kernels, number of mature pods per plant, number of immature pods per plant and number of pods per plant. Positive non-significant correlation was observed with test weight, number of kernels per plant, kernel yield per plant, fresh weight of seedling, harvest index and total seedling length. Similar results of significant association of shelling per cent with pod yield per plant was reported by Nagda *et al.* (2001) [20], Abhay *et al.* (2002) [1], Venkataravana *et al.* (2000) [31] and John *et al.* (2009) [15].

Under normal moisture condition, the percentage of sound mature kernels had positive non-significant relation with total seedling length and test weight. This character had a negative non-significant correlation with number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling, number of days to maturity and harvest index. In moisture stressed condition, this trait has negative non-significant association with all the traits like test weight, number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant, kernel yield per plant, number of days to maturity and harvest index except fresh weight of seedling and total seedling length which had positive non-significant correlation. Similar results of positive significant association of pod yield per plant and test weight with SMK per cent was reported by Francis and Ramalingam (1999) [9] and Roy *et al.* (2003) [23].

The test weight under normal moisture condition recorded positive significant correlation with total seedling length and positive non-significant association with harvest index, kernel yield per plant and number of days to maturity. Negative non-significant correlation was observed with number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant and fresh weight of seedling. In moisture stress condition, the test weight shown positive non-significant correlation with kernel yield per plant, number of days to maturity, fresh weight of seedling and total seedling length in addition to negative non-significant correlation with number of pods per plant, number of mature pods per plant, number of immature pods per plant, number of kernels per plant and harvest index. Similar trend of association of hundred kernel weight with pod yield per plant and seedling length in positive direction was also reported by Sarala and Gowda (1998) [24] and Nagda *et al.* (2001) [20].

Under normal moisture condition, the number of mature pods per plant had positive highly significant correlation with number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, harvest index and fresh weight of seedling also a positive non-

significant association with number of days to maturity. It had a negative significant association with total seedling length. However, this trait under moisture stress condition, exhibited a positive significant correlation with number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant and harvest index in addition it had a positive non-significant correlation with fresh weight of seedling and total seedling length. Negative non-significant correlation was seen with number of days to maturity. Songsri *et al.* (2008a) ^[26] reported significant correlation for number of mature pods per plant. Number of matured pods per plant seemed to play an important role in maintaining high pod yield under drought especially under severe stressed condition. Patil *et al.* (2004) ^[21] reported that number of mature pods were positively significantly associated with pod yield per plant. Similar results were also reported by Francis and Ramalingam (1997) and Sarala and Gowda (1998) ^[24].

Under normal moisture condition, the number of immature pods per plant indicated a positive highly significant correlation with number of pods per plant, number of kernels per plant, kernel yield per plant, harvest index, fresh weight of seedling and number of days to maturity. It also had a negative non-significant correlation with total seedling length. For number of immature pods per plant in moisture stress condition, positive highly significant correlation was observed with number of pods per plant, number of kernels per plant and kernel yield per plant. Positive significant and positive non-significant correlation was recorded with harvest index and fresh weight of seedling, respectively. It also had negative non-significant correlation with number of days to maturity and total seedling length. Similar results were reported by Lakshmidheevamma *et al.* (2004) ^[18], Suneetha *et al.* (2005) ^[27], Venkateswarlu *et al.* (2007) ^[32] and Ravi and Sekhar (2012) ^[2]. Under the conditions of no moisture stress, the number of pods per plant pointed a positive highly significant correlation with number of kernels per plant, kernel yield per plant, fresh weight of seedling and harvest index. Non-significant positive correlation was found with number of days to maturity and negative significant association was observed with total seedling length. Nevertheless, this trait under moisture stress condition exhibited a positive significant correlation with number of kernels per plant and harvest index. A positive significant association was recorded with kernel yield per plant in addition to positive non-significant relation with fresh weight of seedling. Negative non-significant correlation was observed with number of days to maturity and total seedling length. Similar findings were reported by Babariya and Dobariya, (2012) ^[3], Hamidou *et al.* (2012) ^[12], Nandini and Savithramma (2012) and Ravi and Sekhar, (2012) ^[2].

Under normal moisture condition, the number of kernels per plant exhibited a positive highly significant correlation with kernel yield per plant, fresh weight of seedling and harvest index. There exists a negative non-significant correlation of this trait with number of days to maturity and total seedling length. For this trait under moisture stress condition, positive highly significant correlation was observed with kernel yield per plant and harvest index. It had a positive significant relation with fresh weight of seedling. A negative non-significant correlation was observed for number of days to maturity and total seedling length. Similar observations were reported Seyyed and Seyyed, (2012) ^[25].

Under no moisture stress condition, the kernel yield per plant has shown positive highly significant correlation with fresh weight of seedling and harvest index, and also a non-significant positive correlation with number of days to maturity. There was a negative non-significant correlation was recorded with total seedling length. However, under moisture stress condition, positive highly significant correlation was exhibited by kernel yield per plant with fresh weight of seedling besides it also had positive significant association with harvest index. It had negative significant relation with number of days to maturity and also negative non-significant association with total seedling length. Similar results were reported by Jayalakshmi and Nirmala (2015) ^[13] and John and Reddy (2015) ^[14].

Under normal moisture condition, the fresh weight of seedlings recorded a positive highly significant correlation with harvest index and non-significant positive correlation with number of days to maturity. Further, a negative non-significant correlation was observed with total seedling length. However, in moisture stress condition, positive significant correlation was observed for fresh weight of seedling with total seedling length and positive non-significant association with harvest index. Further, the trait had a negative non-significant relation with number of days to maturity.

Under normal moisture condition, the harvest index exhibited a non-significant positive correlation with number of days to maturity and had negative significant correlation with total seedling length. In moisture stress condition, negative non-significant correlation was observed for harvest index with total seedling length and number of days to maturity. Similar results were cited by Kalmeshwer *et al.* (2006) ^[16] and Nagda *et al.* (2001) ^[20].

For number of days to maturity under normal moisture, negative significant correlation was observed with total seedling length. However, under moisture stress condition, number of days to maturity had a negative non-significant relationship with total seedling length.

Table 1: List of genotypes employed in the present experimental study

Sl. No.	Genotype	Source of collection	Features (Branching type)
1	ICGV 15114, ICGV 15119, ICGV 15120, ICGV 15122, ICGV 15123 ICGV 15124, ICGV 15138, ICGV 15141, ICGV 15143, ICGV 15145, ICGV 15146, ICGV 15148, ICGV 15149, ICGV 15151, ICGV 15152, ICGV 15153, ICGV 15154, ICGV 15158, ICGV 15159, ICGV 15161	ICRISAT, Patancheru	Erect type
2	SB-1, SB-14, SB-15, SB-17, VB, VB-11, VB-14	NBPGR, New Delhi	Erect type
3	DH-86, DH-101, DH-234, GPBD-4, GPBD-5, TMV-2, G2-52	UAS, Dharwad	Erect type
4	K-9, K-6, KCG-6, KCG-2	UAS, Bangalore	Erect type
5	LOCAL-1	Local	Erect type
6	R-2001-3	UAS, Raichur	Erect type

ICRISAT – International Crops Research Institute for Semi-Arid Tropics

NBPGR – National Bureau of Plant Genetic Resources

UAS - University of Agricultural Sciences

Table 2: Phenotypic correlation of yield components with pod yield per plant (g) under normal moisture

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1.0000	-0.2100	0.0976	0.4506**	0.1412	0.3260**	-0.3367**	-0.3367**	-0.3500**	-0.2178	-0.2124	-0.2406	-0.3338**	-0.2482*	0.8765**	-0.2580*
X2		1.0000	-0.0972	-0.2436*	0.0806	-0.2377*	0.1631	-0.0336	0.1633	0.1212	0.0250	0.2219	0.1015	-0.0679	-0.0921	0.0866
X3			1.0000	0.0401	0.0514	0.0043	-0.1562	-0.2130	-0.1693	-0.1878	-0.1048	-0.0827	-0.1776	0.2662*	0.0295	-0.1090
X4				1.0000	0.1106	0.0592	-0.1898	-0.1237	-0.2276*	-0.0423	-0.0483	-0.1551	-0.2175	-0.0550	0.3006**	-0.1589
X5					1.0000	0.1685	-0.1474	-0.2173	-0.1694	-0.1655	-0.1047	-0.1582	-0.0940	-0.0753	0.1535	-0.1803
X6						1.0000	-0.1829	-0.1244	-0.1855	-0.1031	0.0081	-0.0038	0.1141	0.0091	0.2320*	0.0646
X7							1.0000	0.5124**	0.9309**	0.8533**	0.7649**	0.6641**	0.7211**	0.0173	-0.2771*	0.8913**
X8								1.0000	0.6038**	0.5125**	0.5142**	0.5151**	0.6076**	0.2800*	-0.3405**	0.5849**
X9									1.0000	0.7818**	0.7155**	0.6536**	0.7320**	0.0228	-0.2848*	0.8404**
X10										1.0000	0.8594**	0.5985**	0.7092**	0.0245	-0.1510	0.8607**
X11											1.0000	0.5240**	0.6764**	0.0702	-0.1686	0.8194**
X12												1.0000	0.5643**	0.1959	-0.1663	0.7245**
X13													1.0000	0.0885	-0.2389*	0.8297**
X14														1.0000	-0.2714	0.1295
X15															1.0000	-0.2068
X16																1.0000

Where,

X1-	Plant height at harvest (cm)	X9-	Number of pods per plant
X2-	Primary branches at harvest	X10-	Number of kernels per plant
X3-	Secondary branches at harvest	X11-	Kernel yield per plant (g)
X4-	Shelling Percentage (%)	X12-	Fresh weight of seedling (g)
X5-	Percentage of sound mature kernels (%)	X13-	Harvest index
X6-	Test weight (g)	X14-	Number of days to maturity
X7-	Number of mature pods per plant	X15-	Total seedling length (cm)
X8-	Number of immature pods per plant	X16-	Pod yield per plant (g)

Table 3: Phenotypic correlation of yield components with pod yield per plant (g) under moisture stress

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1.0000	-0.1189	-0.0676	0.1643	0.1199	0.0710	-0.1186	-0.1758	-0.0880	-0.0787	-0.0951	0.2314*	-0.2251*	0.0039	0.8496**	0.0485
X2		1.0000	-0.0796	-0.2497**	-0.0135	-0.0012	-0.0664	-0.0421	-0.1524	-0.0535	0.1291	0.0076	0.0500	0.0612	-0.1247	-0.0420
X3			1.0000	0.0481	-0.0416	0.4846**	-0.1246	-0.2304*	-0.2339	-0.1701	-0.1244	0.0732	-0.0705	0.2870**	0.0088	-0.1890
X4				1.0000	-0.0750	0.1125	-0.0830	-0.2170*	-0.0328	0.1135	0.0589	0.1641	0.0272	-0.2756*	0.1964	0.0399
X5					1.0000	-0.1084	-0.0361	-0.0877	-0.0105	-0.0146	-0.1944	0.1557	-0.0285	-0.1201	0.1689	0.1101
X6						1.0000	-0.1129	-0.1176	-0.1517	-0.0440	0.0929	0.0434	-0.0192	0.1633	0.1783	0.1573
X7							1.0000	0.2505*	0.6345**	0.5076**	0.4488**	0.1813	0.3925**	-0.0827	0.0067	0.5822**
X8								1.0000	0.4954**	0.3528**	0.4343**	0.0277	0.2505**	-0.0919	-0.1956	0.2485*
X9									1.0000	0.3202**	0.2658**	0.1956	0.3092**	-0.1271	-0.0116	0.5882**
X10										1.0000	0.5798**	0.2336**	0.3721**	-0.1661	-0.0856	0.5464**
X11											1.0000	0.3396**	0.2729*	-0.2226*	-0.0516	0.5680**
X12												1.0000	0.0861	-0.1993	0.3071**	0.4618**
X13													1.0000	-0.1260	-0.2044	0.2710*
X14														1.0000	-0.1442	-0.1749
X15															1.0000	0.1042
X16																1.0000

Where,

X1	Plant height at harvest (cm)	X9	Number of pods per plant
X2	Primary branches at harvest	X10	Number of kernels per plant
X3	Secondary branches at harvest	X11	Kernel yield per plant (g)
X4	Shelling Percentage (%)	X12	Fresh weight of seedling (g)
X5	Percentage of sound mature kernels (%)	X13	Harvest index
X6	Test weight (g)	X14	Number of days to maturity
X7	Number of mature pods per plant	X15	Total seedling length (cm)
X8	Number of immature pods per plant	X16	Pod yield per plant (g)

Conclusion

The association studies revealed that pod yield per plant showed significant positive correlation with number of mature pods per plant, number of immature pods per plant, number of pods per plant, number of kernels per plant, kernel yield per plant, fresh weight of seedling, harvest index, oil content and root to shoot ratio indicating these traits should be given due importance while practicing selection for increasing yield.

Authors' contribution

Conceptualization of research (Dr. Harish Babu B N); Designing of the experiments (Dr. Harish Babu B N); Contribution of experimental materials (Dr. Santhosh K Pattanshetty and Dr. Harish Babu B N); Execution of field/lab experiments and data collection (Chandrashekhara G and Hasanali Nadaf); Analysis of data and interpretation (Chandrashekhara G and Dr. Harish Babu B N); Preparation of the manuscript (Chandrashekhara G)

Declaration

The authors declared that they do not have any conflict of interest.

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