Variability among different yield and yield contributing traits of Okra (*Abelmoschus esculentus* L. Moench) genotypes

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**Abstract**

An investigation was undertaken during rabi season of 2018 to evaluate fifteen okra genotypes for agro-morphological traits. Variability parameters indicated high GCV and PCV values for the number of fruits per plant, yield per plant and 100 seed weight and the narrow differences between GCV and PCV determine that traits under study had negligible environmental influence. High values of heritability coupled with high genetic advance were recorded for all the traits studied. Fruit length and the number of fruits per plant had a positive and significant correlation with yield per plant. The number of fruits per plant had the highest positive and direct effect on yield per plant. The first four principal components (PC1 to PC4) gave eigenvalues > 1 and cumulatively expressed 84.28 per cent of the total variation.

Cluster analysis suggested that the hybridization of cluster I with cluster II will be favourable for developing varieties under multiple environmental conditions in India. Therefore, these quantitative traits in these clusters can be selected to enhance yield potential as they will be beneficial in developing promising varieties under diverse climatic conditions throughout India.

**Key words**

Cluster analysis, Genetic advance, Heritability, Principal component.

**INTRODUCTION**

Okra (*Abelmoschus esculentus* L. Moench) is a flowering, herbaceous, hairy annual plant belonging to the Malvaceae family. Western Africa is considered to be the origin of okra as several number wild species were explored near Ethiopia and Nile Valley (National Research Council, 2006). Okra is distributed into conventional and unconventional types by Martin et al. (1981). The chromosome number of this species has been variously reported as 2n = 130 and 2n = 72; in a number of varieties examined and the chromosome number was invariably found to be 2n = 130 (Joshi and Hardas, 1956).

India is the leader in the world in the area and production of okra with 61.26 lakh tonnes of production obtained from an area of 51.40 lakh ha under the crop with productivity of 11.91 t/ha (Anonymous, 2018). It is an economical and an essential vegetable crop grown because of its high nutritive value, good market and medicinal value. Edible okra is a rich source of various minerals and nutrients, viz., moisture (88%), carbohydrate (7.7%), iron (1.5%), fiber (1.1%), mineral matter (0.7%), 0.09% calcium (0.09%), fat (0.2%), 0.08% phosphorous (0.08%) and calorific values (41 kcal) and a number of vitamins (58 IU) such as vitamin content is vitamin A, vitamin B, vitamin C, Nicotinic acid and Riboflavin (Bhat and Bisht, 2006).

Absence of area explicit varieties that are tolerant or resistant to various pests and diseases such as fruit or pod borer, shoot borer and yellow vein mosaic virus (YVMV) lead to the reduction of productivity and production of okra (Thirupathi Reddy et al., 2012). Assessment of
Variability among different yield genotypes to evaluate their genetic variability for yield and yield related traits is an important aspect for the crop improvement programme. The selection of genetically diverse parents is mandatory for the exploitation of transgressive segregation (Joshi et al., 2004). Upon realization the importance of high yielding varieties of okra, the present study was undertaken to assess the genetic variability and diversity of agro-morphological traits of okra under the rabi season of Northern India.

MATERIALS AND METHODS
The field experiment was carried out at the Experimental Farm, Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India during the rabi season (September 2018 – December 2018) to study the genetic variability and yield potential of fifteen okra genotypes in a randomized block design (RBD) with three replications of 5-meter length at a spacing of 45 x 30 cm. The genotypes were obtained from ICAR - National Bureau of Plant Genetic Resources (NBPGR), New Delhi and details are presented in Table 1. The genotypes were evaluated on the basis of their variation among ten agro-morphological traits viz., plant height (cm), fruit girth (cm), the number of fruits per plant, fruit length (cm), days to 50% flowering, days to 80% maturity, the number of seeds per fruit, 100 seed weight (g), first flowering node and yield per plant (g).

The mean values of each genotype per replication were subjected to analysis of variance (ANOVA) in accordance with Panse and Sukhatme (1954) to determine the presence of statistically significant differences between genotypes for the traits under study. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was estimated as per the formula given by Burton (1952) and genetic advance and heritability were calculated by using the formula recommended by Lush (1949) and Allard (1960). Genotypic correlation coefficient and path coefficient analysis were calculated using OP-STAT (Sheoran et al., 1998). Based on the correlation matrix and similarity matrix, multivariate analysis like principal component analysis (PCA) and cluster analysis was performed with SAS, PAST (Hammer et al., 2001) and SPAR 2.0 (Indian Council of Agricultural Research - Indian Agricultural Statistics Research Institute, New Delhi, India).

Table 1. List of genotypes of okra used for evaluation.

| Sr. No. | Genotypes   | Sr. No. | Genotypes   | Sr. No. | Genotypes   |
|---------|-------------|---------|-------------|---------|-------------|
| 1.      | EC 305615   | 6.      | IC 003769   | 11.     | IC 014026   |
| 2.      | EC 305740   | 7.      | IC 010265   | 12.     | IC 014600   |
| 3.      | EC 305768   | 8.      | IC 013356   | 13.     | AKOLA BAHAR |
| 4.      | EC 306966   | 9.      | IC 013664   | 14.     | SELECTION 2 |
| 5.      | EC 359637   | 10.     | IC 014018   | 15.     | AKO 107     |

RESULTS AND DISCUSSION
The analysis of variance (ANOVA) was carried out for ten traits and showed highly positive and significant differences amongst all the traits (Table 2). The presence of highly significant differences among traits builds up the existence of large variability among genotypes included in the experimental material. Similar results were also declared by Gondane and Lal (1994) and Alam and Hossain (2008). Highly positive and significant results were recorded for yield per plant and days to 80 per cent maturity.

Table 2. Analysis of variance (ANOVA) for various characters of okra genotypes.

|                          | Replication | Genotype  | Error |
|--------------------------|-------------|-----------|-------|
| df                       | 2           | 14        | 28    |
| Plant Height             | 8.86        | 236.50**  | 1.929 |
| Fruit Girth              | 0.00        | 0.32*     | 0.003 |
| Days to 50% Flowering    | 2.62        | 168.93**  | 1.203 |
| Number of Fruits per Plant| 0.07        | 64.83**   | 0.107 |
| Fruit Length             | 0.02        | 23.21**   | 0.036 |
| Days to 80% Maturity     | 5.49        | 657.95**  | 8.15  |
| Number of Seed per Fruit | 0.28        | 124.98**  | 0.521 |
| 100 Seed Weight          | 0.04        | 23.19**   | 0.039 |
| First Flowering Node     | 0.02        | 17.45**   | 0.087 |
| Yield per Plant          | 12.85       | 12369.51**| 10.588|

*,** Significant at 5% and 1% levels, respectively
Genetic variability parameters (Fig. 1, Table 3) studies revealed that the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the characters depicting close relation between them which means environmental influence is very low and hence the phenotypic performance of traits can be used a method for selection. High PCV and GCV values were observed for the number of fruits per plant (54.45 and 52.86), yield per plant (46.49 and 46.42) and 100 seed weight (42.83 and 42.61) whereas it was the lowest for plant height (16.19 and 15.44), days to 50% flowering (16.76 and 16.04) and days to 80% maturity (17.13 and 16.88) which indicated the presence of high magnitude of genetic variability in the genotypes. Shanthakumar and Salimath (2010). Mishra et al. (2015) and Prakash et al. (2011) also observed a greater magnitude for PCV and GCV. The close relation between PCV and GCV all traits indicated that they are comparatively stable to environmental variation (Manjumdar et al., 1969). All ten characters displayed high heritability as well as high genetic advance as per cent over the mean. Crop improvement by selecting these traits would be of benefit as they show a pre-dominance of additive gene effects. Reddy and Dhaduk (2014), Nwangburuka et al. (2012) and Hazra and Basu (2000) also reported high magnitudes of heritability and genetic advance. Heritability is considered as a good index of transmission of traits from parents to their subsequent generations (Falconer, 1981). High values of broad sense heritability help in the identification of the suitable trait for selection which enables the plant breeder to select phenotypically superior genotypes (Johnson et al., 1955).

### Table 3. Estimates of variability parameters for various characters of okra genotypes.

| Character                  | Mean   | Range         | $H^2$ | GCV Per cent | PCV Per cent | GA    | GA % of Mean |
|----------------------------|--------|---------------|-------|--------------|--------------|-------|--------------|
| Plant Height (cm)          | 42.96  | 31.83-47.60   | 91.00 | 15.44        | 16.19        | 13.04 | 30.35        |
| Fruit Girth (cm)           | 1.66   | 1.07-2.30     | 78.81 | 22.84        | 25.73        | 0.69  | 41.77        |
| Days to 50% Flowering      | 49.04  | 34.33-57.00   | 91.61 | 16.04        | 16.76        | 15.51 | 31.63        |
| Number of Fruits per Plant | 9.60   | 4.63-18.57    | 94.25 | 52.86        | 54.45        | 10.15 | 105.72       |
| Fruit Length (cm)          | 6.39   | 3.17-11.13    | 94.82 | 36.02        | 36.99        | 4.62  | 72.25        |
| Days to 80% Maturity       | 94.71  | 72.67-127.67  | 97.06 | 16.88        | 17.13        | 32.44 | 34.26        |
| Number of Seed per Fruit   | 23.95  | 13.87-47.67   | 99.36 | 38.64        | 38.77        | 19.01 | 79.35        |
| 100 Seed Weight (g)        | 6.43   | 3.60-13.10    | 98.99 | 42.61        | 42.83        | 5.61  | 87.33        |
| First Flowering Node       | 11.14  | 8.00-18.20    | 99.51 | 22.67        | 22.72        | 5.19  | 46.58        |
| Yield per Plant (g)        | 139.83 | 32.63-220.70  | 99.68 | 46.42        | 46.49        | 133.49| 95.46        |
The Pearson correlation coefficient is presented in Table 4. The plant height showed a highly significant and positive correlation with days to 50% flowering (0.82**) and days to 80% maturity (0.63*). Days to 50% flowering showed a significant and positive correlation with days to 80% maturity (0.59*). The number of fruits per plant showed significant and positive results with fruit length (0.68**) and yield per plant (0.67**). Fruit length showed a significant and positive correlation with yield per plant (0.60*). Thirupathi Reddy et al. (2012), Raval et al. (2019), Duggi et al. (2013) also reported similar positive correlations with yield. The correlation is the net effect of the segregating genes as some of the genes can increase both the traits causing the positive correlation and others may increase only one and decrease the other initiating the negative correlation (Falconer, 1981). The implication of the inter-relationship of various traits should be known to obtain an ideal combination of yield contributing traits in a single genotype. Therefore, the association of such traits is necessary when rational improvement is to be done through selection. Correlation studies focus on the stability of various traits for indirect selection since the selection of a minimum one trait results in a correlated response of various other traits (Neyhart et al., 2019).

Table 4. Genotypic correlation coefficient studies in okra genotypes.

| Traits                        | Plant Height | Fruit Girth | Days to 50% Flowering | Number of Fruits per Plant | Fruit Length | Days to 80% Maturity | Number of Seed per Fruit | 100 Seed Weight | First Flowering Node | Yield per Plant |
|-------------------------------|--------------|-------------|-----------------------|----------------------------|--------------|----------------------|--------------------------|----------------|----------------------|-----------------|
| Plant Height                  | 1.00         | -0.24       | 0.82                  | -0.39                      | -0.43        | 0.63                 | 0.05                     | -0.36          | -0.13                | -0.47           |
| Fruit Girth                   |              |             |                       |                            |              |                      |                          |                |                      |                 |
| Days to 50% Flowering         | 1.00         | -0.20       | -0.03                 | -0.06                      | 0.23         | -0.20                | -0.25                    | 0.20           | -0.38                |                 |
| Number of Fruits per Plant    |              | -0.41       | -0.35                 | 0.59                       | 0.26         | 0.14                 | -0.13                    | 0.67**         |                      |                 |
| Fruit Length                  | 1.00         | -0.55       | 0.32                  | 0.15                       | -0.16        | 0.60**               |                         |                |                      |                 |
| Days to 80% Maturity          | 1.00         | 0.18        | -0.32                 | -0.09                      | -0.61        |                      |                          |                |                      |                 |
| Number of Seed per Fruit      |              | 0.35        | -0.47                 | 0.26                       |              |                      |                          |                |                      |                 |
| 100 Seed Weight               |              | 1.00        |                      | 0.51                       |              |                      |                          |                |                      |                 |
| First Flowering Node          |              | 1.00        |                      | -0.49                      |              |                      |                          |                |                      |                 |
| Yield per Plant               |              |             |                      |                            |              |                      |                          |                |                      | 1.00            |

* ** Significant at 5% and 1% levels, respectively

The path coefficient analysis is presented in Table 5 and the data revealed that the number of fruits per plant (0.34) had the highest direct positive effect towards the yield per plant and other traits such as fruit length (0.32) had direct effects. Traits such as days to the first flowering node (-0.64), plant height (-0.53), 100 seed weight (-0.53), days to 80% maturity (-0.31), the number of seed per fruit (-0.12) and fruit girth (-0.12) had a direct effect with a negative sign. While days to 50% flowering had no effect on yield. Similar results were also observed by Ahamed et al. (2015), Reddy et al. (2013), Mehta et al. (2006), Dwivedi and Sharma (2007) and Das et al. (2012). Path coefficient analysis gives details about the situation by understanding the causes of the association between two traits. Whereas, it permits the evaluation of the direct effect of various traits on yield as well as their indirect effects via other component traits (Wright, 1921). Hence, it provides a basis for the selection of phenotypically superior genotypes from diverse breeding populations.

Table 5. Genotypic path coefficient analysis for various okra genotypes.

| Traits                        | Plant Height | Fruit Girth | Days to 50% Flowering | Number of Fruits per Plant | Fruit Length | Days to 80% Maturity | Number of Seed per Fruit | 100 Seed Weight | First Flowering Node | Correlation of Yield per Plant |
|-------------------------------|--------------|-------------|-----------------------|----------------------------|--------------|----------------------|--------------------------|----------------|----------------------|--------------------------------|
| Plant Height                  | -0.53        | -0.02       | 0.00                  | -0.05                      | -0.04        | -0.15                | 0.02                     | 0.34           | -0.23                | -0.47             |
| Fruit Girth                   | -0.09        | -0.12       | 0.00                  | -0.11                      | -0.15        | -0.20                | 0.02                     | 0.08           | 0.14                 | -0.38             |
| Days to 50% Flowering         | -0.30        | -0.04       | 0.00                  | -0.04                      | -0.04        | -0.11                | -0.02                    | 0.21           | 0.04                 | -0.17             |
| Number of Fruits per Plant    | 0.09         | 0.04        | 0.00                  | 0.34                       | 0.08         | 0.11                 | -0.02                    | -0.10          | 0.05                 | 0.67**            |
| Fruit Length                  | 0.06         | 0.06        | 0.00                  | 0.08                       | 0.32         | 0.10                 | -0.08                    | -0.19          | 0.15                 | 0.60**            |
| Days to 80% Maturity          | -0.25        | -0.08       | 0.00                  | -0.11                      | -0.10        | -0.31                | -0.01                    | 0.26           | -0.06                | -0.61             |
| Number of Seed per Fruit      | 0.08         | 0.02        | 0.00                  | 0.05                       | 0.22         | -0.03                | -0.12                    | -0.20          | 0.32                 | 0.26              |
| 100 Seed Weight               | 0.34         | 0.02        | 0.00                  | 0.06                       | 0.12         | 0.15                 | -0.04                    | -0.53          | 0.49                 | 0.51              |
| First Flowering Node          | -0.19        | 0.03        | 0.00                  | -0.02                      | -0.08        | -0.03                | 0.06                     | 0.40           | -0.64                | -0.49             |

* ** Significant at 5% and 1% levels, respectively

Residual effect 0.067
PCA (Table 6, Fig. 2) was performed to obtain data set in reduced dimensions and traits under study revealed. When the data of all the traits were subjected to principal component analysis it revealed that the first four principal components contributed to 84.28% variation. From the loading of the variables in PCA I was found that fruit length, 100 seed weight, the number of seed per fruit and yield per plant were the dominant features which contributed to 38.41 per cent of the total variation. In PCA II, plant height, days to 80% maturity and days to 50% flowering exerted a maximum influence which accounts for 24.42% of the total variation. The number of fruits per plant was the dominant features in PCA III which accounted for 10.98 per cent of the total variation. However, fruit girth and first flowering node showed dominant features in PCA IV, which accounted for 10.46 per cent of the total variation. Thus, it is suggested that the use of these traits will help in saving a considerable amount of time for the identification and characterization of okra genotypes. The high contribution of fruit length, 100 seed weight, number of seeds per fruit and yield per plant towards variation had been reported by various workers in okra (Denton and Nwangburuka, 2011; Ahiakpa et al., 2013; Amoatey et al., 2015). There are no instructions as how to interpret the significance or importance of a coefficient, i.e., Eigen-vector (Duzyaman, 2005; Sneath and Sokal, 1973). However, the higher the coefficients of a particular trait, more it is related to the respective principal component axis. A three dimensional representation of principal component analysis plot for yield per plant and Biplot between PC1 and PC2 showing the contribution of various traits responsible for variability in okra.

Table 6. Vector loading, Eigen value and percentage of variation explained by first five principal components and correlations between PC scores and agro-morphological traits.

| Sr. No. | Characters               | PC I  | PC II | PC III | PC IV | PC V | Latent Roots (Eigen Value) |
|---------|--------------------------|-------|-------|--------|-------|------|---------------------------|
| 1.      | Plant Height             | -0.39 | 0.26  | 0.41   | -0.01 | -0.06| 3.84                      |
| 2.      | Fruit Girth              | -0.08 | -0.33 | -0.40  | 0.63  | -0.34| 2.44                      |
| 3.      | Days to 50% Flowering    | -0.32 | 0.42  | 0.23   | 0.07  | -0.17| 1.10                      |
| 4.      | Number of Fruits per Plant| 0.39  | -0.05 | 0.40   | 0.29  | -0.27| 1.05                      |
| 5.      | Fruit Length             | 0.39  | 0.05  | 0.24   | 0.40  | 0.29 | 0.68                      |
| 6.      | Days to 80% Maturity     | -0.42 | 0.15  | -0.14  | 0.31  | -0.02| 0.29                      |
| 7.      | Number of Seed per Fruit | 0.07  | 0.45  | -0.21  | 0.36  | 0.64 | 0.24                      |
| 8.      | 100 Seed Weight          | 0.25  | 0.30  | -0.55  | -0.32 | -0.09| 0.21                      |
| 9.      | First Flowering Node     | -0.10 | -0.52 | 0.15   | -0.15 | 0.49 | 0.14                      |
| 10.     | Yield per Plant          | 0.43  | 0.25  | 0.13   | -0.06 | -0.22| 0.02                      |

Percent of Total Variance Explained

38.41  24.42  10.99  10.46  6.79

Fig. 2. Biplot between PC1 and PC2 showing contribution of various traits responsible for variability in okra.
The hierarchical cluster analysis between fifteen genotypes for yield and yield related traits under the study were grouped into two major clusters and presented through a dendrogram using Ward’s method (Ward, 1963). The clustering was not based on a similar geographical origin. Cluster I was accommodated with seven genotypes and cluster II by eight genotypes (Fig.3). Cluster analysis is applied to place a similar genotypes in one group as it determines the genotype by far or nearness on the basis of variation present between them (Sajad-Bokaei et al., 2008). Therefore, genotypes that are represented far away from each other are having more variation between them and thus, these genotypes can be used further in the crop improvement program. In cluster analysis, there is no prior information about the group or cluster membership for any objects (Abonyi and Feil, 2007).

Fig. 3. Dendrogram showing genetic relationship among fifteen okra genotypes based on agro-morphological traits using Ward’s method.

The 15 genotypes of Okra (Abelmoschus esculentus L. Moench) obtained from ICAR - NBPGR, New Delhi was evaluated during rabi season (2018) for ten agro-morphological traits. High variations were observed for all the traits whereas, maximum were observed yield per plant, days to 80% maturity, plant height and days to 50 % flowering and also exhibited wide range indicating the usefulness of collections in breeding programmes. Yield per plant showed a positive correlation with the number of fruits per plant and fruit length. These can be used in breeding programme for developing high yielding, bold seeded and high oil containing cultivars. The number of fruits per plant and fruit length had a direct positive effect on the yield per plant. The first four principal components accounted cumulative variance to be 84.28 % of the total variation and traits viz. fruit length, 100 seed weight, the number of seed per fruit and yield per plant, plant height, days to 80% maturity and days to 50% flowering contributed for more than 50 % phenotypic variation.

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