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Research Article

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 $2n = 130^2$ and $2n = 72^3$; 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

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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 306696	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).

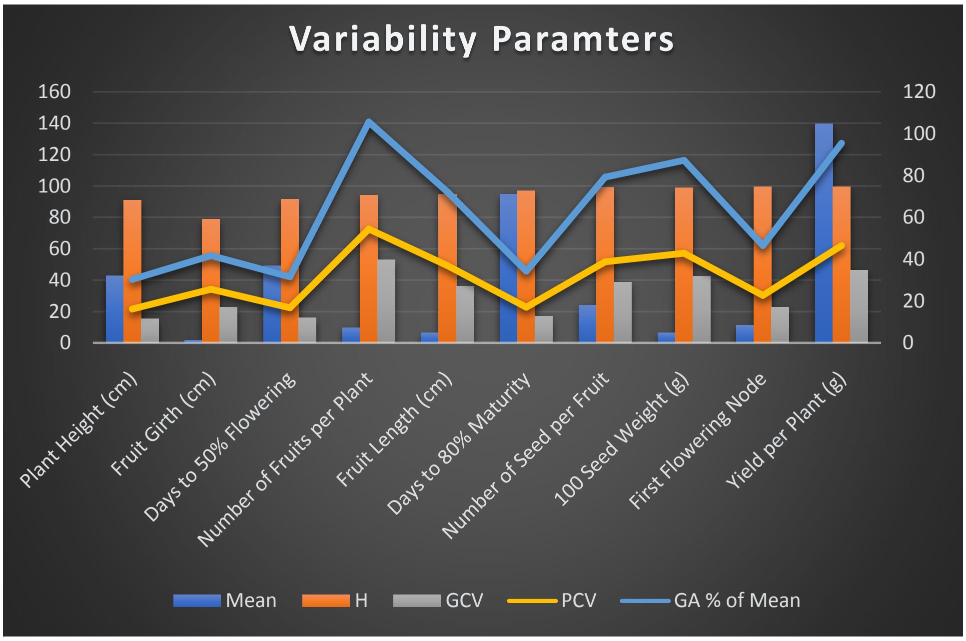

Fig. 1. Estimates of variability parameters for various characters of okra genotypes.

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		**1.00**	-0.20	-0.03	-0.06	0.23	-0.20	-0.25	0.20	-0.38
Days to 50% Flowering			**1.00**	-0.41	-0.35	**0.59***	0.26	-0.14	-0.37	-0.17
Number of Fruits per Plant				**1.00**	**0.68****	-0.56	-0.01	0.06	-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							**1.00**	0.35	-0.47	0.26
100 Seed Weight								**1.00**	-0.50	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 snumber 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	0.05	-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**	

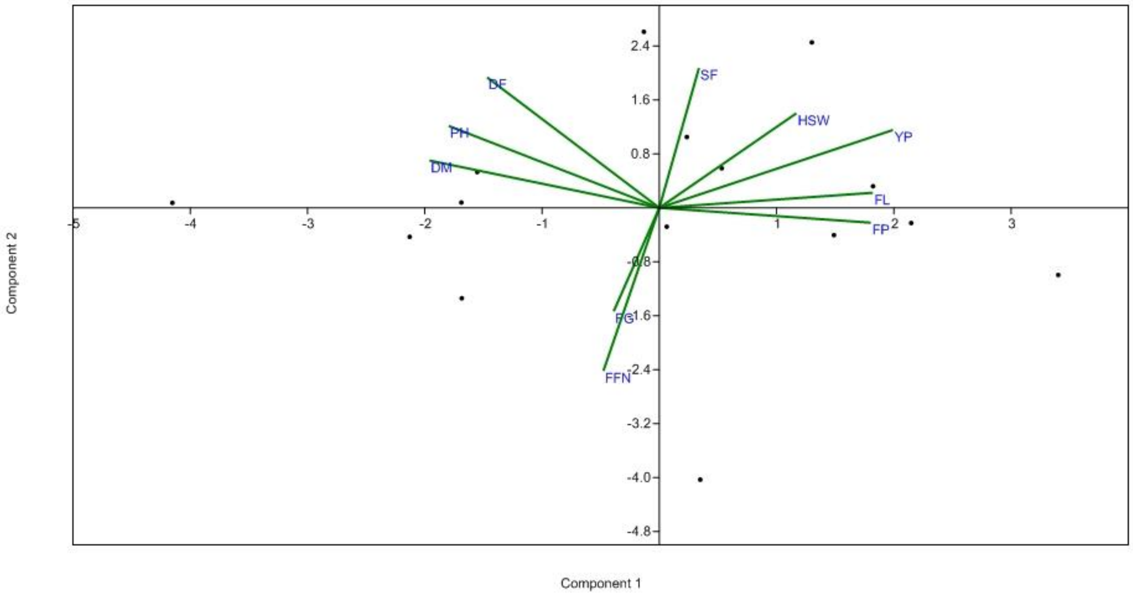

Fig. 2. Biplot between PC1 and PC2 showing contribution of various traits responsible for variability in okra.

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).

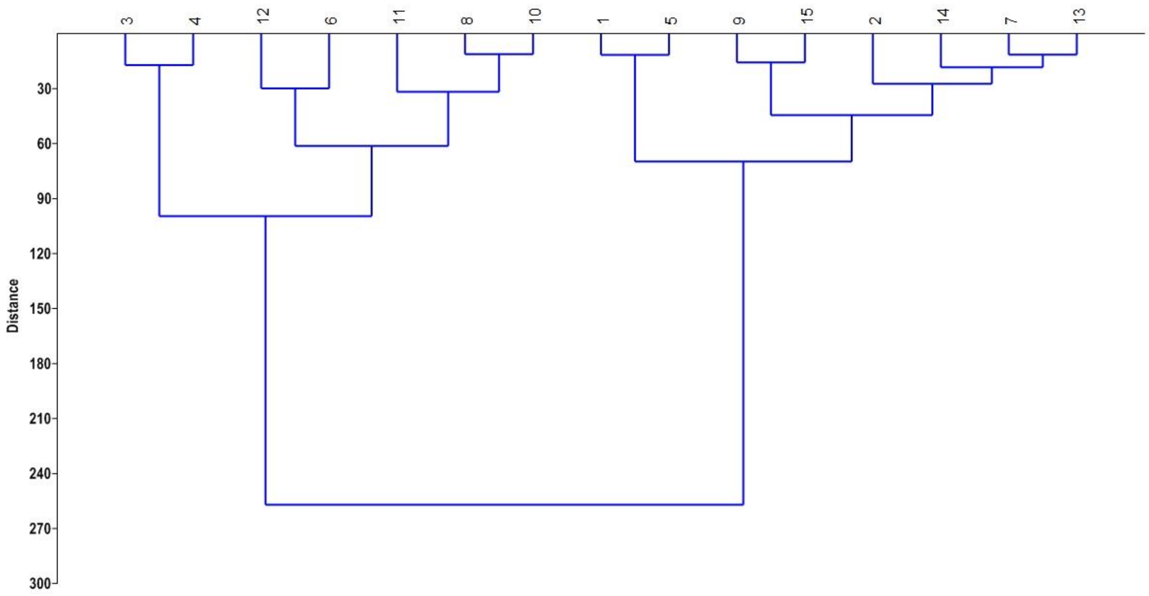

Fig. 3. Dendrogram showing genetic relationship among fifteen okra genotypes based on agro-morphological traits using Ward's method.

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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