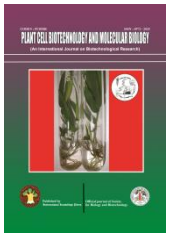

Plant Cell Biotechnology and Molecular Biology

Volume 25, Issue 5-6, Page 43-51, 2024; Article no.PCBMB.12080
ISSN: 0972-2025

Exploring the Genetic Diversity and Agronomic Performance of Okra Varieties Using Variance Analysis

Khalid Syfullah [a], Md. Saiful Islam [a], Md. Mahmudul Hasan Manik [b], Md. Imdadul Haque [c], Aliya Adiba Khanam [a], Abdullah All Imtiaz [d] and Md Ruhul Kuddus Joha [e*]

[a] Department of Genetics and Plant Breeding, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.
[b] Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.
[c] Department of Agriculture Extension and Information System, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.
[d] Faculty of Agriculture, Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh,
[e] Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Authors KS, AAK, MIH, MMHM designed the study, performed the statistical analysis, wrote the protocol. Author AAI managed the analyses of the study. Author MRKJ managed the literature searches and wrote the first draft of the manuscript. Author MSI supervised the whole process.All authors read and approved the final manuscript.

Article Information

DOI: 10.56557/PCBMB/2024/v25i5-68684

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.ikprress.org/review-history/12080

Original Research Article

Received: 26/02/2024
Accepted: 27/04/2024
Published: 06/05/2024

**Corresponding author: E-mail: j7ruhul@yahoo.com;*

ABSTRACT

The experiment was conducted at the experimental field of Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University, Dhaka Bangladesh during March 2017 to July 2017. The experiment was conducted in randomized complete block design with three replications. Twenty eight genotypes of okra were used in this study which was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur and local market. The extent of diversity present between genotypes determines the extent of improvement gained through selection and hybridization. The more divergent the two genotypes are the more will be the probability of improving through selection and hybridization. Mean square of most of the characters studied revealed that genotypes showed highly significant (P< 0.01) differences for all the traits studied. High genotypic and phenotypic coefficient of variation were observed for primary branches (43.91 and 33.64) and fruit yield per plant (37.51 and 32.48). So, divergent genotypes are recommended to use as parents in future hybridization program.

Keywords: Genetic diversity; okra; hybridization; agronomic performance.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is known as “Dheros” in Bangladesh (family: Malvaceae).It is originated from Africa, now found in several countries across Asia and Africa [1]**.** As a vegetable, due to many nutritional benefits, it is essential component of people’s daily diets, which any one can have it fresh or cooked [2]**.** It is an annual, hardy and high-yielding plant, which greatly differs in size, fruit shape, pigmentation, branching habit, fruiting span, fruit yield and fruit firmness [3]. It is a multinutritional vegetable having 88% water, 1.52 g protein, 5.76g carbohydrates, 13.1 mg vitamin C, 0.4 mg calcium, 36.5 µg folic acid, 46 mg Magnesium and 2g fiber. Okra helps in lowering serum cholesterol, reducing heart disease and cancer, especially colorectal cancer [4]**.** Total area under okra cultivation in Bangladesh is estimated to be 31021.88 acres yielding about 96018.37 tons of green pods [5]. The average yield of okra in Bangladesh is 2332.28 Kg acr^{-1} which is very low as compared to other okra growing countries.At present time, enormous amount of commercial cultivars including F1 hybrids of okra is available in the market. But all these are not adapted and suited to all the regions of the country. Further, no specific recommendation about the suitability of genotypes for a particular area is available. Syfullah et al [6] Sufficient information about the genetic variability of a crop is required for the identification of potential genotypes to be used in breeding program as well as germplasm conservation [7]. Selection for breeding depends on the extent of genetic variability in germplasm and the degree to which the desired traits are heritable. Yield is a complex quantitative trait, controlled by several genes that interact with the environment and several traits are associated with it. So, appropriate knowledge of such associations could significantly improve the efficiency of selection for crop improvement [8]**.** This comprehensive research initiative undertakes a methodical approach to assess the genetic diversity present among various okra genotypes. By leveraging the statistical power of variance analysis, the study meticulously evaluates the performance of these genotypes across a spectrum of agronomic traits. Such an analysis is pivotal in quantifying the genetic variability, which serves as the bedrock for the selection and enhancement of okra cultivars. The insights gleaned from this variance analysis are anticipated to shed light on the heritability of essential traits and the prospects for genetic improvement.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the experimental field of Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University, Dhaka Bangladesh during March 2017 to July 2017.

2.2 Plant Materials

Twenty eight genotypes of okra were used in this study which was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur and local market.

Table 1. Details of experimental materials

Genotypes	Name of Genotypes	Source
G1	BARI Dheros1	Bangladesh Agricultural Research Institute
G2	BARI Dheros2	Bangladesh Agricultural Research Institute
G3	BD-1928	Bangladesh Agricultural Research Institute
G4	BD-1929	Bangladesh Agricultural Research Institute
G5	BD-1930	Bangladesh Agricultural Research Institute
G6	BD-1931	Bangladesh Agricultural Research Institute
G7	BD-1932	Bangladesh Agricultural Research Institute
G8	BD-1933	Bangladesh Agricultural Research Institute
G9	BD-1934	Bangladesh Agricultural Research Institute
G10	BD-1935	Bangladesh Agricultural Research Institute
G11	BD-1936	Bangladesh Agricultural Research Institute
G12	BD-1937	Bangladesh Agricultural Research Institute
G13	BD-1938	Bangladesh Agricultural Research Institute
G14	BD-1939	Bangladesh Agricultural Research Institute
G15	BD-1940	Bangladesh Agricultural Research Institute
G16	BD-1941	Bangladesh Agricultural Research Institute
G17	BD-1942	Bangladesh Agricultural Research Institute
G18	Orka Onamika	Krishibid Seed Limited
G19	Ladies Finger	Krishibid Seed Limited
G20	Kohnur	Krishibid Seed Limited
G21	Mukta	Krishibid Seed Limited
G22	Soft Finger	Krishibid Seed Limited
G23	KS-3	Krishibid Seed Limited
G24	KS-1201	Krishibid Seed Limited
G25	Shruti-16	Local Market
G26	Preeti-72	Local Market
G27	NF-1003	Local Market
G28	SONIYA-86	Local Market

2.3 Experimental Design

The experiment was conducted in randomized complete block design (RCBD) with three replications. In each block, each genotype was planted in one row of 8.4 m length and 1 m width, maintaining a plant to plant spacing of 0.6 m and accommodated 14 plants per plot.

2.4 Field Managements

The recommended dosage of Urea, TSP (Triple Super Phosphate), MP (Muriate of Potash) was applied in field at the rate of 150, 100, 150 Kg/ha respectively. Irrigation was done once a week at emergence and every two weeks at flowering and pod production. Chemicals and cultural practices were applied to control insect pest.

2.5 Observations Recorded

Observations were recorded on five plants in each genotype in each replication for all the characters studied. The observations are given below-Days to first flowering, Days to 50% flowering, Days to maturity, Plant height (cm), Number of primary branches per plant, Fruit character and yield, Fruit length (cm), Fruit diameter (mm), Average fruit weight (g), Number of tender fruits per plant, Number of seeds per pod, Hundred seed weight (g), Fruit yield per plant (g)

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The results of analysis of variance of 11 quantitative characters for 28 okra genotypes are presented (Table 2). Mean square of most of the characters studied revealed that genotypes showed highly significant ($P< 0.01$) differences for all the traits studied. This was revealed that existence of a good deal of variation for all the traits among the population. This could be exploited through selection to improve the crop for desired traits. This result is in agreement with Akinyele and Osekita [9-11] who reported that significant differences among the tested okra genotypes for most of the studied traits. This

study results also supported by Salesh [12] and found highly significant differences. A wide range of variations for yield contributing traits was also observed by Hazra et al and Gandhi et al [13] [14].

3.2 General Performance of Genotypes

3.2.1 Germination (%)

Germination% varied significantly among the genotypes (Table 2). It was ranged from 60.67% to 88.00% with a general mean of 75.40%. The coefficient of variation was 3.79% for this trait (Table 3). The maximum germination was recorded in G5 (88.00%) and minimum was observed in G28 (60.67%). When compared to population mean (75.40%) (Table 4). Fifteen genotypes exhibited better germination percentage. Rest of the genotypes showed lower germination% than population mean.

3.2.2 Days to 1st flowering

Days to first flowering varied significantly among the genotypes (Table 2). Days to first flowering ranged from 29.67 to 36.00 days with a general mean of 32.74 days (Table 3). Early flowering was observed both in the genotypes G1 and G8 (29.67 days) followed by G7 (23.33) and G11 followed by G12 (30.00 days) and G4 (30.33 days). The late first flowering was observed in the genotype G23 (36.00 days) followed by G17 (35.67 days) and G11 (35.33 days) (Table 4). Fourteen genotypes expressed better values i.e. lower the days to first flowering compared to population mean (32.74 days). From these genotypes early varieties could be selection for further study.

3.2.3 Days to 50% flowering

Days to 50% flowering varied significantly among the genotypes (Table 2). Days to 50% flowering ranged from 36.00 to 43.00 days with a general mean of 39.27 days (Table 3). Early 50% flowering was observed in the genotype G13 (36.00 days) followed by G1, G8, G24 and G26 (36.67 days). The late 50% flowering was observed in the genotype G19 (43.00 days) followed by G17 (42.67 days) and G3 (42.33 days) (Table 4).Thirteen genotypes expressed better values i.e. lower the days to 50% flowering compared to population mean (39.27 days). From these genotypes early varieties could be selected for further study.

3.2.4 Plant height (cm)

Plant height is usually a good index of plant vigor, which may contribute towards greater production of fruit yield in okra. Plant height varied significantly among the genotypes (Table 2). Plant height ranged from 79.83 cm to 152.67 cm with a general mean of 108.48 cm. The coefficient of variation was 2.45% for this trait (Table 3). The maximum plant height was recorded in G1 (152.67 cm) and minimum was observed in G14 (79.83 cm) (Table 4). When compared to population mean (108.48 cm), sixteen genotypes exhibited better plant height. Rest of the genotypes showed lower plant height than population mean. Significant differences for plant height were reported by Singh [15,16] also reported the tallest plants during rainy season in their experiments. Hazra and Basu [13] observed low general value for plant height (80.8 cm).

Table 2. Mean sum of square of different characters of 28 okra genotypes

Characters	Mean sum of square		
	Replication (r-1) = 2	Genotype (g-1) = 27	Error (r-1)(g-1) = 54
Germination (%)	17.76	157.86**	8.16
Days to 1st flowering	8.37	12.38**	2.21
Days to 50% flowering	13.58	14.54**	2.50
Plant height (cm)	8.56	775.61**	7.05
Primary branches	0.06	2.71**	0.51
No. of fruit per plant	7.58	61.92**	2.56
Fruit length (cm)	0.08	5.09**	2.37
Fruit diameter (cm)	0.08	0.06**	0.02
Average fruit weight (gm)	1.35	28.10**	5.02
Seed per fruit	506.18	245.78**	26.96
Fruit yield per plant (g)	114.19	30528.76**	3054.35

*** Denote significant at 1% level of probability*

Table 3. Range, mean and CV (%) of 28 okra genotypes

Parameters	Range		Mean	CV (%)
	Min.	Max.		
Germination (%)	60.67	88.00	75.40	3.79
Days to 1st flowering	29.67	36.00	32.74	4.54
Days to 50% flowering	36.00	43.00	39.27	4.02
Plant height (cm)	79.83	152.67	108.48	2.45
Primary branches (cm)	1.50	6.00	2.54	28.22
No. of fruit per plant	10.33	26.33	17.10	9.36
Fruit length (cm)	10.21	16.46	12.92	11.93
Fruit diameter (cm)	1.07	1.60	1.35	10.42
Average fruit weight (gm)	10.67	25.33	17.07	13.12
Seed per fruit	24.00	58.67	44.21	11.74
Fruit yield per plant (g)	124.00	535.33	294.65	18.76

CV (%) = Coefficient of Variation

Table 4. Mean performance of eleven characters of 28 okra genotypes

Genotypes	G (%)	DFF	D50%F	PH	PB	NFP	FL	FD	AFW	SPF	FYP
G1	78.67	29.67	36.67	152.67	2.00	26.33	12.77	1.27	18.67	47.00	481.00
G2	71.67	33.00	40.00	124.43	1.67	21.33	12.02	1.50	20.00	40.67	428.00
G3	66.67	35.33	42.33	102.53	3.33	20.33	12.47	1.50	19.33	29.67	402.33
G4	82.33	30.33	37.33	110.27	1.80	20.67	14.29	1.37	17.33	31.67	369.67
G5	88.00	34.67	41.67	118.77	2.33	20.00	14.50	1.17	16.50	54.67	312.67
G6	74.00	33.33	40.33	108.17	3.00	19.67	12.81	1.50	14.67	24.00	293.33
G7	73.33	35.00	42.00	114.27	1.70	23.33	13.89	1.13	16.00	44.33	381.33
G8	76.67	29.67	36.67	87.07	2.33	11.67	16.46	1.27	16.67	31.00	193.67
G9	80.00	32.33	39.33	123.97	2.67	22.67	11.45	1.30	14.00	37.33	328.33
G10	80.67	31.00	38.00	98.83	2.67	16.67	11.84	1.37	17.20	42.33	285.20
G11	68.00	35.33	37.00	117.10	2.33	23.00	13.19	1.30	19.33	55.33	429.67
G12	86.67	30.00	41.33	107.27	1.62	17.00	14.30	1.27	21.67	52.67	358.00
G13	83.33	34.67	36.00	111.73	3.00	20.33	11.26	1.07	15.33	46.33	321.33
G14	84.00	31.67	40.67	79.83	3.67	11.00	13.94	1.60	21.67	45.00	228.00

G (%): Germination (%), DFF: Days to 1st Flowering, D50%F: Days to 50% flowering, PH: PLANT HEIGHT (cm), PB: Primary Branches, NFP: No. of Fruit Per Plant, FL: Fruit Length (cm), FD: Fruit Diameter (cm), AFW: Average Fruit Weight (gm), SPF: Seed Per Fruit and FYP: Fruit Yield Per Plant (g)

3.2.5 Number of primary branches per plant

Number of primary branches per plant varied significantly among the genotypes (Table 2). Number of primary branches per plant ranged from 1.50 to 6.00 with a general mean of 2.54 (Table 3). Fourteen genotypes expressed better values as compared to population mean (2.54). The results of the present study were also in conformity with Gondane [17]**.** The genotype expressing the maximum value was in G27 (6.00) and the minimum was recorded in G21 (1.50). The general mean of primary branches per plant were recorded as 2.9 and 1.57 by Hazra and Basu [13] Alam and Hossain [18] respectively.

3.2.6 Number of fruits per plant

Number of fruits varied significantly among the genotypes (Table 2). Number of fruits per plant ranged from 10.33 to 26.33 with a general mean of 17.10 (Table 3). More number of fruits per plant was recorded in G1 (26.33) followed by G7 (23.33) and G11 (23.00) (Table 4). Thirteen genotypes expressed better values compared to population mean (17.10). These findings may be due to greater plant height, and more number of branches per plant may be because of getting more space for fruit development.

3.2.7 Fruit length (cm)

The fruit length varied significantly among the genotypes (Table 2). Fruit length ranged from 10.21 cm to 16.46 cm with a general mean of 12.92 cm (Table 3). The maximum fruit length was recorded in G8 (16.46 cm) followed by G5 (14.50 cm) and G25 (14.37 cm) (Table 4). As compared to population mean (12.92 cm), fifteen genotypes exhibited higher fruit length. Genotype G28 recorded the minimum fruit length (10.21

cm). This result may be due to environment influence and/or varietal characteristics of the genotypes as also reported by Singh et al, Wankhade et al and Mohapatra et al [19,16,20].

3.2.8 Fruit diameter (cm)

The fruit diameter varied significantly among the genotypes (Table 2). Fruit diameter ranged from 1.07 cm to 1.60 cm with a general mean of 1.35 cm (Table 3). The maximum fruit diameter was recorded in G13 (1.07 cm) followed by G19 (1.10 cm) and G7 (1.13 cm) (Table 4).As compared to population mean (1.35 cm), thirteen genotypes exhibited higher fruit diameter. Genotype G13 recorded the minimum fruit diameter (1.07 cm).

3.2.9 Average fruit weight (gm)

Statistically significant variation was found in terms of average fruit weight of okra (Table 2). The highest average fruit weight (25.33 g) was found in G18, while the lowest was (10.67 g) recorded in G28. The general mean of average fruit weight was 17.07 g and around 50% lines gave more than that general mean fruit weight. Due to different plant height, length of fruit and other morphological structure of different lines the mean fruit weight of different lines were varied from each other. Mishra [21] and Hazra and Basu [13] reported that genotypes differed significantly for Individual fruit weight.

3.2.10 Number of seeds per fruit

Number of seeds per pod ranged from 24.00 to 58.67 with a general mean of 44.21. Number of seeds per fruit varied significantly among the genotypes. More number of seeds per fruit was recorded in G19 (58.67) followed by G26 (57.33) and G11 (55.33) (Table 4). Seventeen genotypes expressed higher values compared to population mean (44.21). The least value was recorded in G6 (24.00) followed by G3 (29.67), G8 (31.00) and G4 (31.67) (Table 4). Similar significant differences for this trait were also noted by Kumar [22]**.** Hazra and Basu [13] also reported similar general mean for seeds per fruit (53.3).

3.2.11 Fruit yield per plant (g)

Performance of genotypes differed significantly for fruit yield per plant (Table 2). Fruit yield per plant ranged from 124 g to 535.33 g with a general mean of 294.65 g (Table 3). Maximum fruit yield was exhibited by G18 (535.33 g) followed by G1 (481.00 g) and G11 (429.67 g) (Table 4 and Fgure1). Among all the genotypes, thirteen genotypes exhibited higher fruit yield per plant compared to population mean (294.65 g). Minimum fruit yield per plant was observed in G28 (124.00 g). Gondane [17] recorded highest fruit yield per plant (418 g). This higher fruit yield per plant maybe due to higher fruit length and more number of fruits per plant showing genetic response of genotypes to environmental conditions also reported by earlier workers viz**.,** [23] Muhammad et al*.* (2001) and [20] Mohapatra et al (2007).

Table 5. Mean performance of eleven characters of 28 okra genotypes (Contn'd)

Genotypes	G (%)	DFF	D50%F	PH	PB	NFP	FL	FD	AFW	SPF	FYP
G15	61.67	34.67	37.33	110.70	1.53	18.00	12.27	1.27	14.33	41.67	258.67
G16	64.33	32.00	40.33	103.03	2.00	12.00	13.87	1.47	14.33	51.00	171.67
G17	67.00	35.67	42.67	108.90	2.67	16.33	13.39	1.30	15.00	47.67	245.00
G18	72.00	33.00	40.00	121.57	3.33	19.67	12.08	1.33	25.33	51.33	535.33
G19	75.00	35.00	43.00	120.90	2.33	13.67	13.48	1.10	15.33	58.67	207.33
G20	75.33	31.67	38.00	115.03	2.67	17.00	11.41	1.57	18.33	30.67	297.00
G21	80.33	34.33	41.33	127.43	1.50	21.33	11.27	1.33	15.00	51.67	328.00
G22	82.00	31.00	38.00	97.10	2.67	10.33	12.23	1.27	20.00	49.67	208.67
G23	80.67	36.00	42.00	116.40	3.67	14.33	13.19	1.57	13.00	36.33	191.33
G24	76.67	31.00	36.67	108.77	3.00	13.00	12.70	1.37	17.00	39.00	221.00
G25	76.33	30.67	37.33	99.77	2.67	14.33	14.37	1.17	17.00	46.33	248.00
G26	75.33	30.67	36.67	87.00	1.50	11.67	13.30	1.43	15.33	57.33	186.33
G27	70.00	31.67	37.67	82.67	6.00	11.33	12.75	1.43	19.00	46.67	215.33
G28	60.67	33.33	39.33	81.30	1.50	11.67	10.21	1.47	10.67	48.00	124.00

G (%): Germination (%), DFF: Days to 1st flowering, D50%F: Days to 50% flowering, PH: Plant Height (cm), PB: Primary Branches, NFP: No. of Fruit Per Plant, FL: Fruit Length (cm), FD: Fruit Diameter (cm), AFW: Average Fruit Weight (gm), SPF: Seed Per Fruit and FYP: Fruit Yield Per Plant

Table 6. Estimation of variance parameters for eleven characters in okra genotypes

Parameters	σ^2p	σ^2g	σ^2 e	PCV	GCV	ECV
Germination (%)	58.06	49.90	8.16	10.10	9.37	3.79
Days to 1st flowering	5.60	3.39	2.21	7.23	5.62	4.54
Days to 50% flowering	6.51	4.02	2.50	6.50	5.10	4.02
Plant Height (cm)	263.24	256.19	7.05	14.96	14.75	2.45
Primary branches (cm)	1.25	0.73	0.51	43.91	33.64	28.22
No. of fruit per plant	22.35	19.79	2.56	27.65	26.02	9.36
Fruit length (cm)	3.28	0.90	2.37	14.02	7.36	11.93
Fruit diameter (cm)	0.03	0.01	0.02	13.71	8.91	10.42
Average Fruit weight (gm)	12.71	7.69	5.02	20.89	16.25	13.12
Seed per fruit	99.90	72.94	26.96	22.61	19.32	11.74
Fruit yield per plant (g)	12212.49	9158.14	3054.35	37.51	32.48	18.76

σ^2p: Phenotypic Variance, PCV: Phenotypic Coefficient of Variation , σ^2g: Genotypic Variance ,GCV: Genotypic Coefficient of Variation, σ^2e: Environmental Variance, ECV: Environmental Coefficient of Variation

3.3 Variability Study in Genotypes

3.3.1 Phenotypic and genetic variances

Estimation of variance and coefficients of variation at genotypic and phenotypic levels in a population is decisive factor for scope and efficiency of selection of individuals for future breeding program in crop species. The 28 genotypes of okra in present investigation were grown to estimate the variability parameters for eleven characters comprising yield and yield attributing traits.

The highest phenotypic variances were calculated for fruit yield per plant (12212.49) followed by plant height (263.24) and seed per fruit (99.90) while the lowest value was recorded for fruit diameter (0.03) followed by primary branches per plant (1.25) and fruit length (3.28). The genotypic variance ranged from 0.01 (fruit diameter) to 9158.14 (fruit yield per plant). Consistence result was reported by Mehta et al and Pradip et al [24,25] for fruit yield per plant, plant height, number of seeds per fruit and number of tender fruits per plants. This result is in agreement with Ehab et al [26]**,** who reported that phenotypic variances were higher than the corresponding genotypic variances indicating predominance of environmental effects on the expression of these studied characters. This study result showed that the traits exhibited phenotypic variances higher than their respective genotypic variances thus revealing the great significant influence of environmental factors in the expressions of the traits in okra genotypes and the apparent variation is not only due to the genotypes but also due to the influence of environment. This result supported by Adeoluwa et al, Nwangburuka et al, Thirupathi et al, Adekoya et al [27-29] [8]) who reported that most of the traits exhibited highly phenotypic variance higher than their respective genotypic variances.

3.3.2 Phenotypic and genetic coefficient of variation

The phenotypic coefficient of variation (PCV) ranged between 6.50% (days to 50% flowering) to 43.91% (primary branches per plant) while genotypic coefficient of variation (GCV) ranged between 5.10 (days to 50% flowering) to 33.64% (number of primary branches per plant) (Table 5). Similar results were reported by Ehab et al [26] for okra. According to Sibsankar et al [30]) PCV and GCV values greater than 20% are regarded as high, values between 10% and 20% to be medium whereas values less than 10% are considered to be low. Based on this delineation PCV and GCV recorded in this study, days to first flowering (7.23% and 5.62%), days to 50% flowering (6.50% and 5.10%) had low values (<10%) for both phenotypic and genotypic coefficient of variations and it was low in case of genotypic level for fruit length (7.36%) and fruit diameter (8.91%). Sibsankar et al [31] reported that low PCV and GCV values for days to first flowering. The low PCV and GCV value of traits suggests the higher influence of environment on these traits thus; selection on the phenotypic basis would not be effective for the genetic improvement ([32-34],[29,26]) **.**

Moderate GCV and PCV were found in germination% (9.375 and 10.10%), plant height (14.75% and 14.96%) and average fruit weight (16.25% and 20.89%) (Table 5). Medium PCV and GCV value suggests that these characters are controlled more of by the genetic factors. Hence, these characters amenable to selection

for further improvement. This result is in agreement with the finding of Bharathiveeramani and Prakash [33], [29]) and [26] who reported medium PCV and GCV values of characters.

4. CONCLUSION

Results of the present studies indicated significant variation among the genotypes for all the characters studied. Plant height, fruits per plant and fruit weight contributed maximum towards fruit yield improvement. Twenty eight okra genotypes formed five different clusters. Considering genetic variability, diversity and other agronomic performance selection of genotypes G1 and G18 could be selected for earliness and high fruit yield and genotypes G6 and G20 selected for less seeds per fruit for future breeding program.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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