



Agricultural characteristic performance of local and exotic okra (*Abelmoschus esculentus* L. Moench) genotypes in Bangladesh

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ARTICLE INFO

Original Article

Article history:

Received 18 December 2020

Revised 3 May 2021

Accepted 12 May 2021

Available online 7 July 2021

Keywords:

Hybrid

Ladies finger

Open pollinated variety

Yield

YVMV

DOI:10.22077/jhpr.2021.3842.1179

P-ISSN: 2588-4883

E-ISSN: 2588-6169

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ABSTRACT

Purpose: Twenty genotypes of okra including hybrids and open pollinated varieties both from local and exotic sources were evaluated in the field to study their yield performance and disease response. **Research method:** Experiment was conducted following randomized complete block design with three replications. **Findings:** Analysis of variance indicates significant variation among the okra cultivars for all the characters studied except days to first germination. The highest number of fruits per plant (19.98) and maximum yield of green fruits per plant (279.59 g) and maximum yield (1.33 kg/m²) was obtained in the genotype G₄ (F₁-hybrid) followed by G₇ and G₁₈. The maximum edible fruit length was observed in G₇ followed by G₁₉ and G₁₅. The maximum number of seeds per fruit was recorded in G₄. The highest 100-seed weight was found in G₄ followed by G₁₇. On the contrary, the lowest seeds per fruit, 100-seed weight, and green fruit yield per plant were obtained from G₆. The highest incidence of yellow vein mosaic virus (YVMV) was observed in the genotype G₆ and the lowest in the genotype G₁₉ followed by G₈, G₂, G₄, G₁₇ and G₁₂. The cluster analysis grouped 20 genotypes into five cluster and maximum number of genotypes included in cluster 5. Strong positive correlation was observed between yield per plant and days to 50% germination, germination percentage, number of seeds per fruits and 100-seed weight (g). **Limitations:** No significant limitation to the report. **Originality/Value:** The results help to identify the suitable okra genotypes and generate breeding materials.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a very popular for its delicious, tasty, gelatinous, tender fruits as vegetable. It is the best source of iodine and calcium. It is a nutritious vegetable containing 86.1% water, 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1% fibre and 0.8% ash (BBS, 2010; Benchasri, 2012) and rich in vitamins (A, B, C) and other minerals (Gopalan et al., 2007; Varmudy, 2011). Consumption of 100 g of fresh okra fruit provides 20, 15 and 50% of the daily requirement of calcium, iron and ascorbic acid, respectively (Schippers, 2000; Petropoulos et al., 2018). It belongs to the family *Malvaceae* with chromosome number $2n=8x=72$ or 144 is a polyploid. The evidence from several reports confirm that *A. esculentus* exists more stably as a diploid species with 36 pairs of chromosomes, $2n=2x=72$ (Ugale, 1976). It is a self pollinated crop occurrence of out crossing to an extent of 4-19% with the maximum of 42.2% is noticed with the insect assisted pollination (Kumar et al., 2006). It is a preferable fruit vegetable grown extensively in tropical, subtropical and warm area of the temperate zones of the world (Tindall, 1983; Siemonsma & Kouame, 2004). It is believed to be native of tropical Africa (Hammon & Van Stolen, 1989). It is widely cultivated as an important vegetable crop in Bangladesh (Chowdhury & Hassan, 2013). About 43.21 thousand metric tons of okra is produced from 10.35 thousand hectare of land per year in Bangladesh and its average yield is about 4.17 t/ha (BBS, 2018). Average yield of okra in this country is quite low because of cultivating low yielding varieties (Saifullah & Rabbani, 2009; Appiah et al., 2020). Presently cultivated okra varieties in Bangladesh gave poor yield due to poor seed quality and their disease susceptibility (Chowdhury & Hassan, 2013). High yield potential with good horticultural characteristics is the basis for successful crop production and important for increasing the productivity (Taber, 2008). Therefore, it was considered appropriate to carry out a comparative study of local and exotic cultivars of okra for screening high yielding varieties suitable to local agro-climatic conditions. In the present study, twenty okra genotypes including high yielding OP cultivars and hybrids both from local and exotic sources were evaluated for their yield performance and infestation of yellow vein mosaic virus (YVMV).

MATERIALS AND METHODS

The experiment was conducted at the experimental farm under the Department of Genetics and Plant Breeding of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur. Twenty genotypes (including hybrid and open pollination (OP) variety) of okra (Table 1) were collected from the seed market and different seed companies of Bangladesh which are cultivated commercially as well as popular at farmer's level.

The experiment was laid out in randomized complete block design with three replications during kharif season. The unit plot size was 2.25 m^2 maintaining row spacing 60 cm having plant spacing of 50 cm within the row. Required amount of the recommended dose fertilizer (Cow dung 10 t/ha, Triple Super Phosphate 100 kg/ha, Urea and Muriate of Potash 150 kg/ha) was applied uniformly to each plot (Anonymous, 1997; Chowdhury & Hassan, 2013). Total cow dung, TSP was applied during the final land preparation. Urea and MP were applied as side dressing in three equal installments after 20, 40 and 60 days after seed germination (DAG). All the cultural practices were provided to raise a good crop. Randomly selected competitive plants from each of the entries were used for recording the data on the following characters:

Growth characteristics:

Days to 1st germination
Days to 100% germination
Germination percentage
Days to 1st flowering
Days to 50% flowering
Plant height (cm) at 1st flowering
Plant height (cm) at 1st fruit harvest

First flower bearing node
First fruit bearing node
Days to edible fruit maturity
Primary branches (no.)
Leaves per plant (no.)
Internodal length (cm)

Yield characteristics:

Fruit per plant
Fruit length (cm) at edible stage
Fruit length (cm) at mature stage
Fruit girth (mm)

Yield per plant (g)
Individual green pod weight (g)
Seed per fruits (no.)
100-seed weight (g)

Table 1. List of experimental materials with their origin and sources

Sl. No.	Name of Genotype	Variety	Origin	Company/ organization
G ₁	Greenstar	OP	Bangladesh	Afroza Seed company
G ₂	Iron 40	OP	Bangladesh	M.R.Hybrid Seed Co.
G ₃	Baromasi	Hybrid	Bangladesh	Mousumi Bizagar
G ₄	F ₁ -hybrid	Hybrid	India	Seed Works India Pvt. Ltd.
G ₅	SB11	Hybrid	Bangladesh	Shohid Beej Bhandar
G ₆	Pretom	Hybrid	Bangladesh	Krishmart Bhandar
G ₇	Moonmoon	Hybrid	Bangladesh	Aftab Bahumukhi Farms Ltd.
G ₈	Orka Anamika	Hybrid	Bangladesh	Mitali Seed Co.
G ₉	G.Hossain	Hybrid	Bangladesh	Mollika Seed Co.
G ₁₀	Comola	Hybrid	Bangladesh	Manik Seed Co.
G ₁₁	Apurbo	Hybrid	Bangladesh	Zillion Seed
G ₁₂	Titanic	Hybrid	Bangladesh	Bikrampur Seed Co.
G ₁₃	Champion	Hybrid	Bangladesh	Talikder Seed Co.
G ₁₄	Victory	Hybrid	Bangladesh	Supreme Seed Co.L.
G ₁₅	Pride	Hybrid	India	Maharashtra Hybrid Seed Co. Ltd.
G ₁₆	Ok-630	Hybrid	Bangladesh	Supreme Seed Co. Ltd.
G ₁₇	Ok-628	Hybrid	Bangladesh	Supreme Seed Co. Ltd.
G ₁₈	Luky -7	Hybrid	Bangladesh	Lal Teer Seed Co.
G ₁₉	Green Finger	Hybrid	Bangladesh	Lal Teer Seed Co.
G ₂₀	Silva	Hybrid	Bangladesh	Lal Teer Seed Co.

Table 2. Disease rating scale of okra YVMV on the basis of incidence percentage

Rating scale	Severity range (%)
0 Immune	0
1 Highly resistant	1-10
2 Moderately resistant	15-25
3 Tolerant	26-50
4 Moderate susceptibility	51-60
5 Susceptibility	61-70
6 High Susceptibility	71-100

Source: Ali et al. (2005a,b)

For screening the genotypes infested through natural infestation was rating using percent infestation disease rating scale (0-6) of yellow vein mosaic virus (YVMV) (Table 2) was used.

The recorded data for different characters were analyzed statistically using SAS (SAS, 2010). The analysis of variance and the mean separation was done using Tukey's test to compare the difference among the means and significance was accepted at $P \leq 0.05$ (Steel et al., 1997).

RESULTS & DISCUSSION

The analysis of variance showed significant differences among the genotypes for all the characters studied except days to 1st germination (Table 3). Hence, there was opportunity to select desirable genotypes with desired traits.

Growth characters

First germination was observed in the genotypes G₁ and G₂ which took 3.00 days after sowing. Complete (100%) germination was recorded in G₁₁ and G₁₈ genotypes after 5.67 days of sowing (Table 3). The genotype G₂ took the lowest time (3.33 days) to germinate 100% followed by the genotypes G₃, G₁₃ and G₁₆ (3.67, 4.00 and 4.00 days, respectively). The maximum germination percentage was recorded in G₆ (68.50%) and the minimum seed germination was recorded in G₁₃ (42.46%).

The maximum number of days for first flowering was required in the genotype G₂ (45.0 days) followed by genotype G₃, G₈, G₁₂, G₁₄ and G₁₉ (42.67 days). The minimum number of days for first flowering was required in the genotype G₁₀ (40.67 days) and followed by genotype G₄, G₉ and G₁₆ (41.00 days). Amjad et al. (2001) recorded the earliest flowering (45 days after sowing) in an evaluation trial with four high yielding okra genotypes. Ali (1999) reported that it required 47 days to initiate flowering. The longest duration for 50% flowering was recorded by the genotype G₆ (56.67 days) followed by the genotype G₁₂ (53.67 days) and G₅ (52.33 days) and the minimum duration of 50% flowering was recorded by the genotype G₃ (45.6 days) followed by the genotypes G₁₉ (47.33 days) and G₁ (47.00 days).

The maximum plant height (cm) at 1st flowering was recorded in the genotype G₉ (23.65 cm) followed by genotype G₄, G₁₅ and G₁₇ with 23.59, 23.47 and 23.36 cm, respectively. The minimum plant height (cm) at 1st flowering was observed in the genotype G₈ (16.46 cm) followed by the genotypes G₁₁ (16.88 cm) and both were statistically alike (Fig. 1). Kuwar et al. (2001) reported that plant height varied from 13.0 to 18.9 cm in okra. The maximum plant height (37.73 cm) at 1st fruit harvest was observed in the genotype G₁₅, which was statistically at par with the genotypes G₁₄ (34.81 cm). The minimum plant height (20.06 cm) was observed in G₆ that was statistically at par with G₈ (23.33 cm) genotype at 1st fruit harvest (Fig. 2). The plant height in G₆ became reduced due to the severe infestation of mosaic disease. A number of researchers (Chaudhary et al., 2006; Hussain et al. 2006; Desai et al., 2007; Katung, 2007) who also found significant differences among different okra cultivars for plant height at 1st fruit harvest. The highest node number to 1st flowering was found in the genotype G₁₄ (8.07) and the lowest node number to 1st flowering was observed in the genotypes G₄ and G₇ (6.33). Similar result was observed by Pradip et al. (2010) and Ansari et al. (2020). The highest node number of 1st fruiting was recorded in the genotype G₉ (9.28) and the lowest node number to 1st fruiting was observed in the genotypes G₁₈ (6.83).

Table 3. Mean performance of 20 okra genotypes for growth characters during kharif season

Sl. No.	Days to 1 st germination	Days to 100% germination	Germination percentage	Days to 1 st flowering	Days to 50% flowering	First flower bearing node
G ₁	3.00 a	4.67 a-c	53.06 ab	41.33 b	47.00 e-f	7.14 a-c
G ₂	3.00 a	3.33 c	53.33 ab	45.00 a	48.33 c-f	6.40 c
G ₃	3.33 a	3.67 bc	47.10 ab	42.67 ab	45.67 f	7.67 ab
G ₄	3.67 a	4.33 a-c	66.44 ab	41.00 b	48.67 c-f	6.33 c
G ₅	4.00 a	5.00 ab	52.41 ab	42.33 b	52.33 a-c	6.53 bc
G ₆	3.33 a	4.33 a-c	68.50 a	41.33 b	56.67 a	7.10 a-c
G ₇	3.67 a	4.33 a-c	66.70 ab	41.33 b	49.33 b-f	6.37 c
G ₈	4.00 a	4.67 a-c	53.52 ab	42.67 ab	51.00 b-e	7.27 a-c
G ₉	3.33 a	4.33 a-c	45.63 ab	41.00 b	50.00 b-f	6.73 bc
G ₁₀	3.67 a	4.33 a-c	52.10 ab	40.67 b	48.33 c-f	6.60 bc
G ₁₁	3.33 a	5.67 a	44.77 ab	42.00 b	51.33 b-e	6.73 bc
G ₁₂	3.67 a	4.33 a-c	57.33 ab	42.67 b	53.67 ab	7.20 a-c
G ₁₃	4.00 a	4.00 bc	42.46 b	42.00 b	49.00 b-f	7.13 a-c
G ₁₄	3.33 a	4.33 a-c	57.36 ab	42.67 ab	52.00 a-d	8.07 a
G ₁₅	4.00 a	5.00 ab	44.59 ab	42.00 b	48.00 c-f	6.57 bc
G ₁₆	3.67 a	4.00 bc	59.39 ab	41.00 b	49.33 b-f	6.67 bc
G ₁₇	3.67 a	4.67 a-c	46.01 ab	41.33 b	50.67 b-e	6.33 c
G ₁₈	3.67 a	5.67 a	51.05 ab	42.00 b	49.67 b-f	6.50 c
G ₁₉	4.00 a	4.67 a-c	54.75 ab	42.67 ab	47.33 d-f	7.40 a-c
G ₂₀	4.00 a	4.33 a-c	57.32 ab	42.33 b	51.00 b-e	7.67 ab
F-Value	ns	**	**	**	**	**
Mean	3.62	4.48	53.69	42.00	49.97	6.92
CV (%)	12.25	11.29	14.84	1.88	3.19	5.38
Range	3-4	3.33-5.67	42.46-68.50	40.67-45.00	45.67-56.67	6.33-8.07
r ² value	0.47	0.49	0.61	0.69	0.79	0.75
MSD	1.36	1.32	24.73	2.45	4.96	1.16

The earliest fruit harvested was done in the genotype G₄ which required only 45.33 days after sowing and late fruit harvest was recorded in the genotype G₅ after 58.00 days of sowing (Table 3). Days to edible fruit maturity available from commercial literature ranged from 46 days after planting for ‘Rani’ and North & South’ to 60 days for Burgudy (Simonee et al., 2000). The maximum number of primary branches per plant was produced by the genotype G₅ (4.56) followed by the genotype G₈ and G₁₀ (3.81 and 3.75, respectively). The minimum number of primary branches per plant was produced by the genotype G₁₆ (2.14). Kuwar et al. (2001) and Satish and Kanwar (2005) reported that number of primary branches varied from 4.28 to 4.58. The maximum number of leaves per plant was produced by the genotype G₁₈ (62.43 at 75 DAS) followed by the genotypes G₂₀ (61.62), G₁₅ (59.39), G₁₄ (58.77) and G₁₃ (58.61) (Table 3). The minimum number of leaves per plant was recorded in the genotype G₆ (28.66 at 75 DAS) followed by the genotypes G₂ (34.21) and G₅ (35.36). These results are in full conformity with Gondane and Bahatia (1995); Martin and Rhodes (1983); Hossain and Alam (2008) who found significant varietal differences for number of leaves per plant in okra. The longest internodal length was recorded in the genotype G₄ (6.65 cm) and the shortest internodal length was observed in the genotype G₆ (2.96 cm).

Table 3. Continued.

Sl. No.	First fruit bearing node	Days to edible fruit maturity	Primary branches (no.)	Leaves per plant (no.)	Internodal length (cm)
G ₁	8.42 a-d	52.33 ab	2.39 b-d	44.80 a-d	4.39 d-g
G ₂	7.27 e-h	52.67 ab	2.68 b-d	34.21 c-d	4.70 c-f
G ₃	8.55 a-c	55.00 ab	3.36 a-d	51.77 a-c	4.43 d-g
G ₄	7.17 g-h	45.33 b	3.00 b-d	48.34 a-d	6.65 a
G ₅	8.30 a-g	58.00 a	4.56 a	35.36 b-d	4.45 d-g
G ₆	7.47 c-h	49.67 ab	2.81 b-d	28.66 d	2.96 g
G ₇	7.21 f-h	46.33 b	3.30 a-d	49.33 a-d	5.37 a-e
G ₈	8.87 a-b	55.67 ab	3.81 a-b	51.48 a-c	4.52 d-g
G ₉	7.20 f-h	47.67 ab	2.92 b-d	46.75 a-d	6.23 a-c
G ₁₀	7.17 g-h	47.33 ab	3.75 a-c	44.84 a-d	4.78 c-f
G ₁₁	7.88 b-h	54.67 ab	2.33 c-d	46.33 a-d	5.24 a-e
G ₁₂	8.40 a-d	54.67 ab	2.83 b-d	41.95 a-d	4.16 e-g
G ₁₃	8.33 a-f	50.67 ab	3.38 a-d	57.61 a	4.00 e-g
G ₁₄	8.65 a-b	52.67 ab	2.77 b-d	58.78 a	4.61 d-f
G ₁₅	7.34 d-h	53.33 ab	3.61 a-c	59.39 a	5.95 a-d
G ₁₆	7.40 d-h	52.67 ab	2.14 f	51.50 a-c	4.78 c-f
G ₁₇	7.47 c-h	45.67 b	3.49 a-d	55.62 ab	6.42 ab
G ₁₈	6.83 h	48.67 ab	3.29 a-d	62.43 a	3.43 fg
G ₁₉	9.28 a	52.33 ab	3.12 a-d	46.54 a-d	5.03 b-e
G ₂₀	8.55 a-c	53.00 ab	3.29 a-d	61.62 a	4.55 d-f
F-Value	**	**	**	**	**
Mean	7.88	51.42	3.14	48.87	4.83
CV (%)	4.67	7.01	14.73	13.77	10.57
Range	6.83-9.28	45.33-58.00	2.14-4.56	28.66-62.43	2.96-6.65
r ² value	0.85	0.64	0.69	0.74	0.84
MSD	1.14	11.19	1.44	20.88	1.59

Yield related characters

The highest number (19.98) of fruits per plant was obtained from the genotype G₄ (Fig. 5) which were at par with G₇ (18.17) and G₁₈ (17.49). On the other hand, the lowest number (1.57) of fruits per plant was found in the genotype G₆ (Fig. 2). Jordan-Molero (1986) reported variation in number of fruits per plant among several okra cultivars. Khan et al. (2002) reported wide range of variability for number of fruits per plant in okra. The maximum fruit length (14.78 cm) at edible stage was observed in the genotype G₇ (Fig. 5) followed by the genotypes G₁₉, G₁₅ and G₁₄ (12.98, 12.74 and 12.37 cm, respectively), whereas minimum fruit length (8.18 cm) was recorded in the genotype G₆ (Fig. 3). The difference in edible fruit length might be due to the different genotypes and their response to prevailing environmental conditions. Amjad et al. (2001) and Mikejoy (2010) also reported variation in fruit length in okra. The maximum length of mature fruits was recorded in G₁₉ (13.06 cm) and the shortest length of mature fruits was recorded in the genotype G₆ (8.433 cm). The widest girth of fruit (18.43 mm) was recorded in the genotypes G₁₇ and minimum girth (15.23 mm) was recorded in the genotype G₁₃ (Table 4). The mean value of fruit girth was recorded at 17.11 mm. Similar result was observed by Mikejoy (2010). The heaviest edible fruit (17.62 g) was recorded from the genotype G₅ and the lowest fruit weight at edible stage was recorded in G₁₁ (8.74 gm) which was also statistically different from all other genotypes (Table 4). Mikejoy (2010) and Ojo et al. (2012) also reported similar results from an investigation of okra.

Table 4. Mean performance of 20 okra genotypes for yield and yield contributing characters during kharif season

Sl. No.	Fruit length (cm) at mature stage	Fruit girth (mm)	Individual green fruit weight (g)	Seeds per fruit (no.)	100-seed weight (g)	Yield (kg/m ²)
G ₁	12.42 ab	16.72 ab	16.29 a-d	43.70 f-g	5.00 c-e	0.66 c-f
G ₂	11.35 ab	17.02 ab	14.57 a-f	56.12 b-d	5.49 b-d	0.54 e-g
G ₃	10.69b	16.41 ab	14.80 a-e	47.11 e-g	4.83 c-e	0.77 b-f
G ₄	12.40 ab	16.44 ab	15.58 a-e	9.54 a	6.51 a	1.33 a
G ₅	11.83 ab	17.30 ab	17.62 a	47.01 e-g	5.10 c-d	0.60 d-f
G ₆	8.43 c	16.82 ab	11.50 f-g	13.06 h	3.70 f	0.01 g
G ₇	12.35ab	17.31 ab	14.38 b-f	50.55 d-e	5.40 c-d	1.19 a-c
G ₈	11.71 ab	18.39 a	15.66 a-e	57.97 b-c	4.19 e-f	0.35 f-g
G ₉	11.03 ab	17.62 ab	11.58 f	43.51 g	3.72 f	0.88 a-f
G ₁₀	10.77b	17.01 ab	14.42 b-f	45.10 e-g	4.82 c-e	0.97 a-e
G ₁₁	11.50 ab	16.22 ab	8.47 g	42.89 g	5.27 c-d	0.74 b-f
G ₁₂	11.16 ab	16.71 ab	14.13 b-f	59.96 b-c	4.84 c-e	0.46 e-g
G ₁₃	10.78 b	15.23 b	13.25 d-f	60.91 b	4.81 c-e	0.84 a-f
G ₁₄	11.82 ab	17.24 ab	12.63 e-f	46.37 e-g	5.46 b-d	0.87 a-f
G ₁₅	11.94 ab	18.28 ab	13.47 c-f	60.97 b	5.59 b-c	0.83 a-f
G ₁₆	11.91 ab	18.07 ab	15.15 a-e	54.44 b-d	5.32 c-d	0.83 a-f
G ₁₇	11.80 ab	18.44 a	16.46 a-c	46.37 e-g	6.32 a-b	1.24 ab
G ₁₈	11.63 ab	16.58 ab	14.11 b-f	50.17 d-f	4.98 c-e	1.14 a-d
G ₁₉	13.06 a	17.68 ab	16.96 a-b	54.27 b-d	4.67 d-e	1.14 a-d
G ₂₀	10.43 bc	16.72 ab	14.03 b-f	42.13 g	4.15 e-f	0.73 b-f
F-Value	**	*	**	**	**	**
Mean	11.45	17.11	14.25	50.09	5.01	0.81
CV (%)	5.86	5.93	6.96	13.77	5.74	21.97
Range	8.43-13.06	15.23-18.44	8.47-17.62	13.06-79.54	3.70-6.51	0.84-1.33
r ² value	0.76	0.49	0.87	0.98	0.91	0.83
MSD	2.08	3.15	3.08	6.62	0.89	5.49

The maximum number of seeds per fruit was recorded in the genotype G₄ (79.54) and the lowest number of seed per fruit was recorded in the genotype G₆ (13.06). Both were significantly different from all other genotypes (Table 4). Similar result was also reported by Mikejoy (2010) and Ojo et al. (2012) Satish and Kanwar (2005). The highest 100-seed weight was recorded in G₄ (6.51 g) and the lowest 100-seed weight was recorded in G₆ (3.70 g) (Table 4). All other varieties were statistically similar. This difference in 100 seed weight is possibly due to the differences of the genotypes. Maximum 100-seed weight in G₄ followed by G₁₇ may be attributed due to better source sink relationship than the other genotypes. These results are in line with those of Amjad et al. (2001), Satish and Kanwar (2005) and Ojo et al. (2012) those who found significant differences for 100-seed weight. The maximum yield of green fruits per plant (279.57 g) was obtained in t G₄ whereas the minimum yield of green fruits per plant (1.77 g) was obtained from G₆ (Figure 4). In case of the genotype G₆, fruit yield was drastically reduced because of severe infestation of yellow vein mosaic virus of okra. This result was consistent with the findings of Martin and Rhodes (1983), Karri and Acharyya (2012). Khan et al. (2002) reported from an evaluation trial with cultivated okra genotypes that maximum yield was 17.85 t/ha.

Table 5. Virus infestation of plants at different growth stages and grading of 20 okra genotypes based on infection of yellow vein mosaic virus

Sl. No.	% disease incidence (40 DAS*)	% disease incidence (60 DAS)	% disease incidence (80 DAS)	Mean incidence (%)	Level of resistance (40 DAS)	Level of resistance (60 DAS)	Level of resistance (80 DAS)
G ₁	20.83	40.90	81.81	47.85	MR	T	HS
G ₂	4.00	30.00	68.18	34.06	HR	T	S
G ₃	8.33	34.78	86.36	43.16	HR	T	HS
G ₄	8.42	34.44	72.22	38.36	HR	T	HS
G ₅	29.16	52.38	85.00	55.51	T	MS	HS
G ₆	60.00	100.00	100.00	86.67	MS	HS	HS
G ₇	16.66	31.44	86.36	44.82	MR	T	HS
G ₈	00.00	18.18	68.18	28.78	HR	MR	S
G ₉	16.67	35.00	100	50.56	MR	T	HS
G ₁₀	16.67	42.85	89.47	49.66	MR	T	HS
G ₁₁	4.16	35.55	83.33	41.01	HR	T	HS
G ₁₂	00.00	40.86	78.62	39.83	HR	T	HS
G ₁₃	26.63	73.31	100	66.65	T	HS	HS
G ₁₄	22.00	46.67	71.42	46.70	MR	T	HS
G ₁₅	13.18	44.16	82.60	46.78	MR	T	HS
G ₁₆	12.5	33.33	75.00	40.28	MR	T	HS
G ₁₇	00.00	28.00	90	39.33	HR	T	HS
G ₁₈	19.04	86.14	100	68.39	MR	T	HS
G ₁₉	00.00	17.39	56.12	24.50	HR	MR	MS
G ₂₀	20.83	64.00	100	61.61	MR	S	HS

*: Days after sowing; HR= highly resistant; MR= moderately resistant; T= tolerant; S= susceptible; MS= moderately susceptible; HS= highly susceptible

Table 6. Distribution of 20 lady's finger genotypes in five clusters

Cluster	Number of genotypes	Genotypes
1	1	G2 (Iron 40)
2	1	G6= Pretom
3A	1	G4= F1-hybrid
3B	2	G7= Moonmoon, G17= Ok-628
3C	4	G1= Greenstar, G9= G.Hossain, G10= Comola, G16= Ok-630
4	3	G3= Baromasi, G13= Champion, G14= Victory
5A	1	G18= Luky -7
5B	2	G8= Orka Anamika, G12= Titanic
5C	2	G15= Pride, G19= Green Finger
5D	4	G5= SB11, G11= Apurbo, G20= Silva

Yellow vein mosaic virus incidence

The most important and destructive viral disease YVMV (yellow vein mosaic virus) in okra infects crops at all the growth stages. The disease causes 50-100% loss in yield if the plants get infected at early growth stage. The disease incidence was recorded at twenty days interval upto final harvesting. After germination of seedling, there was no virus infected plant in the experimental plot. With the increase of days infection of virus was higher. The highest number of infected plants were found in G₆ (60%) at 40 days after sowing and in that time G₈, G₁₂, G₁₇ and G₁₉ genotypes were uninfected (Table 5). At 80 DAS the highest and the lowest virus infection found in genotypes G₆ (100%) and G₁₉ (56.12%), respectively. Mathew et al. (1993) recorded six resistant varieties of okra from an investigation and infestation of virus varied from 2.31 to 54.0%. The okra genotypes in relation to YVMV incidence impact on growth and yield contributing characters. All the genotypes showed high susceptibility at 80

DAS except G₂ and G₈ and G₁₉, in which former both were susceptible and later on moderately susceptible (Table 5). The genotype G₁₉ showed slow incidence of YVMV and it was considered as moderately susceptible. Rests of the genotypes were highly susceptible. Considering yield performance, the genotype G₄, G₁₇ and G₇ are most suitable varieties for commercial cultivation.

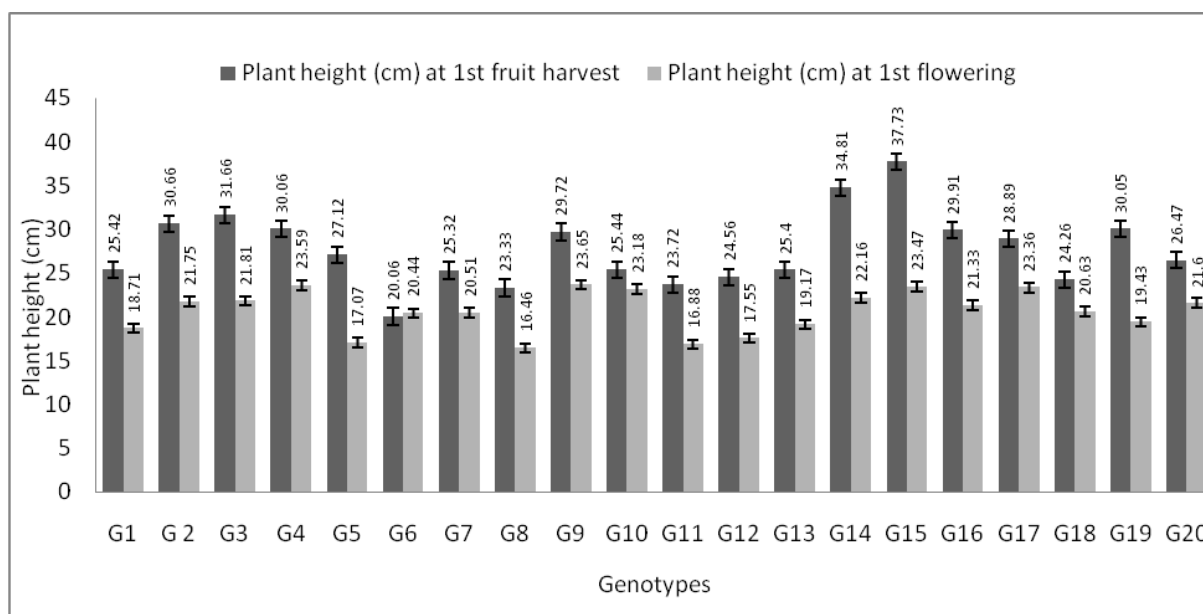


Fig. 1. Mean performance of different okra genotypes for plant height (cm) at 1st flowering and 1st fruit harvest (vertical bar represents Tukey's at 5% level of probability).

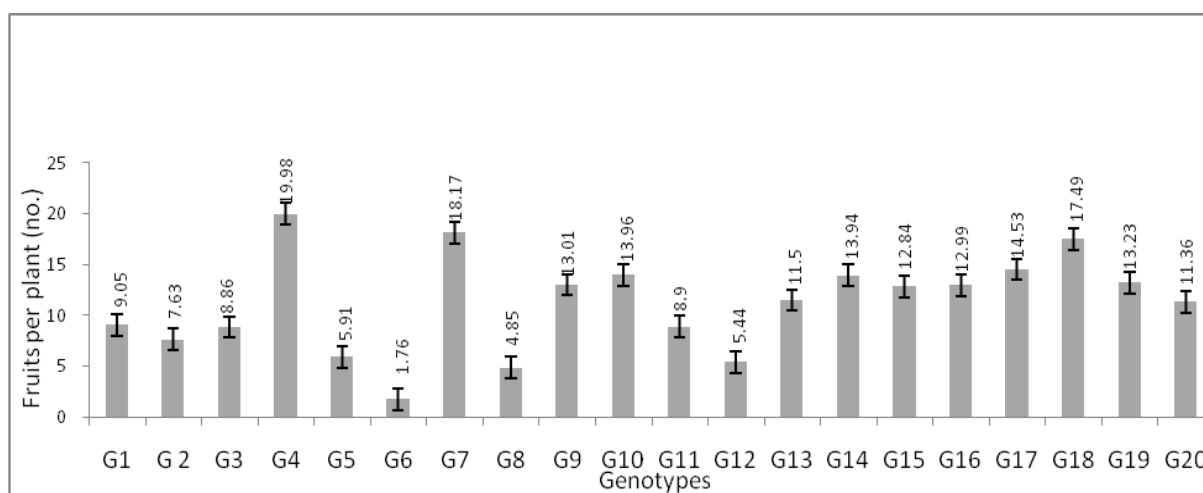


Fig. 2. Variation in number of fruits per plant of okra genotypes (vertical bar represents Tukey's at 5% level of probability).

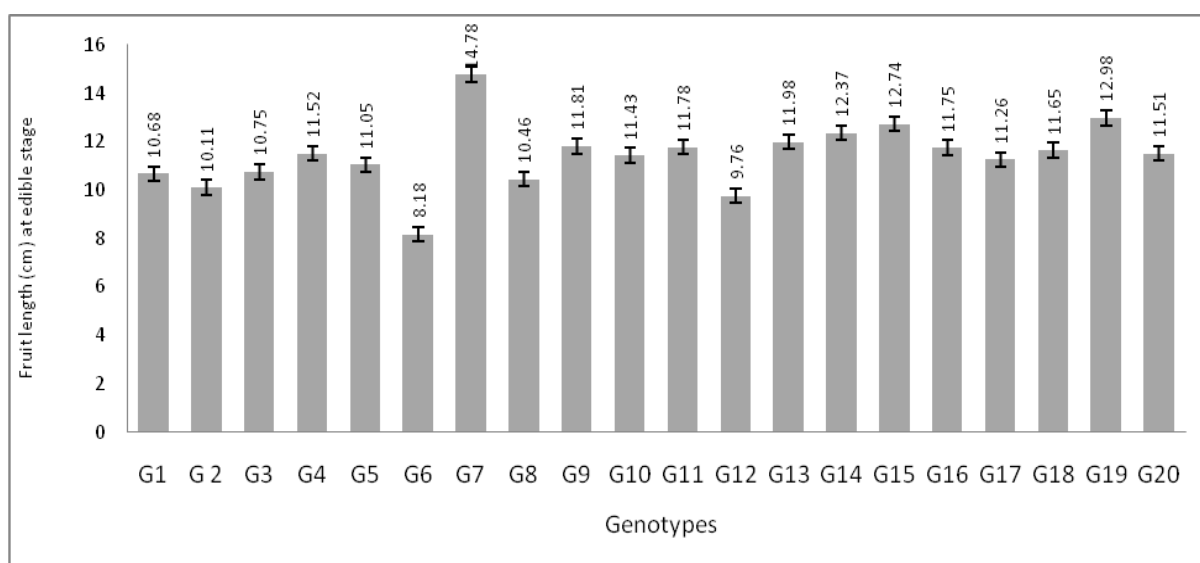


Fig. 3. Variation in fruit length observed in different genotypes of okra at edible stage (vertical bar represents Tukey's at 5% level of probability).

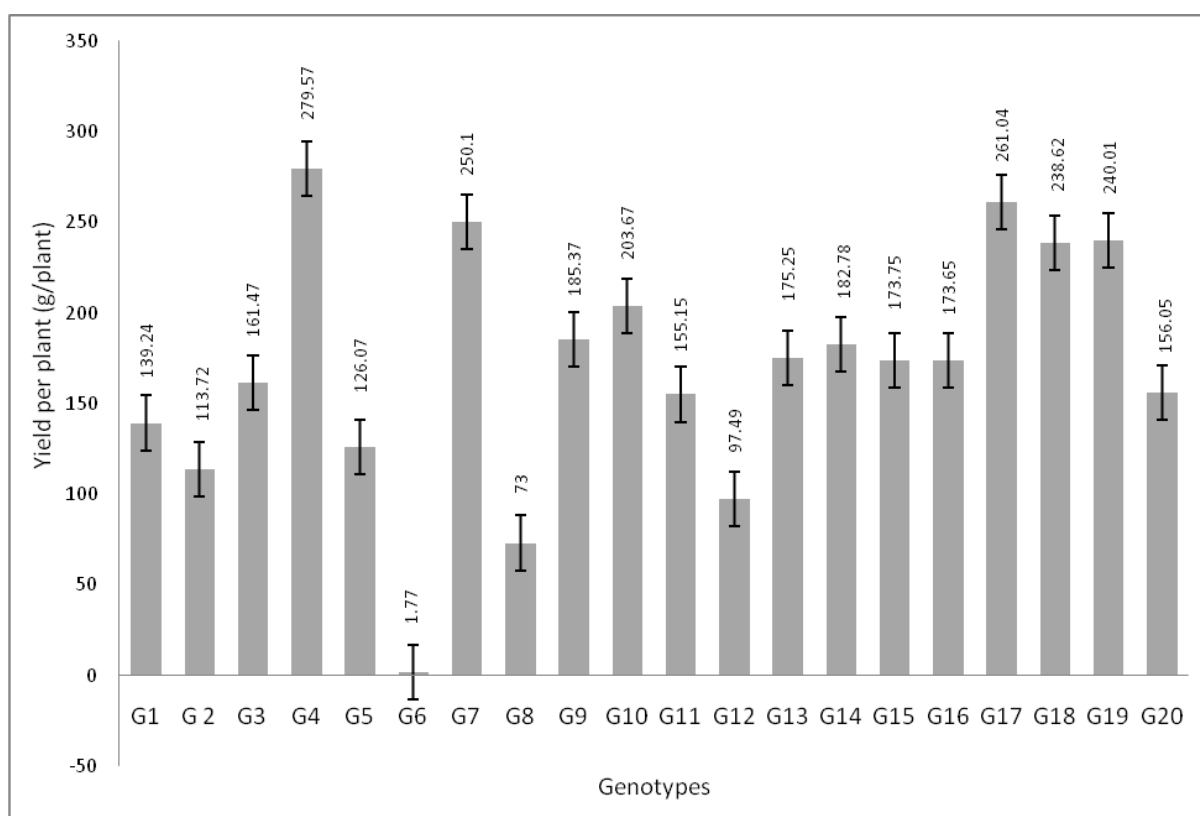


Fig. 4. Yield of green fruit of 20 okra genotypes (vertical bar represents Tukey's at 5% level of probability).

Cluster analysis

Cluster analysis is one of the statistical techniques aimed at grouping objects in clusters so that the items in one cluster have high similarities to those in other clusters. The clusters represent uncorrelated groups which may be useful for future heterotic breeding as their traits; performance may be governed by different sets of alleles (Twumasi et al., 2017; Singh et al., 2017). Based on the cluster analysis on 23 traits, 20 lady's finger genotypes were separated into five groups and further divided into subgroups (Fig. 5). Thus, Figure 1 illustrates the five clusters formed by hierarchical clustering with subgroups, and Table 6 summarizes the number of genotypes in each cluster.

Cluster 1 and 2 consists of only one genotype, G2 and G6, respectively signifying their divergence from other genotypes of the experimental population. The third cluster (3) was again divided into two subgroups; 3A and 3B (Fig. 5). Subgroup 3A consisted of one genotype; 3B consisted of two genotypes; G7 and G17, while subgroup 3B comprised of four genotypes; G1, G9, G10 and G16. Cluster 4 consists of three genotypes, G3, G13 and G14, signifying its divergence from the member of other clusters of the experimental population. Cluster 5 contains a maximum number of genotypes, and subdivided into four subgroups; 5A comprises of one genotype; 5B consists of two genotypes; 5C comprises of two genotypes and 5D comprises three genotypes. Cluster 5 consists of eight genotypes.

Biplot analysis based on principal components

Biplot analysis is mostly used to determine the components which create the genotypic variation. The highest values indicate the resilient influence of the trait on the total variation. It also provides a tool for visual comparison among genotypes based on multiple traits (Al-Naggar et al., 2020; Davinder et al., 2018). Biplot in the principal component represents variables that are super imposed on a plot as vectors where relative length of vectors represents the relative proportion of variability in each variable defined on the biplot. If the angle between vectors of two traits is $< 90^\circ$, both are positively correlated, whereas if the angle is $> 90^\circ$ there is a negative correlation and both vectors show no correlation if the angle is 90° (Sabaghnia et al., 2011). Genotype by Trait (GT) biplot is an effective tool for revealing the interrelationships among the traits. Also, it can be used in independent culling based on multiple traits and in comparing selection strategies (Alvi et al., 2003).

The associations between 23 characters among the 20 genotypes were visualized by the biplot analysis. Biplot analysis revealed the trait profiles of the genotypes, primarily, those genotypes positioned far away from the origin, and the results indicated a correlation between traits with genotypes. In PC1 and PC2, together differences among individual pod weight, 100-seed weight, raceme per plant, and pods per plant are well represented in the biplot, but leaflet length and pod yield per plant have minimum differences between PC1 and PC2 biplot (Fig. 6). These variations are sources of varietal improvement in the respective quantitative trait, which contribute toward better agronomic performance and increase in yield potential.

In PC1 and PC2 biplot graph, it was indicated that pod yield per plant had a strong positive correlation with days to 1st germination (DFG), days to 50% germination (DPG), days to 100% germination (DHG), germination percentage (GPP), internode length in cm (ILT), number of seeds per fruits (SPF), 100-seed weight in g (HSW) and yield per hectare in Kg (YPH). Whereas yield per plant (g) has a strong negative correlation with days to 1st flowering, days to 50% flowering, plant height (cm) at 1st flowering, plant height (cm) at 1st fruit harvest, first flower bearing node, first fruit bearing node, days to edible fruit maturity, primary branches (no.), leaves per plant (no.), fruit per plant, fruit length (cm) at edible stage, fruit length (cm) at mature stage, fruit girth (mm) and individual green pod weight (g) (Fig.

6). A principal component scatters plot of okra genotypes depicts the similarity among the performance of the genotypes in respect of 23 variables. In contrast, genotypes that are further apart from one another are different. Genotypes that are nearer to variable vectors are more significant for that trait and vice versa. Therefore, a scatter plot helped to select genotypes for the yield contributing trait or for the trait that helped in better agronomic performance. In PC1 and PC2 biplot it is indicated that genotypes G4 is suitable for yield per plant, yield per hectare and internode length; genotype G15 can be selected based on seeds per fruits and hundred seed weight; G8, G12, G14 and G20 are suitable for days to 1st flowering, days to 50% flowering, plant height (cm) at 1st flowering, plant height (cm) at 1st fruit harvest, first flower bearing node, first fruit bearing node. The genotypes G1, G3, G9, G10 and G16 were further from any trait vector indicated that they are not suitable for any traits (Fig. 6).

As PC1 and PC3 were imposed in the biplot, differences among internode length in cm (ILT), number of seeds per fruits (SPF), 100-seed weight in g (HSW) and yield per plant (YPP), and yield per hectare (kg) are well represented, but days to first germination, days to fifty percent germination, days to hundred percent germination and germination percentage have maximum differences between PC1 and PC3 biplot (Fig. 7). On the other hand, days to 50% flowering, plant height (cm) at 1st fruit harvest, first fruit bearing node, days to edible fruit maturity, primary branches (no.), leaves per plant (no.), fruits per plant, fruit length (cm) at edible stage, fruit girth (mm) and individual green fruit weight (g) had minimum differences between PC1 and PC3 biplot.

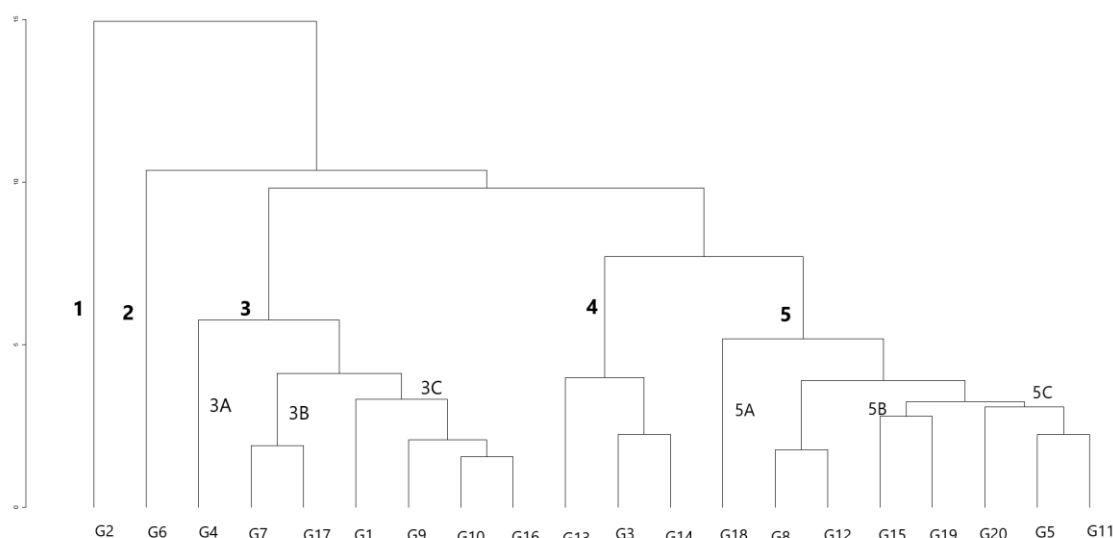
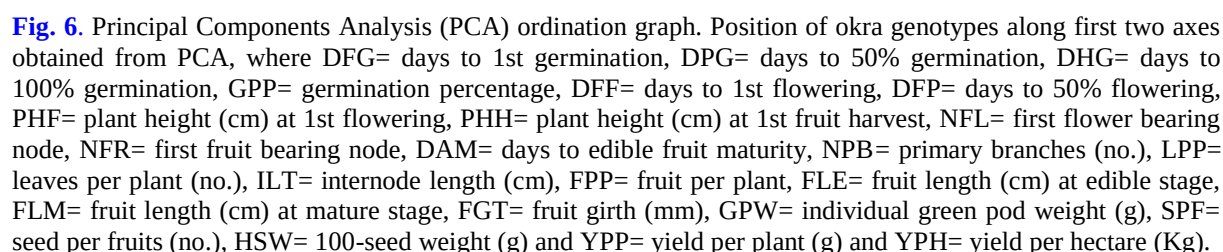


Fig. 5. Tree diagram of 20 genotypes of okra based on 23 yield contributing traits [G1= Greenstar, G 2= Iron 40, G3= Baromasi, G4= F1-hybrid, G5= SB11, G6= Pretom, G7= Moonmoon, G8= Orka Anamika, G9= G.Hossain, G10= Comola, G11= Apurbo, G12= Titanic, G13= Champion, G14= Victory, G15= Pride, G16= Ok-630, G17= Ok-628, G18= Luky -7, G19= Green Finger, G20= Silva].



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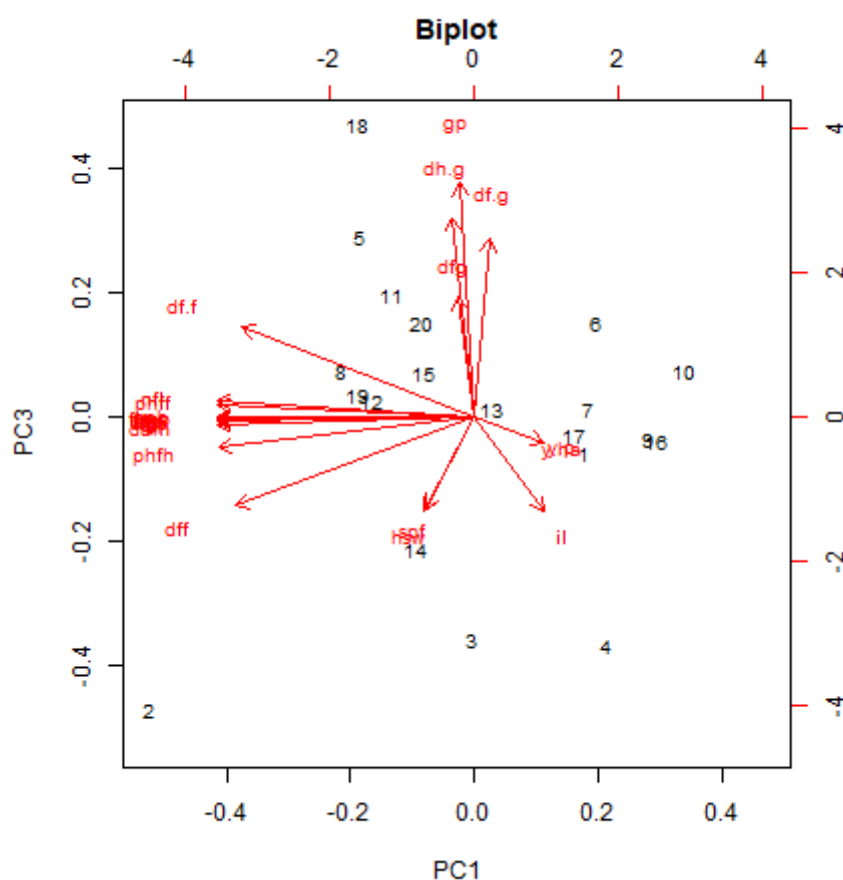


Fig. 7. Principal Components Analysis (PCA) ordination graph. Position of okra advance genotypes from the selected germplasm pools along first and third axes obtained from PCA where DFG= days to 1st germination, DPG= days to 50% germination, DHG= days to 100% germination, GPP= germination percentage, DFF= days to 1st flowering, DFP= days to 50% flowering, PHF= plant height (cm) at 1st flowering, PHH= plant height (cm) at 1st fruit harvest, NFL= first flower bearing node, NFR= first fruit bearing node, DAM= days to edible fruit maturity, NPB= primary branches (no.), LPP= leaves per plant (no.), ILT= internode length (cm), FPP= fruit per plant, FLE= fruit length (cm) at edible stage, FLM= fruit length (cm) at mature stage, FGT= fruit girth (mm), GPW= individual green pod weight (g), SPF= seed per fruits (no.), HSW= 100-seed weight (g) and YPP= yield per plant (g) and YPH= yield per hectare (Kg).

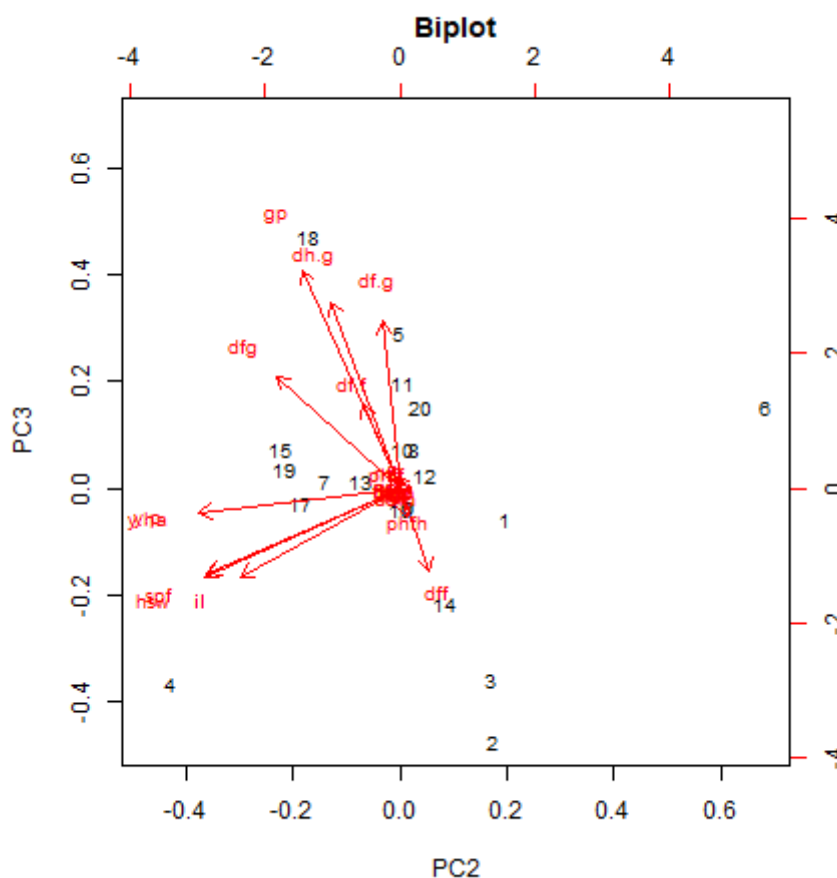


Fig. 8. Principal Components Analysis (PCA) ordination graph. Position of okra advance genotypes from the selected germplasm pools along second and third axes obtained from PCA where DFG= days to 1st germination, DPG= days to 50% germination, DHG= days to 100% germination, GPP= germination percentage, DFF= days to 1st flowering, DFP= days to 50% flowering, PHF= plant height (cm) at 1st flowering, PHH= plant height (cm) at 1st fruit harvest, NFL= first flower bearing node, NFR= first fruit bearing node, DAM= days to edible fruit maturity, NPB= primary branches (no.), LPP= leaves per plant (no.), ILT= internode length (cm), FPP= fruit per plant, FLE= fruit length (cm) at edible stage, FLM= fruit length (cm) at mature stage, FGT= fruit girth (mm), GPW= individual green pod weight (g), SPF= seed per fruits (no.), HSW= 100-seed weight (g) and YPP= yield per plant (g) and YPH= yield per hectare (Kg).

CONCLUSION

The genotype G₁₀ (Comola) showed earliness in flowering followed by G₄ (F₁-hybrid) and G₉ (G. Hossain). The tallest plant was produced by the genotype G₉ (G. Hossain). The genotype G₄ (F₁-hybrid) produced highest number of fruits per plant followed by G₇ (Moonmoon) and G₁₈. Maximum length was observed in the genotypes G₇ (Moonmoon) and maximum diameter was observed in G₁₇ (Ok-628). The heaviest fruits were produced by G₁₉ (Green Finger) followed by G₁₇ (Ok-628). The highest 100-seed weight was recorded in the genotypes G₄ (F₁-hybrid) followed by G₁₇ (Ok-628). The maximum yield of green fruits per plant and maximum yield (kg/m²) was obtained in the genotype G₄ (F₁-hybrid) followed by the genotypes G₁₇ (Ok-628), G₇ (Moonmoon), G₁₉ (Green Finger) and G₁₈. G₁₉ (Green Finger) showed slow increase of YVMV incidence. The cluster analysis grouped 20 genotypes into

five cluster. Cluster 5 consists with maximum number of genotypes and are again subdivided in to four subgroups. Cluster 1 and 2 consists of only one genotype, G2 and G6, respectively signifying their divergence from other genotypes of the experimental population. Biplot analysis revealed that yield per plant had a strong positive correlation with days to 50% germination (DPG), germination percentage (GPP), internode length in cm (ILT), number of seeds per fruits (SPF), 100-seed weight in g (HSW) and yield per hectare in Kg (YPH).

Acknowledgements

The present project work is financed by the Research Management Wing (RMW) of Bangabandhu Sheikh Mujibur Rahman Agricultural University. The authors would like to acknowledge their gratitude towards university authority for financial support.

Conflict of interest

The authors declare that there is no conflict of interest.

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