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Evaluation of best quality okra parental lines based on morpho-physiological and nutritional attributes

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Abstract

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The study was conducted to investigate the best quality parental line selection of okra (*Abelmoschus esculentus*) varieties based on morpho-physiological and nutritional attributes. Significant variations were observed for the measured morpho-physiological and nutritional attributes among those varieties. Among the major traits; highest fresh and dry weight of fruit was recorded in variety 3 (Ok1-MKB1) and 7 (Ok7-GGS). Days to 50% flowering and days to mature fruit harvest showed that varieties 2 (Ok2-0366) and 4 (Ok4-LG) were the earliest. Variety 4 possessed the highest level of P while variety 6 (Ok6-ABM) of okra fruits contained the highest concentration of K. Zinc content was the highest in variety 4 and the lowest was in variety 1. Next, Variety 7 had the highest concentration of Mg and the lowest was in variety 6. Variety 5 (Ok5-SS103) contained the highest concentration of Fe while variety 3 had the lowest. Lastly, variety 3 possessed the highest content of Ca while the lowest was in variety 1, respectively. Pearson's correlation analysis revealed the strongest correlation ($P \leq 0.001$) in between days to 50% flowering and days to harvest, while fruit fresh weight and fruit dry weight as well. Cluster analysis grouped those 7 okra varieties into five different clusters; where V2, V3 and V6 were solely different from others, indicating the highest diversity compared to other accessions. So, for varietal improvement program, the most judicious crossing combination can be made with V2, V3 and V6 with V1 or V5 and V4 or V7, which would bring about the greater genetic diversity.

Keywords: Parental line; improved variety; nutritional quality; crossing; breeding; pollination

Introduction

Okra (*Abelmoschus esculentus*) is an economically essential vegetable crop grown in tropical to sub-tropical and is sensitive to frost; low temperature, water logging and drought conditions and the cultivars from different countries have certain adapted distinguishing specific characteristics. It belongs to Malvaceae family. Okra is also known by many local names in different parts of the world such as bhindi in India and Malaysia, lady's finger in England, gumbo in USA, guino-gombo in Spanish and guibeiro in Portuguese (Benchasr, 2012).

In India, okra is quite popular because of easy cultivation, dependable yield and adaptability to varying moisture conditions. This crop has various uses from the root, stem, fruit and seed. The roots and stem of okra are used for clarification of sugarcane juice from which brown sugar is prepared (Singh et al., 2018). The mature seeds are good source of oil and protein (Petropoulos et al., 2017) and also known to have superior nutritional quality. Okra seed oil is rich in unsaturated fatty acids such as linoleic acid, essential for human nutrition. Mature fruits and stems contain crude fiber, which is used in the paper industry. Okra provides an important source of vitamins, calcium, potassium and other mineral matters which are often lacking in the diet in developing countries (IBPGR, 1991).

According to Santos et al. (2019), in addition to yield, fruit quality plays an important role in okra productivity and marketability. Criteria defining fruit quality are not completely clear except for the characteristics of pod length, which is indicated by the United States Department of Agriculture (USDA, 2019; Santos et al., 2019). Several desirable quality characteristics of okra fruit are length, diameter, greenness, mucilage and fiber content.

The genetic improvement of crops involves hybridization among different varieties resulting significant morpho-physiological and nutritional changes. Natural hybridization is recognized as an important evolutionary process in plants, animals and fungi (Whitney et al., 2010). Hybridization is the process of crossing two or more plants together to get offspring's of new desirable characteristics as a result of genetic recombination. To go for any desirable hybridization or breeding activities the first and foremost job is to select better parental lines. In this point of view, this study was conducted to evaluate and to select better parental combinations among 7 different varieties of okra based on morpho-physiological and nutritional attributes.

Materials and Methods

Collection of okra seeds and experimental design

Seven (7) different varieties of open pollinated (OP) okra (*Abelmoschus esculentus*) seeds were collected from different locations of Malaysia (Table 1) and preserved in chiller until further use for experimental purpose. The experiment was designed in randomized complete block design (RCBD) with 4 replications.

Table 1. Detailed information of the collected seeds samples of okra

Acc. No.	Variety/local name	Variety code	Location of collection
1	BENDI MKBe 1 Okra	Ok1-MKB1	Mardi, Selangor
2	Okra 0366	Ok2-0366	Nursery, Selangor
3	Okra Serbajadi	Ok3-SBD	Nursery, Selangor
4	Okra Long Green	Ok4-LG	Ipoh, Perak
5	Okra-Seven Star 103, Green World Genetics	Ok5-SS103	Kepong, Kuala Lumpur
6	Bendi Alabama	Ok6-ABM	Sabah
7	Bendi Gergasi	Ok7-GGS	Sabah

Seedling preparation

All seeds were soaked for overnight to break the dormancy and boost up germination. On the next day, the seeds were sown in the tray filled with peatmoss. The tray was put under the shaded area to reduce direct sunlight. The purpose of the peatmoss is to give the good aeration to plant roots in heavier soil after transplanting. It also can absorb and retain moisture and reduce leaching of nutrients in the soil.

Growing of okra plants

Twelve days after sowing (DAS), the seedlings were transplanted into polybags (16 cm x 18 cm) filled with prepared soils (topsoil : compost : sand = 3:2:1) at the farm field of Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin (UniSZA), Besut Campus, Terengganu. Five days after transplanting, 5 g of NPK 15:15:15 compound fertilizer was applied to every polybag and incorporated well with soils. Then, 10 g of NPK 15:15:15 was applied again to the seedlings on the next two weeks. High K fertilizer was also applied during flowering stages (33-45 DAS). Watering was applied to every plant every day at afternoon time. All types of weeds were controlled manually removing by hands while for disease and insect control recommended pesticides were applied.

Determination of morphological attributes

Plant height, days to 50% flowering, numbers of leaves, fruit length, fruit diameter, fruit fresh weight, fruit dry weight and days to mature fruit harvest.

The Okra plant height was measured from the soil surface to the longest shoot emerged from the whorl by straighten the plant to its fullest length and was measured by using measuring tape. Fruit length and fruit diameter were measured by using thread and ruler in centimeter (cm) unit.

Days to 50% flowering were determined when two replicates of plant shown 50% of blooming completed. The fresh weight of okra fruit was determined by using the electronic weighing scale. For dry weight, the fruits were sliced and placed in the oven at 70°C for 72 hours. Oven-dried samples of okra fruits were ground and stored in plastic vials until analysis.

Determination of physiological parameters

Chlorophyll content and stomatal conductance

The total chlorophyll content was measured by using SPAD chlorophyll meter. The measurement was taken by inserting a leaf sample and closing the measuring head. Three reading were taken on different part of leaves per plant for calculating the average. Stomatal conductance is the rate at which either water vapor or carbon dioxide passes through the stomata, which are the small pores of a plant. It was determined by using leaf porometer (Decagon SC-1, USA).

Determination of major micro-macro nutrients

The compositions of micro and macro nutrient contents were determined by using Kjedahl method for Nitrogen (N); where Phosphorus (P), Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Ferum (Fe), Zinc (Zn) and Manganese (Mn) were determined by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES Analysis).

The Kjeldahl method can conveniently be divided into three steps which are digestion, neutralization and titration. It was digested with a strong acid and so that it releases nitrogen which can be determined by a suitable titration technique.

The concentration of mineral elements (Phosphorus, Potassium, Sodium, Magnesium, Calcium, Ferum, Zinc and Manganese) in okra fruits were calculated using the following formula:

$$C = (A X B) / B$$

where C = Concentration of test samples (mg);
A = Reading from ICP (mg)
B = Volume of final solution (L); M = weight of sample (mg).

Multivariate analysis

A cluster analysis was performed to construct a dendrogram based on the similarity matrix data using the unweighted pair group method with arithmetic averages (UPGMA) and the *SHAN* clustering program. All of the analyses were performed with the *NTSYS-pc 2.10* software (Rohlf, 2002). The binary data were also subjected to a PCA (Principal Component Analysis) to investigate the structure of our collection. The PCA of the 7 okra varieties were calculated using the EIGEN module of *NTSYS-pc 2.10* software (Rohlf, 2002).

Statistical analysis

Recorded data were analyzed by using one-way ANOVA test of SPSS version 17.0 and a difference of mean among varieties were determined by Least Significance Difference (LSD). Differences at $P<0.05$ was considered as significant. Pearson's correlation coefficient analyses were also done to assess the associations between different parameters.

Results and Discussion

Morphological and physiological attributes

According to the findings presented in Table 2, the plant height of varieties V3 (Ok3-SBD – Okra Serbajadi) and V6 (Ok6-ABM – Bendi Alabama) were statistically similar and non-significant variation ($p \geq 0.05$) was observed among them, while a highly significant ($p \leq 0.05$) variation was observed for other varieties. Factor levels within a group were not significantly different from each other. Among the 7 varieties, the longest plant height was recorded for V1 (BENDI MKBe 1; 1.84 m) and the shortest was recorded in V2 (Okra 0366; 1.01 m), respectively compared to other varieties. Plant height of okra was determined during 76 days after sowing. Based on growth and development of okra, its stem is robust, erect, variable in branching and varying 0.5 to 4.0 meters in height (Tripathi et al., 2011). Thus, the plant height measured in this study was in the range stated in various other findings (Moyin-Jesu & Ojeniyi, 2006; Tripathi et al., 2011).

From the study output (Table 2), it is also observed that, for 50% flowering and mature fruits harvest varieties V2 – Okra 0366 (34 and 73 DAS) and V4 – Okra Long Green (34 and 73 DAS) were the earliest varieties compared to others, while variety V7 – Bendi Gergasi (43 and 82 DAS) was very late both in days to 50% flowering and mature fruit harvest, respectively. The flowering and the fruit harvesting stages are directly depends on weather conditions. Heavy raining and drought badly affects the growth and maturity of any vegetable crop. Early days to flowering and fruit harvest-

Table 2. Morpho-physiological and yield contributing attributes of different okra varieties

Variety	Plant height, cm	Days to 50% flowering	Avg. No. of leaves	Fruit length, cm	Fruit diameter, mm	Days to harvest	Fruit fresh wt., g	Fruit dry wt., g	RWC, %	Stomatal Conduct.	Chlorophyll content
V1	183.88a	38 DAS	18.25b	22.65c	7.88c	77 DAS	36.53d	5.38b	85.54c	577.5b	18.48c
V2	100.63e	34 DAS	17.5b	19.4b	8.63c	73 DAS	38.50d	5.18c	86.77b	492.1e	24.65b
V3	107.13d	35 DAS	21.75a	23.15a	8.43c	74 DAS	44.05c	6.05a	86.16b	643.85a	20.65c
V4	136.7b	34 DAS	12.75c	18.50b	8.33c	73 DAS	34.33d	5.28b	84.33c	564.45b	36.83a
V5	118.6c	36 DAS	21.75a	24.68a	8.68c	75 DAS	51.53b	5.25b	89.77a	579.15b	14.68d
V6	104.98d	42 DAS	12.75c	12.55c	13.0a	81 DAS	43.63c	5.28b	88.12a	524.75d	20.75c
V7	140.5b	43 DAS	16.75b	24.68a	10.05b	82 DAS	57.70a	5.93a	89.94a	553.08c	23.93b

Note: mean value with different lower case letters are significantly different at $p \leq 0.05$

ing is an important and desirable characteristics for any crop varieties and a better criteria to be safe from environmental impact (Tuomisto et al., 2017).

Based on the results in Table 2; it was found that varieties V4 (Ok4-LG – okra long green) and V6 (Ok6-ABM – Bendi Alabama) were non-significantly different for mean numbers of leaves and they produced the lowest numbers of leaves (13) compared to other varieties, while varieties V3 (Ok3-SBD – Okra Serbajadi) and V5 (Ok5-SS103 – Seven Star 103) were also varied non-significantly, but they produced the highest numbers of leaves (22) compared to others (Table 2). On the other hand, V1 (BENDI MKBe 1), V2 (Okra 0366), and V7 (Bendi Gergasi) showed highly significant variations ($p \leq 0.05$) with V3 or V5 and V4 or V6, but there was non-significant variations among them independently (Table 2). Numbers of leaves were also determined 76 days after sowing and was counted after removing some branches that was affected by diseases and insects. Falusi et al. (2012) conducted an experiment with 3 different varieties of okra and reported that average number of leaves at the time of maturity were 12.40. In our study the result is higher than the reported result because of different genotypes. On the contrary, in another study average higher numbers of leaves (29.25) over our findings were stated by Biswas et al. (2016); it might be due to different genotypes.

From the findings presented in Table 2, very interestingly the fruit lengths of varieties V1 (BENDI MKBe 1), V3 (Okra Serbajadi), V5 (Okra-Seven Star 103) and V7 (Bendi Gergasi) were differed non-significantly and they were statistically same. But among those 4 varieties the fruit length of V5 and V7 were the highest (24.68 cm) compared to other varieties (Table 2). Furthermore, the fruit lengths of V2 and V4 were also found statistically same but differed significantly ($p \leq 0.05$) with V1 or V3 or V5 or V7 and with V6, respectively. On the other hand, the fruit length of V6 was the lowest (12.55 cm) compared to all other varieties and showed a very high significant variation with others (Table 2). Very interestingly closely similar fruit lengths (min.11.49 cm to max.14.88 cm) of ten different varieties okra has been reported by Aminu et al. (2016), while in this study the longest fruit length (24.68 cm) is almost double over the shortest fruit length (12.55 cm), which is a proof of higher variability among those genotypes. Furthermore, very short lengths (5.38 cm to 8.43 cm) of fruits are reported by Falusi et al. (2012) in their study conducted with 3 different varieties of okra.

Results in Table 2 represented the mean of fruit diameter of 7 varieties of okra. From the analysis results, non-significant ($p \geq 0.05$) variation was observed for majority of the varieties (V1, V2, V3, V4 and V5) for the fruits diameter of okra varieties (Table 2), among which the lowest fruit diameter was recorded in variety V1 (7.88 mm). On the contrary, fruits of variety V6 achieved the maximum fruit diameter (13.0 mm) compared to all other varieties which was statistically significant ($p \leq 0.05$) with variety V7 and others too (Table 2). The variations of fruit diameters among different varieties are very narrow and most of the cases it is less than 2.00 cm. In an experiment conducted with 10 different varieties of okra by Aminu et al. (2016) where they reported the range of fruits diameter was 1.22 cm to 1.84 cm, while Falusi et al. (2012) stated a very narrow fruit diameters; even less than 0.60 cm (4.95 mm to 5.15 mm) which is also narrower than the lowest diameter fruits in our findings.

From the analysis results it was revealed that, among all the seven varieties of okra, fruits of variety V7 produced the highest fresh weight (57.7 g) and the variety V4 produced the lowest amount of fruit fresh weight (34.33 g), respectively. On the other hand, for the overall fruit fresh weight significant ($p \leq 0.05$) variations were observed among all those 7 varieties of okra (Table 2). The variability among fresh fruit weight of okra fruits are also cultivars dependent. The fresh fruits weight in our study were more higher compared to the finding of Aminu et al. (2016; 13.14 g to 16.84 g) and Biswas et al. (2016; 12.31g to 15.84 g), respectively.

From the analysis results (Table 2) revealed that variety V4 and V5 did not show any significant difference with each other for fruit dry weight. Fruit dry weight of variety 3 was significantly higher (6.05g) compared to all others. On the contrary, fruit dry weight of variety 2 was the lowest (5.18 g) compared to all other varieties. Dry weight was taken after oven drying of harvested fruits at 70°C temperature for 72 hours. After that the dry weight of completely dried okra fruits were measured using electronic weighing scale. Though significant variation was observed for fruit dry weight between V3 and V2 but the variation was very narrow and the variation of the highest to the lowest was less than one gram. Meaning is that okra fruits were not so fatty and watery and most of the fruits were medium narrow to long narrow types and intact, rather than flappy except variety V6, which had the highest diameter compared to others.

The study output (Table 2) showed the mean percentage of relative moisture content of okra fruit. Highly significant variation was revealed among 7 different okra varieties for percentages of moisture contents (Table 2). Among those 7 varieties the fruits of variety V7 contain the highest amount of moistures (89.94%) and the lowest percentage of moisture (84.33%) was recorded in the fruits of variety V4, respectively (Table 2). The fruits that contains more moistures are fatty is shapes and individual fruit weight is also higher than others. The similar types of relative water content in okra was also reported by Bahadur et al. (2009) in their experiment with different aspect of irrigation and mulching effect.

Significant variation was also observed for stomatal conductance of okra leaves among all those 7 varieties. The highest stomatal conductance was recorded in the leaves of okra variety V3 (643.85 mmol/m^{2-s}) and the lowest stomatal conductance was recorded in leaves of the variety V2 (492.1 mmol/m^{2-s}), respectively (Table 2). Stomatal conductance of okra leaves of all other varieties also showed significant variations among each other (Table 2). Comparatively similar results were also described by Hasan (2015); who conducted an experiment with 16 different types of okra varieties, the ranges of stomatal conductance were 310.0 mmol/m^{2-s} to 640.0 mmol/m^{2-s}.

Based on the results presented in Table 2, okra leaves of variety V4 contains the highest total amount of chlorophyll content (36.83 mmol m^{-2}), while leaves of variety V5 contains the lowest amount (14.68 mmol m^{-2}), respectively. On the contrary, there was statistically non-significant ($p \geq 0.05$) variation observed among the leaves of varieties V1, V3 and V6 for total chlorophyll contents (Table 2). Furthermore, the leaf chlorophyll contents of variety V2 and V7 also showed non-significant variations among them (Table 2). Green vegetables contain valuable chlorophyll. Chlorophyllin as an important component of chlorophyll was reported for enormous health benefits (Ebermann et al., 2006).

Major macro-micro mineral elements among different varieties of okra

Based on findings showed in Table 3; okra fruits of variety V4 contains the highest amount of nitrogen (2.29%), while fruits of variety V1 contained the lowest amount of nitrogen (1.58%), respectively. But statistically non-significant ($p \geq 0.05$) variation was observed among fruits of the variety V2, V3 and V7, while significant ($p \geq 0.05$) variations were recorded among variety V1, V4 and V5 for nitrogen content (Table 3). N is essential for plants and animals to survive. It is one of the building blocks of life. It is used to make amino acids in our body which in turn make proteins. It is also needed to make nucleic acids, which form DNA and RNA (Aczel, 2019).

Significant variation was also observed for concentration of phosphorus (P) of okra fruits among all those varieties except variety V3 and V7 and also in-between V1 and V5. The highest concentration of phosphorus was recorded in the fruits of okra variety V4 (95.42 mg/100 g) and the lowest concentration of phosphorus was recorded in okra fruits of variety V2 (36.23 mg/100 g), respectively (Table 3). This finding is comparable with a study conducted by Gemede et al. (2016), who reported P content ranges from 25.62 mg/100 g DW to 59.72 mg/100 g DW, from an experiment with 8 different types of okra varieties in Ethiopia. The average P content in okra is about 90 mg/100 g DW is also stated by Gemede et al. (2015) in their review article, which is also very similar amount to the okra varieties V4 (95.42 mg/100 g DW) and V6 (85.61 mg/100 g DW) in this experiment, respectively (Table 3).

For the concentration of potassium (K) in okra fruits showed that, variety V6 had the highest concentration (415.17 mg/100 g) while the lowest concentration of potassium was recorded in variety V5 (262.28 mg/100 g), respectively. On the contrary, statistically non-significant ($p \geq 0.05$) variation was observed in between varieties V3 and V4 but varieties V1, V2 and V7 showed significant ($p \geq 0.05$) variations among each other (Table 3). A group of Scientist from Ethiopia, Gemede et al. (2016) reported K content ranges from 122.59 mg/100 g DW to 318.20 mg/100 g DW, in their experiment conducted with 8 different types of okra varieties. But in our study most of the okra fruits possessed surplus amount of K contents compared to their study (Table 3).

From the analysis results significant variations were also observed for zinc (Zn) concentration among those 7 okra varieties. Variety 7 had the highest (4.55 mg/100 g) concentration of Zn and the lowest (2.15 mg/100 g) was recorded in variety 1 (Table 3). Furthermore; Zn concentrations in V2 and V3 differed non-significantly, the same was also observed in between V4 and V6, respectively (Table 3). Gemede at al. (2016) reported additional contents of Zn in their experiment of about 8 different types of okra compared to our findings.

Based on the results presented in Table 3, concentration of sodium (Na) in variety V1 contained the highest concen-

Table 3. Major micro and macro elements (mg/100 g DW) determined from 7 varieties of okra fruits

Variety	N, %	P, mg	K, mg	Zn, mg	Na, mg	Mg, mg	Fe, mg	Ca, mg
V1	1.58d	47.11d	271.31e	2.15e	5.04a	36.1bc	43.2ab	228.11e
V2	1.9c	36.23e	292.13d	2.93c	4.89b	37.8bc	38.3c	229.92e
V3	1.85c	54.31c	331.55c	3.16c	4.91b	15.9d	28.2d	391.22a
V4	2.29a	95.42a	331.23c	4.31b	4.87b	43.6b	41.1b	315.33c
V5	2.04b	43.37d	262.28e	2.87d	4.84b	46.9ab	47.7a	278.13d
V6	1.80c	85.61b	415.17a	4.18b	4.81b	26.5c	40.9b	265.19d
V7	1.94c	61.77c	391.67b	4.55a	4.64c	51.1a	44.4ab	357.74b

Note: mean value with different lower case letters are significantly different at $p \leq 0.05$

Table 4. Pearson's correlation coefficients among different morpho-physiological and major minerals nutrient attributes

Factors	ph	d5f	nl	fl	fd	dh	ffw	fdw	rwc	stc	tcc	N	P	K	Zn	Na	Mg	Fe	Ca
ph	1.0																		
d5f	0.19^{ns}	1.0																	
nl	-0.04^{ns}	-0.31^{ns}	1.0																
fl	0.36^{ns}	-0.14^{ns}	0.77*	1.0															
fd	-0.39^{ns}	0.73^{ns}	-0.53^{ns}	-0.68^{ns}	1.0														
dh	0.19^{ns}	1.0**	-0.31^{ns}	-0.14^{ns}	0.73^{ns}	1.0													
ffw	-0.17^{ns}	0.59^{ns}	0.34^{ns}	0.46^{ns}	0.31^{ns}	0.59^{ns}	1.0												
fdw	0.02^{ns}	0.28^{ns}	0.37^{ns}	0.49^{ns}	-0.06^{ns}	0.28^{ns}	0.49**	1.0											
rwc	-0.25^{ns}	0.60^{ns}	0.26^{ns}	0.26^{ns}	0,45^{ns}	0.60^{ns}	0.92*	0.16^{ns}	1.0										
stc	0.20^{ns}	-0.19^{ns}	0.57^{ns}	0.52^{ns}	-0.40^{ns}	-0.19^{ns}	0.11^{ns}	0.64^{ns}	-0.17^{ns}	1.0									
tcc	0.01^{ns}	-0.27^{ns}	-0.67^{ns}	-0.32^{ns}	-0.11^{ns}	-0.27^{ns}	-0.45^{ns}	-0.09^{ns}	-0.57^{ns}	-0.21^{ns}	1.0								
N	-0.31^{ns}	-0.34^{ns}	-0.26^{ns}	-0.01^{ns}	-0.13^{ns}	-0.37^{ns}	0.03^{ns}	-0.15^{ns}	-0.06^{ns}	-0.04^{ns}	0.66^{ns}	1.0							
P	-0.01^{ns}	0.24^{ns}	-0.80*	-0.61^{ns}	0.47^{ns}	0.24^{ns}	-0.20^{ns}	-0.05^{ns}	-0.28^{ns}	-0.03^{ns}	0.65^{ns}	0.46^{ns}	1.0						
K	-0.27^{ns}	0.70^{ns}	-0.60^{ns}	-0.51^{ns}	0.82*	0.70^{ns}	0.32^{ns}	0.35^{ns}	0.24^{ns}	-0.18^{ns}	0.26^{ns}	0.05^{ns}	0.66^{ns}	1.0					
Zn	-0.27^{ns}	0.45^{ns}	-0.65^{ns}	-0.35^{ns}	0.58^{ns}	0.45^{ns}	0.32^{ns}	0.22^{ns}	0.21^{ns}	-0.20^{ns}	0.58^{ns}	0.56^{ns}	0.75*	0.84*	1.0				
Na	0.32^{ns}	-0.59^{ns}	0.23^{ns}	-0.04^{ns}	-0.52^{ns}	-0.58^{ns}	-0.78*	0.33^{ns}	-0.71^{ns}	0.24^{ns}	-0.13^{ns}	-0.39^{ns}	-0.27^{ns}	-0.67^{ns}	-0.8*	1.0			
Mg	0.35^{ns}	0.15^{ns}	-0.15^{ns}	0.35^{ns}	-0.16^{ns}	0.15^{ns}	0.34^{ns}	-0.28^{ns}	0.38^{ns}	-0.39^{ns}	0.19^{ns}	0.43^{ns}	-0.04^{ns}	-0.16^{ns}	0.22^{ns}	-0.44^{ns}	1.0		
Fe	0.41^{ns}	0.36^{ns}	-0.19^{ns}	0.11^{ns}	0.12^{ns}	0.36^{ns}	0.29^{ns}	-0.51^{ns}	0.47^{ns}	-0.42^{ns}	-0.14^{ns}	0.14^{ns}	0.01^{ns}	-0.14^{ns}	0.06^{ns}	-0.27^{ns}	0.84*	1.0	
Ca	-0.17^{ns}	0.08^{ns}	0.21^{ns}	0.35^{ns}	-0.03^{ns}	0.08^{ns}	0.45^{ns}	0.86*	0.10^{ns}	0.65^{ns}	0.19^{ns}	0.37^{ns}	0.27^{ns}	0.41^{ns}	0.49^{ns}	-0.46^{ns}	-0.19^{ns}	-0.47^{ns}	1.0

Note: ns-Non-significant; *, ** Significance at 5 and 1 % levels; ph-Plant height; d5f-Days to 50% flowering; nl-Numbers of leaves; fl-fruit length; fd-fruit diameter; dh-days to harvest; ffw-fruit fresh weight; fdw-fruit dry weight; rwc-relative water content; stc-stomatal conductance; tcc-total chlorophyll content; N-Nitrogen; P-Phosphorus; K-Potassium; Zn-Zinc; Na-Sodium; Mg-Magnesium, Fe-Iron and Ca-Calcium, respectively tration (5.04 mg) and variety V7 possessed the lowest concentration (4.64 mg), respectively (Table 3). On the contrary, there was statistically insignificant ($p \geq 0.05$) variation observed among variety V2, V3, V4, V5 and V6. On an average this finding is comparable with a study conducted by Gemede et al. (2016), who reported Na content ranges from 3.33 mg/100 g DW to 8.31 mg/100 g DW, from an experiment with 8 different types of okra varieties in Ethiopia.

From the analysis output (Table 3); data shown that the concentration of magnesium (Mg) had the highest in V7 (51.1 mg) while variety V3 had the lowest concentration (15.9 mg), respectively. Okra variety V1, V2 and V6 showed statistically similar results for Mg contents, the same was also observed for V4 and V5, respectively (Table 3). The similar amount of Mg content in raw and cooked okra (45.3 to 18.3 mg/100 g) has also been reported by dos Santos et al. (2013) from 15 different varieties of okra in Brazil.

Among those 7 okra varieties the variety V5 contained the highest concentration of iron (47.7 mg) while variety V3 contains lowest concentration of ferum (28.2 mg). On the other hand, statistically non-significant ($p \geq 0.05$) variations were observed among varieties V1, V4, V6 and V7 for the concentration of Fe. Furthermore, varieties V2, V4 and V5 showed significant ($p \geq 0.05$) variations among each other (Table 3). The Iron content in this experiment was higher than the report published by Gemede et al. (2016), who conducted an experiment with 8 different types of okra in Ethiopia. On the other hand Gemede et al. (2015) stated a very minimum content of Fe (1.20 mg/100 g DW) as an average amount.

Lastly, for the concentration of calcium (Ca) in okra fruits; variety V3 had the highest concentration (391.22 mg) while the lowest concentration of calcium was in variety V1 (228.11 mg), respectively (Table 3). On the contrary, V1 or V2 and V5 or V6 were statistically non-significant ($p \geq 0.05$) for the concentration of calcium. Furthermore, varieties V1, V3, V4, V6 and V7 showed significant ($p \geq 0.05$) variations among each other (Table 3). Closely similar amount of Ca content in raw and cooked okra (366 to 325 mg/100 g) has also been reported by dos Santos et al. (2013) from 15 different varieties of okra in Brazil. On the contrary, Gemede et al. (2015) reported a very lower average amount of Ca content (84 mg/100g DW) in okra. Furthermore, Gemede et al. (2016), conducted an experiment with 8 different varieties of okra in Ethiopia where they recorded lower amount of Ca (140.88 to 311.35 g/100 g DW) compared to the findings of this study.

Correlation matrix

The correlation matrixes for 19 different morpho-physiological and mineral nutritional attributes in 7 different okra varieties are presented in Table 4. Days to 50% flowering had a strong positive correlation ($P \leq 0.001$) with days to harvest, while number of leaves had significant ($P \leq 0.05$) correlation with fruit length but had negatively significant ($P \leq 0.05$) correlation with P content. On the other hand, fruit diameter had significant correlation ($P \leq 0.05$) with K content. Furthermore, very strong correlation ($P \leq 0.001$) was observed in between fruit fresh weight and fruit dry weight. Fruit fresh weight had positive significant correlation ($P \leq 0.05$) with relative water content but had negatively significant correlation ($P \leq 0.05$) with Na content. A positive significant correlation ($P \leq 0.05$) was observed in between fruit dry weight and Ca content, while P and K was significantly correlated ($P \leq 0.05$) with Zn content. Moreover, negatively significant correlation ($P \leq 0.05$) was seen in between Zn and Na content, while Mg was positively correlated ($P \leq 0.05$) with Fe content (Table 4).

Cluster analysis

To assess the patterns of variation, a UPGMA cluster analysis were performed using the measured parameters. All 7 different varieties of okra were primarily grouped into two vital groups and secondly clustered into 3 groups at 1.0 similarity coefficient level and thirdly assembled into 5 different groups at 0.7 similarity coefficient level (Figure 1). In the primary two vital groups; V1, V2 and V5 is clustered into first group (A), whereas V3, V4, V6 and V7 in another groups (B). In the secondary grouping; V1, V2 and V5 formed the 1st cluster (1), V3 itself formed the 2nd cluster (2) and V4, V6 and V7 formed the 3rd clusters (3). Finally in the 3rd grouping pattern; V1 and V5 formed the 1st cluster (I); V2 itself formed the 2nd clusters (II); V3 itself formed the 3rd clusters (III); V4 and V7 formed the 4th clusters (IV) and V6 itself formed the last 5th clusters (V), respectively (Figure 1).

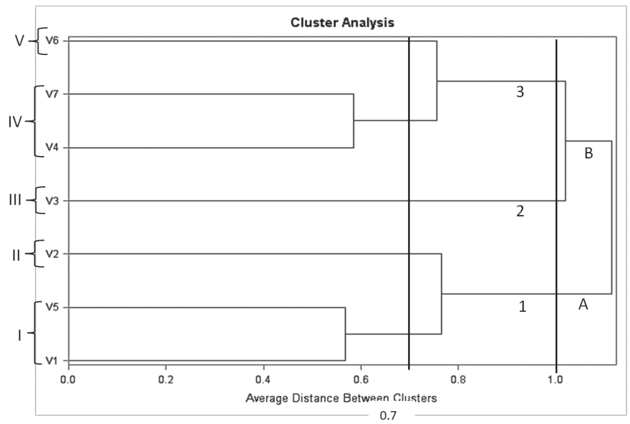

Fig. 1. A UPGMA dendrogram of measured traits derived from 7 different varieties of okra

The Pearson's similarity coefficient obtained through morpho-physiological and mineral traits ranged between 0.6 and 1.0 (Figure 1) indicating the strong diversity among okra varieties. Cluster analysis, as a multivariate technique, can group individuals or objects on the basis of their characteristics. Individuals with similar descriptions are mathematically congregated within the same cluster (Alam et al., 2014, 2015). Distance, similarity and relatedness of varieties are the foundation of this method.

The UPGMA constructed dendrogram revealed 5 clusters (at 0.7 similarity coefficient level) where V2, V3 and V6 were most different from all of the others, indicating the highest diversity compared to other accessions. To improve variety development, the most judicious crossing combination can be made with V2, V3 and V6 with V1 or V5 and V4 or V7, which would bring about the greater genetic diversity (Alam et al., 2016).

Conclusions

As a conclusion, regarding the objectives to identify the best quality parental line selection of okra for varietal improvement based on morpho-physiological and nutritional attributes, all the varieties showed their own characteristics in each parameter. From the overall data analysis and evaluation of morpho-physiological and major micro-macro elements of all those 7 varieties of okra, in order to obtain varietal improvement, breeders or growers can choose better combinations among those varieties targeting the desired characteristics. For instance, consumers nowadays, demands for longer shelf life of food or fruit. The breeder can select variety 6 which have bigger diameter of fruit with variety 7 which have higher percentage of water content of fruits because bigger size of fruit may loss high water content. In order to have bigger size of fruits with longer shelf life, breeder needs to breed with the higher percentage of moisture fruit. From the cluster analysis all those 7 okra varieties also grouped into different cluster where V2, V3 and V6 were most different from all the others, indicating the highest diversity compared to other accessions. So, based on cluster analysis for varietal improvement program, the most judicious crossing combination can be made with V2, V3 and V6 with V1 or V5 and V4 or V7, which would bring about the greater genetic diversity. For the major micro-macro elements improvement also have to choose target based combinations of parental lines, that is which specific nutrients is expected to increase or decrease.

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