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ASSESSMENT OF GENETIC DIVERSITY AMONG OKRA GENOTYPES THROUGH PCA AND CORRELATION ANALYSIS FOR FRUIT TENDERNESS, AND MORPHOLOGICAL AND YIELD TRAITS

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Abstract

Most of the local okra varieties grown in Pakistan are prone to several challenges like long maturity periods yet short harvesting time, biotic and abiotic stress, inferior quality and low yield in comparison to countries like India, Nigeria and Iraq. Therefore, this study was designed to measure diversity in available okra germplasm comprising of twenty four genotypes for morphological, yield and quality related traits. Considerable variation was observed for all studied traits except for internodal length, fruit girth, days to fruit maturity and vitamin C. Highest variation was recorded for plant height, leaves plant^{-1}, leaf area, days to flowering, number of fruits plant^{-1}, fruiting span, fruit yield plant^{-1} and fruit tenderness at 10th and 12th day from flower opening. Plant height was significantly positively correlated with all measured traits except days to flowering, days to fruit maturity and fruit tenderness. Days to flowering were significantly positively correlated with fruit weight and tenderness of at all intervals of picking. Moreover, number of fruits plant^{-1} was positively correlated with average fruit weight and both were significantly correlated with fruit weight plant^{-1}, fruiting span, protein contents and vitamin C. However, fruit weight plant^{-1} was significantly positive correlated with fruiting span, but negatively correlated with fruit tenderness. Principal component analysis (PCA) unveiled that PC-I and PC-II had Eigen values greater than one and these two contributed 80.82% of total variability for various traits, but PC-III to PC-VI had Eigen value 0.68, 0.62, 0.58 and 0.39, respectively. Among the three clusters of all genotypes, highest yield and related traits were perceived in cluster I and III, while lowest values of these parameters were recorded in cluster II. Moreover, highest genetic divergence was noticed among cluster I and cluster II. As a result, it is recommended that genotypes residing in I and III clusters can be crossed to assess heterosis for okra yield and quality traits like fruit tenderness.

Key words: *Abelmoschus esculentus*, Germplasm, Maturity, Quality, Variability.

Introduction

Okra (*Abelmoschus esculentus* L. Moench), locally famous as Bhindi, belongs to Malvaceae family, originated from West Africa and South East Asia (Akash *et al*., 2013). Okra is a promising vegetable, famous for its green coloured soft and delightful fruits, which are mostly eaten in several forms as raw, canned or cooked. Fruits of okra are highly nutritious and comprise of many nutritional compounds and elements *viz.*, vitamins, minerals, soluble fibers, carbohydrates and unsaturated oils (Rashwan, 2011). 100 g of edible okra comprises plentiful components including protein (2.1 g), minerals (175.2 mg), fat (0.2 g), fiber (1.7 g), calories (36), carbohydrate (8 g), maximum quantity (88 ml) of water, and also contains good quantities of total phenolics, folate and vitamin C (Bawa & Badrie, 2016). Okra can be extensively cultivated in diverse regions of tropics and subtropics. India is ranked highest in okra production on the globe with 6.17 million tonnes year^{-1} and 12.03 tonnes ha^{-1} yield, while Pakistan ranks 5th with production of 0.124 million tonnes and yield of 7.68 tonnes ha^{-1} (Anon., 2020). This difference in yield potential of okra is largely due to unavailability of high yielding varieties, quality seed and less adoption of improved production practices (Shahid *et al*., 2013). Therefore, the principal step for its improvement must implicate appraisal of germplasm to find diversity especially quality and yield traits. Information about substantial variability in breeding material would help in further selection of best performing potential genotypes to use them in crop improvement of okra through breeding (Sharma and Prasad, 2010). Principal component analysis and cluster analysis have been employed in many crops to notice the degree of genetic variability as well as association among many economically important parameters for genetic improvement (Ziaf *et al*., 2016). Desirable selection is a fundamental step for any breeding program through which promising genotypes with significantly higher production potential and other desirable traits in a given environment may be developed. Selection of desired genotypes based on their yield potential highly dependent on several other traits which are polygenic in nature. Association and significant influence of other traits with yield helps to devise a reliable criterion for selection of promising genotypes (Akbar *et al*., 2001). Simple correlation coefficients accompanied by path coefficient analysis would be excellent for the selection of traits related to improvement in yield (Yucel, 2004; Kumar & Paul, 2016; Polat *et al*., 2020). Principal coordinate analysis is also employed to assess the degree of diversity in studied germplasm (Esmail *et al*., 2008). Several authors proposed the assessment of scores of 1st principal component as input variables for clustering (Brown, 2000; Mujaju & Chakuya, 2008). Therefore, cluster analysis has earlier been reported to employ extensively for the classification of a pool of genotypes on the basis of similarity and dissimilarity present among them. Similarly, both cluster as well as principal component analysis is used to the classification of different accessions (Yousef *et al*., 2018; Okatan, 2020). It is essential to clearly understand the degree of genetic diversity in okra germplasm to plan a selection program aimed at improvement in quality and yield. A lot of work related to the correlation and component analysis of okra germplasm related to morphological characters has been reported by many researchers, but there is no work regarding genetic diversity of okra for fruit quality especially okra fruit tenderness, has been published so far. Keeping in view the need to developing high yielding promising okra varieties with better yield and fruit quality, the current study was initiated for the estimation of genetic diversity in available germplasm of okra regarding several morphological, yield and quality traits including fruit tenderness under agro-climatic conditions of Faisalabad, Pakistan.

Materials and Methods

Plant material: For this study, Seeds of twenty four genotypes of okra *viz.,* 'Pen Beauty', 'Click-5769', 'Okra-7100', 'Ikra-02', 'Line Brand', 'Evergreen', 'OH-152', 'Sabz Pari', 'Kiran-51', 'Super Green', 'Tulsi', 'MF-02', 'Ikra-04', 'Green gold', 'Durga', 'MF-03', 'Greenstar', 'Anmol', 'Rama Krishna', 'Anarkali', 'Patel', 'Prabhani Karanti', 'Arka Anamika' and 'Sudan' were collected, sown and selfed to ensure purity. Collected seeds of each genotype from tagged plants were sown on 3rd March in field conditions during 2014 and subsequently repeated during 2015 at Experimental Area of Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan. Climatic data of the experimental site for the reported period is given in Fig. 1 that indicates highest temperature during June followed by May during both years. Rainfall was minimum during June in both years. This planned study was executed with three replications (each replication comprised of 15 plants) and laid out in a randomized complete block design (RCBD). Standard practices regarding hoeing, weeding as well as plant protection were adopted for the entire course of study.

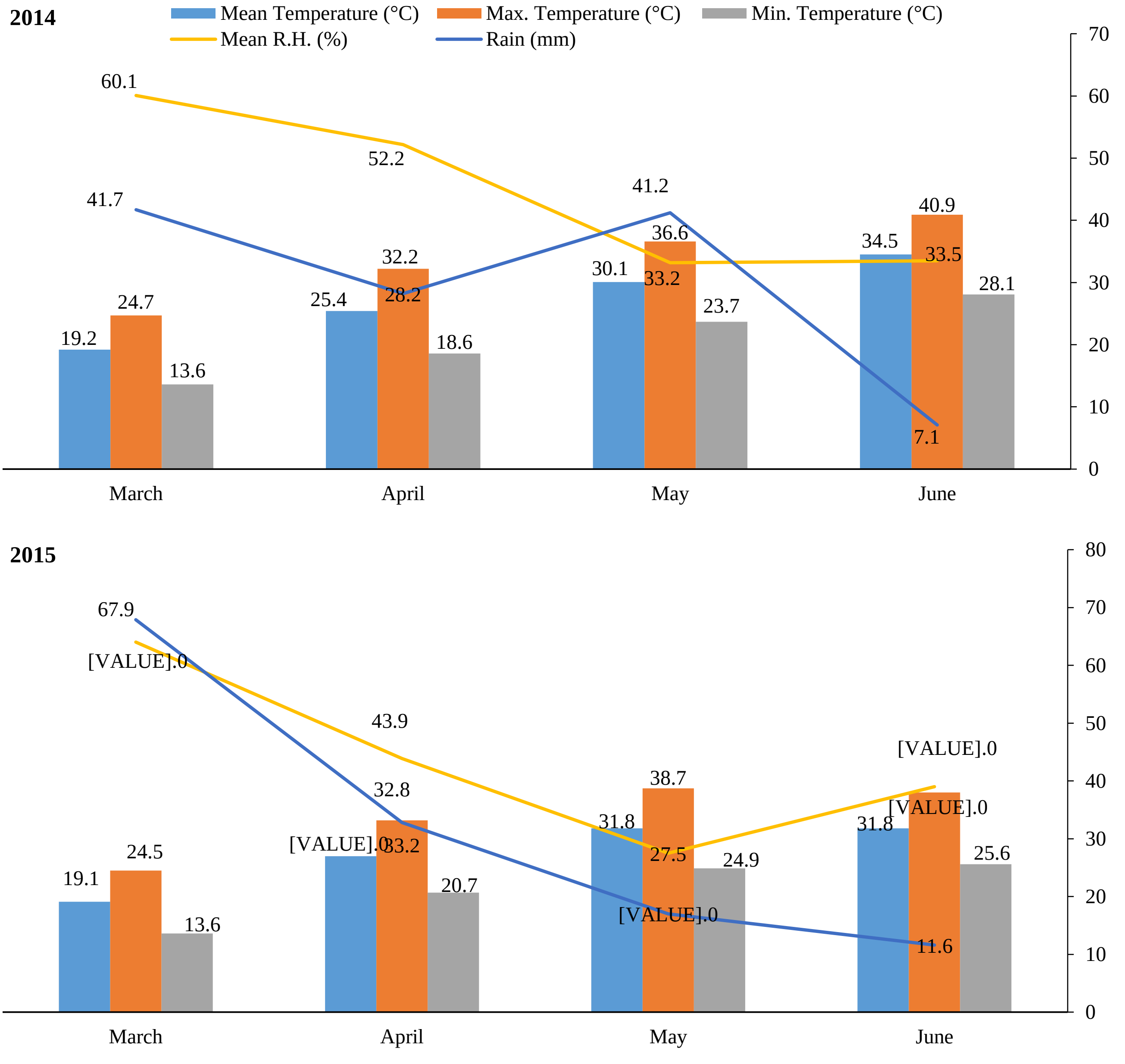

Fig. 1. Climatic data of the experimental site for the cropping period during two years.

Table 1. Mean values of different traits of okra genotypes.

Variable	Minimum	Maximum	Mean	Std. Dev.
Plant height (PH)	104.90	128.10	112.48	7.04
No. of leaves plant^{-1} (NOL)	22.80	34.90	28.42	4.03
Leaf area (LA)	319.10	365.20	344.50	12.55
Days to flowering (DTF)	31.70	46.30	38.00	3.64
Internodal length (INL)	6.60	10.70	7.89	0.78
Stem diameter (SD)	18.80	26.60	22.11	2.38
Fruit length (FL)	10.90	15.20	12.63	1.33
Fruit girth (FG)	5.00	5.80	5.39	0.25
No. of fruits plant^{-1} (NFPP)	16.10	26.30	19.98	2.63
Average fruit weight (AFW)	10.60	14.20	12.20	1.09
Fruit weight plant^{-1} (FWPP)	171.50	373.50	246.46	54.28
Days to fruit maturity (DTFM)	6.00	9.00	7.00	0.70
Fruiting span (FS)	55.10	79.70	68.36	6.24
Protein contents (PC)	11.50	14.70	13.01	0.78
Vitamin C (VC)	0.21	0.29	0.25	0.02
Fruit tenderness at 6th day (FT 6th)	2.05	3.90	2.52	0.39
Fruit tenderness at 8th day (FT 8th)	2.97	5.79	3.70	0.58
Fruit tenderness at 10th day (FT 10th)	4.13	7.67	5.38	0.80
Fruit tenderness at 12th day (FT 12th)	5.29	11.42	7.41	1.50

Date collection and statistical analysis: Data were assembled regarding morphological, yield and fruit quality traits by consulting Anon., (1991) descriptor developed for okra. Height of plants (PH) was measured at sixty days from seed sowing and same plants were further considered for the measurement of leaf number plant^{-1} (NOL) and leaf area (LA). 10th and 15th healthy, mature fully expanded leaves were taken from the base of tagged plant and calculations were done for leaf area by using the method of Carleton & Foote (1965). Days to flowering (DTF) were counted from the date of seed sowing till anthesis of 1st flower. For the calculations of internodal length (IL), distance between two consecutive nodes (5th and 6th) on the main stem was measured using measuring tape. From one feet above soil surface, stem diameter (SD) was measured two inches above soil level using digital caliper. Length (FL) and girth (FG) of green marketable fruit was measured using measuring tape. Fruit number plant^{-1} (NFPP) was reckoned by counting the fruits 1st picking of fruits till last picking from tagged plants and averaged. Average weight of fruit of each genotype (AFW) was determined from the freshly harvested marketable fruits using electronic weighing balance. Weight of fruits plant^{-1} (FWPP) was reckoned by adding the weight of fruits from first to last picking. Days to fruit maturity (DTFM) was reckoned by calculating from the day of initiation of flowers to reach marketable fruit size, while span of fruiting (FS) was calculated by counting the days from first fruit setting to last picking of marketable fruits. Fruit tenderness (FT) was assessed by using the instrument Texture Analyzer (TA.XT. *Plus*, Agrosta, France) with the interval of every two days starting from sixth day after flowering, *i.e.* first 6th, second 8th, third 10th and fourth at 12th day from flowering. Protein contents (PC) and vitamin C was calculated from fresh pods of all genotypes using the method described by Anon., (2000) and Haddad (1977), respectively. Mean data were investigated with the help of a sophisticated software (DSAASTAT) by performing analysis of variance technique developed by Steel *et al*., (1997) at $p \leq 0.05$. Moreover, XLSTAT (Version, 2014.5.04) was consulted for the estimation of principal component analysis and for the construction of agglomerative hierarchical clustering of the recorded data.

Results and Discussion

Correlation patterns: Data regarding morphological, yield and quality related traits for all the studied okra genotypes exhibited significant variation except internodal length, fruit girth, average fruit weight, days to fruit maturity, protein and vitamin C contents as well as fruit tenderness at 6th and 8th day from flower initiation, for which very low range in measured data was noticed (Table 1). Fruits of all genotypes picked at 6th and 8th day from flower initiation exhibited little variation for tenderness but this difference increased with increase in the interval of fruit picking, particularly when their fruits were harvested at 12th day from flower opening. Considerable variations were recorded for certain morphological and yield related traits including height of plant, area and no. of leaves, days from sowing to flower initiation, stem diameter, length as well as number of fruit plant^{-1}, span of fruiting, total weight of harvested fruit plant^{-1}, protein contents and tenderness of pods of okra harvested at 10th and 12th day form flower opening. Yield enhancement is the ultimate goal of a crop breeder to consider some potential genotypes out of a pool of germplasm like fruit yield and tenderness as in okra. Yield of okra genotypes ranged from 171.5 g plant^{-1} to 373.5 g plant^{-1}, which presented significant variation in the performance of studied genotypes (Table 1). Similar findings were earlier reported by Duggi *et al*., (2013) as well as Temam *et al*., (2021) that variation in yield and related traits while observing the performance of a pool of okra genotypes. Yield itself is a complex trait so, it is necessary to recognize the importance and correlation of various yield contributing components with yield and among themselves (Dhankar & Dhankar, 2002). Correlation analysis revealed significantly positive correlation of plant height with all other measured indices except for days taken to flowering and to mature fruits and fruit tenderness at 6th, 8th, 10th and 12th day from flower opening (Table 2). These results are in accordance with earlier published results of Agyare *et al*., (2017) and Hazare & Basu (2000) who reported positive association of plant height with other traits directly related to yield. Positive significant correlation of leaf number plant^{-1} was noted that of area of leaf, stem diameter, no. and length of fruit, single weight of fruits as well as total fruit weight pant^{-1}, span of fruiting, protein contents and vitamin C, but negative correlation was noted for days taken to flowering and fruit maturity as well as fruit tenderness at all intervals of picking. Leaf area was significantly positively correlated with stem diameter, length and no. of fruits, single as well as total weight of fruits, span of fruiting, protein contents and vitamin C but negatively correlated with days to flower initiation, tenderness of fruits at all intervals as well as length between two consecutive nodes. Similarly, days to flowering presented positive correlation with internodal length, fruit weight plant^{-1}, vitamin C and fruit tenderness (Table 2). Patro & Shankar (2006) and Mohapatra *et al*., (2007) also reported significant association of days to start flowering with average fruit weight, total fruits as well as total yield of okra plant^{-1}. However, diameter of stem, length and total number of fruits, average weight of fruit, days to fruit maturity, fruiting span and protein contents were significantly correlated with days to flowering. Positive correlation of internodal length was also observed with days to fruit maturity and fruit tenderness at all intervals of fruit picking but number of fruits plant^{-1}and total weight of fruit as well as span of fruiting, protein contents and vitamin C were negatively correlated. Positive correlation of stem diameter was observed with fruit length and both parameters showed positive significant correlation with fruit related traits including fruit number and weight plant^{-1}, individual weight of fruit, fruiting span, protein contents and vitamin C (Table 2). Positive correlation of fruit girth was noticed with individual weight of fruit, number and weight of fruit plant^{-1} and fruiting span. Singh *et al*., (2006) and Kamal *et al*., (2003) also envisaged positive correlation of total fruit yield with girth and fruit number plant^{-1}. Likewise, positive correlation of fruit number plant^{-1}was noticed with individual fruit weight and both were positive correlated with fruit weight plant^{-1}, fruiting span, protein contents and vitamin C. Similar association of fruit characteristics with total yield of okra was confirmed earlier by Adiger *et al*., (2011) and Sindhumole *et al*., (2006). Fruit weight plant^{-1} had significant correlation with fruiting span, protein contents and vitamin C, while days to fruit maturity showed positive correlation with fruit tenderness. Fruiting span and protein contents were significantly correlated with each other, while fruiting span, protein contents and vitamin C content of fruits were negatively correlated with fruit tenderness (Table 2). Hence, number of days to start flowering, length as well as average weight of fruit plant^{-1}, total fruit weight, total span of fruiting and tenderness of harvested pods at all intervals picking, should be given due significance while performing selection for maximum yield in okra which was also confirmed by earlier researchers (Mehta *et al*., 2006; Adeniji & Aremu, 2007).

Table 2. Correlation coefficients among various traits of different okra genotypes.

Variables	PH	NOL	LA	DTF	INL	SD	FL	FG	NFPP	AFW	FWPP	DTMF	FS	PC	VC	FF 6th	FF 8th	FF 10th	FF 12th
PH	1																		
NOL	0.78**	1																	
LA	0.59**	0.68**	1																
DTF	-0.82**	-0.73**	-0.70**	1															
INL	-0.24^{NS}	-0.38^{NS}	-0.47**	0.55**	1														
SD	0.84**	0.72**	0.54**	-0.71**	-0.21^{NS}	1													
FL	0.71**	0.73**	0.55**	-0.67**	-0.32^{NS}	0.53**	1												
FG	0.49**	0.35^{NS}	0.34^{NS}	-0.31^{NS}	0.13^{NS}	0.54**	0.57**	1											
NFPP	0.86**	0.85**	0.73**	-0.86**	-0.46*	0.79**	0.77**	0.47*	1										
AFW	0.89**	0.75**	0.77**	-0.89**	-0.40^{NS}	0.76**	0.77**	0.54**	0.86**	1									
FWPP	0.91**	0.84**	0.76**	-0.86**	-0.43*	0.80**	0.81**	0.52**	0.98**	0.94**	1								
DTMF	-0.70**	-0.73**	-0.75**	-0.90**	0.50**	-0.68**	-0.52*	-0.28^{NS}	-0.75**	-0.83**	-.79**	1							
FS	0.87**	0.80**	0.75**	-0.76**	-0.59**	0.70**	0.81**	0.41*	0.91**	0.90**	0.93**	-0.82**	1						
PC	0.81**	0.71**	0.65**	-0.59**	-0.44**	0.62**	0.67**	0.33^{NS}	0.84**	0.82**	0.87**	-0.70**	0.77**	1					
VC	0.62**	0.67**	0.70**	0.79**	-0.53**	0.51**	0.53**	0.15^{NS}	0.68**	0.66**	0.69**	-0.62**	0.64**	0.73**	1				
FF 6th	-0.62**	-0.67**	-0.76**	0.79**	0.69**	-0.59**	-0.47*	-0.21^{NS}	-0.76**	-0.77**	-0.77**	0.88**	-0.81**	-0.76**	-0.65**	1			
FF 8th	-0.60**	-0.70**	-0.57**	0.79**	0.74**	-0.62**	-0.49**	-0.07^{NS}	-0.73**	-0.66**	-0.71**	0.80**	-0.78**	-0.68**	-0.62**	0.89**	1		
FF 10th	-0.62**	-0.79**	-0.79**	0.79**	0.65**	-0.59**	-0.56**	-0.26^{NS}	-0.83**	-0.75**	-0.81**	0.82**	-0.81**	-0.76**	-0.67**	0.90**	0.84**	1	
FF 12th	-0.69**	-0.75**	-0.66**	0.87**	0.69**	-0.70**	-0.64**	-0.32^{NS}	-0.86**	-0.78**	-0.84**	0.83**	-0.87**	-0.76**	-0.64**	0.85**	0.90**	0.90**	1

Table 3. Principal component analysis for various traits in different okra genotypes.

	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	13.486	1.868	0.681	0.621	0.580	0.391
Variability (%)	70.981	9.834	3.583	3.270	3.055	2.057
Cumulative %	70.981	80.815	84.398	87.668	90.723	92.779
Eigen vectors:						
Variables	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
PH	0.234	0.252	-0.071	-0.304	-0.223	-0.141
NOL	0.235	0.073	0.082	-0.172	-0.139	0.302
LA	0.219	-0.045	0.269	-0.033	0.618	-0.117
DTF	-0.250	0.029	0.193	-0.024	0.127	0.386
INL	-0.157	0.489	-0.129	-0.389	0.147	-0.155
SD	0.213	0.232	-0.420	-0.264	-0.033	0.392
FL	0.207	0.254	0.373	0.389	-0.319	-0.101
FG	0.116	0.532	-0.073	0.455	0.344	0.341
NFPP	0.258	0.101	0.034	-0.005	-0.130	0.055
AFW	0.253	0.155	0.012	-0.005	0.105	-0.302
FWPP	0.263	0.145	0.056	-0.009	-0.068	-0.086
DTFM	-0.240	0.105	0.278	0.108	-0.269	0.256
FS	0.258	0.011	0.007	0.217	-0.096	-0.189
PC	0.236	0.027	0.225	-0.201	-0.127	-0.136
VC	0.204	-0.117	0.540	-0.392	0.067	0.317
FT 6^{th}	-0.239	0.246	0.147	-0.025	-0.263	0.043
FT 8^{th}	-0.228	0.300	0.253	-0.014	0.192	-0.188
FT 10^{th}	-0.244	0.192	0.004	-0.082	-0.193	-0.171
FT 12^{th}	-0.250	0.141	0.176	-0.190	0.111	-0.184

Table 4. Distribution of okra genotypes in clusters

Clusters	Genotypes
I	Ikra-04, Line Brand, Patel, Ikra-02, Rama Krishna, Durga
II	Super Green, Kiran-51, Prabhani Karanti, Arka Anamika, OH-152, Greenstar, Click-5769, Tulsi, Pen beauty, Sudan, Green gold, MF-03, Anarkali, MF-02
III	Evergreen, Anmol, Okra-7100, Sabz Pari (Check)

Principal component analysis (PCA): PCA showed maximum genetic diversity among okra genotypes. PCA unveiled that PC-I and PC-II had Eigen values more than 1 and exhibited 70.98% and 9.83% variability but the Eigen values of PC-III, PC-IV, PC-V and PC-VI were 0.68%, 0.62%, 0.58% and 0.39%, respectively (Table 3). Interestingly, it can be clearly seen that in cumulative variability of measured traits, involvement of PC-I and PC-II was 80.82%. PC-I exhibited positive factor loadings for almost all the measured traits except for days taken to flowering, internodal length, days to fruit maturity and fruit tenderness which showed negative factor loading in PC-I. Highest contribution in PC-I was noticed for total weight of fruits followed by fruiting span, fruit no. plant^{-1} and average fruit weight, while lowest contributor was fruit girth. Factor loading in PC-II was positive for all parameters except for leaf area and vitamin C. It was evident form the results (Table 3) that in PC-II, maximum contribution for factor loadings was recorded for fruit girth followed by internodal length and fruit tenderness on 8^{th} day from flower initiation, while minimum positive contribution was noticed for fruiting span. Highest positive contributor in PC-III was vitamin C, while lowest positive contributors were fruit tenderness on 10^{th} days form flower opening and by fruiting span. Highest contribution in PC-IV was of fruit girth followed by fruit length. In contrast, leaf area followed by fruit girth was highest positive contributors in PC-V, while lowest positive contribution was of vitamin C. In PC-VI, highest positive loading factors were stem diameter and days to flowering. Moreover, association in PC-I and II that exhibited 80.82% variability, was elaborated with the help of a graph by taking PC-I and II on X-axis and Y-axis, respectively (Fig. 2). It is evident from the results of this experiment that height of plant was positively correlated with a number of morphological and yield related traits *viz.,* leaves plant^{-1}, days to start flowering, length between two consecutive nodes, stem diameter, weight, length and girth of a single fruit, fruit no. plant^{-1}, total weight of fruits, span of fruiting as well as no. of days to fruit maturity, protein contents and tenderness of fruits at 8^{th}, 10^{th} and 12^{th} day from flower initiation. It can also be observed from the results that days to flowering, intermodal length, days to fruit maturity, fruit tenderness were negatively correlated with all other studied parameters. Similar finding were earlier reported by Chernet *et al.*, (2013) who also showed positive association of morphological and yield traits in different principal components while evaluating tomato germplasm.

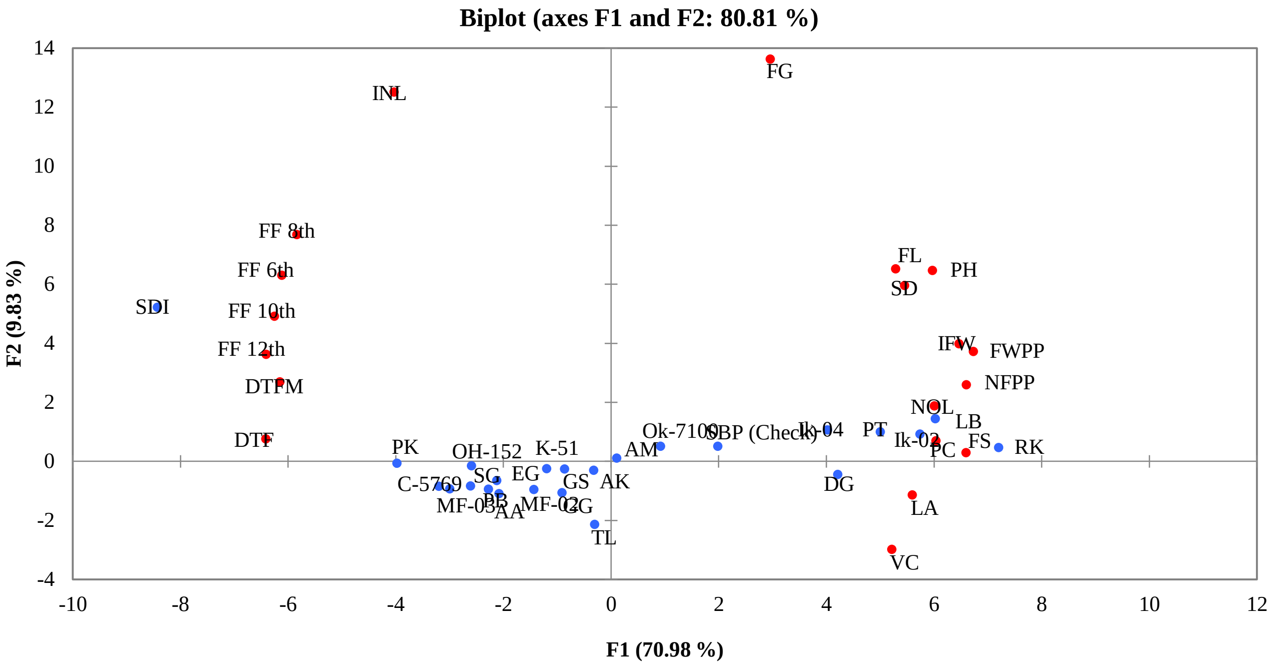

Fig. 2. Bi-plot of okra genotypes for PC-I and II.
PT= Patel; PK= Prabhani Karanti; DG= Durga; OK-7100= Okra-7100; RK= Rama Krishna; K-51= Kiran-51; AA= Arka Anamika; GS= Greenstar; AK= Anarkali; IK-02= Ikra-02; EG= Evergreen; PB= Pen Beauty; LB= Line Brand; TL= Tulsi; MF-02; IK-04= Ikra-04; AM= Anmol; SDI= Sudani; C-5769= Click-5769; OH-152; SG= Super Green; MF-03; GG= Green gold; SBP (Check)= Sabz Pari (Check)

Cluster analysis: It was performed for the grouping of okra genotypes because cluster analysis has been taken as an effective and trustworthy technique to design breeding program (Feng-Mei *et al*., 2006) taking into consideration the classification pattern of available germplasm of a particular crop (Iqbal *et al*., 2014). Twenty four okra genotypes were grouped into three clusters using agglomerative hierarchical clustering on the basis of measured traits (Fig. 3). Cluster I had six (25%) okra genotypes in it, while II and III consisted of fourteen (58.33%) and four (16.67%) genotypes, respectively (Table 4). Cluster I comprised of genotypes with maximum plant height, leaf number and area, minimum days to initiate flowering, excellent fruit characteristics comprising single fruit length, weight and girth, prolonged fruiting span, higher protein contents as well as minimum fruit firmness at all durations of picking (Table 5). Furthermore, yield of okra also exhibited highest genetic divergence among cluster I and II because all promising genotypes with maximum production potential were flocked in cluster I, but cluster II consisted of low yielding varieties, which required highest number of days to initiate flowering. However, negligible differences were recorded for a number of traits including intermodal length, stem diameter, days to fruit maturity and vitamin C in all three clusters. Although, the least values for stem diameter, length, weight and thickness of a single fruit, total fruits plant^{-1}, fruiting span, protein contents and vitamin C were recorded in cluster II, while the highest values were noticed in cluster I (Table 5). It can be concluded form the results of cluster analysis that promising genotypes bearing highest fruits, length, thickness, and weight of a single fruit as well as total weight, significant fruit quality (protein contents, vitamin C and retention of fruit tenderness on 6th, 8th, 10th and 12th days from flower opening) were clustered in cluster I followed by cluster III, while genotypes with least fruit quality and yield were resided in cluster II. So, it can be envisaged from results of cluster analysis that superior and promising okra genotypes from cluster I and III should be selected for effective breeding to improve yield and fruit tenderness as these two clusters showed maximum genetic divergence for these traits. Findings of this executed study are in accordance with the earlier reported results of Iqbal *et al*., (2014), Akotkar *et al*., (2010), Duggi *et al*., (2013), and Zia-ul-Qamar *et al*., (2012) where they elaborated that those indices which have higher contribution in genetic divergence must be prioritized over other traits while choosing the clusters for crop improvement. Breeding program involving genetically diverse genotypes has been effective for developing hybrids with maximum heterosis in the preferred domain (Mallikarjun *et al*., 2010). Interestingly, cluster I and cluster III exhibited excellent results for fruit tenderness even when fruits were harvested after 10th and 12th days of flowering, which increased the significance of these clusters for this quality trait and the choice of ultimate consumers in local and international market. Moreover, crossing of genotypes from cluster I and cluster III would show more hybrid vigor in their F_1 generation. However, specific traits contributing to the yield enhancement like minimum number of days for flowering, shorter distance between two consecutive internodes, fruits plant^{-1}, length, weight and thickness of individual fruit and fruiting span positively influenced the final yield of okra. Similar findings were also confirmed by Duggi *et al*., (2013) as well as also supported by the findings of Akotkar *et al*., (2010). Moreover, D^2 statistics elaborated that Cluster II was found closer to that of III with genetic distance of (45.01) but cluster I and II exhibited greatest genetic distance (1213.97) (Table 6) as also evident from Fig. 3.

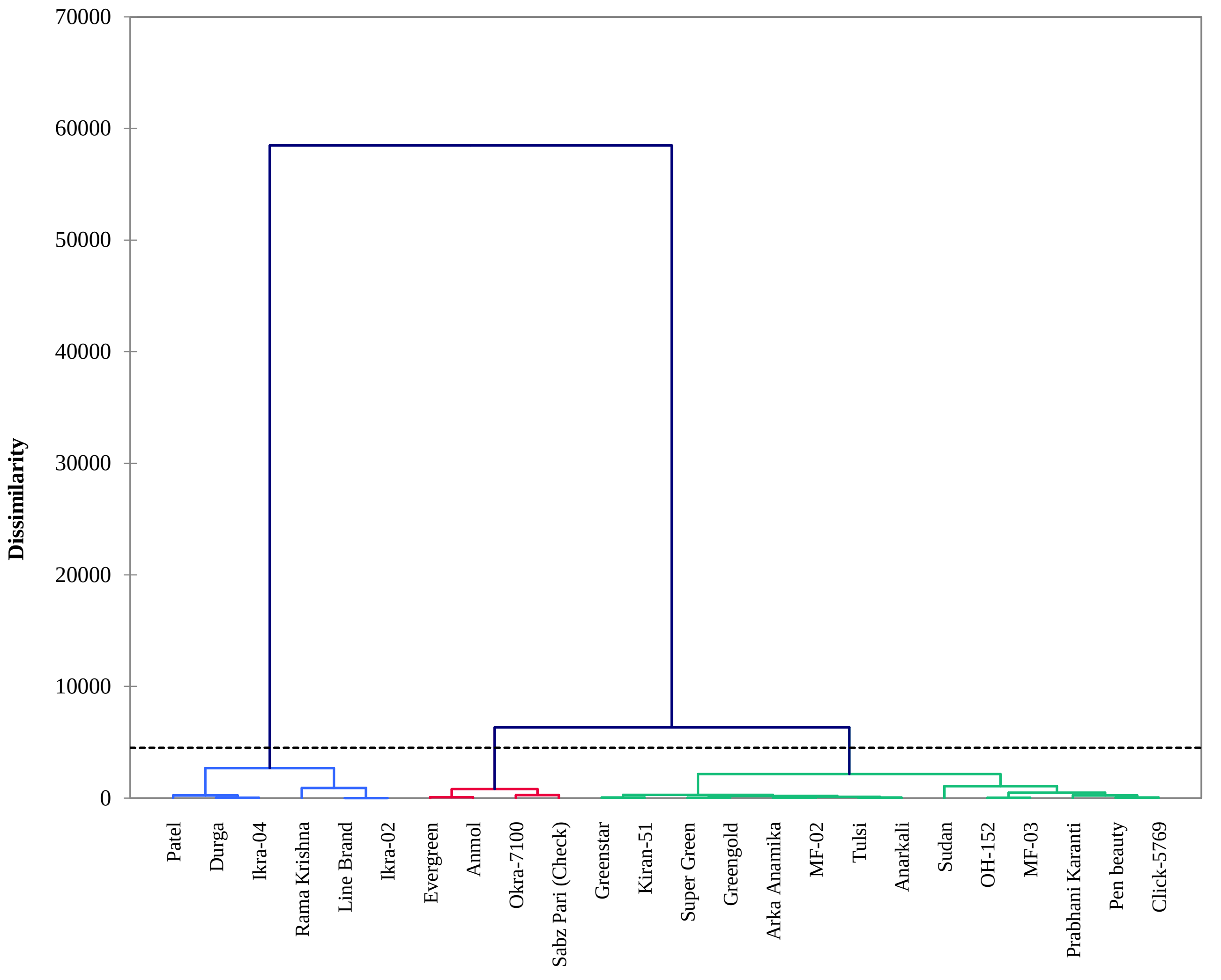

Fig. 3. Dendrogram based on nineteen traits of okra genotypes.

Table 5. Average values of traits of okra genotypes in cluster analysis.

Traits	Clusters		
	I	II	III
PH	122.250	108.150	112.950
NOL	33.583	25.929	29.375
LA	357.267	337.986	348.150
DTF	33.350	40.021	37.925
INL	7.467	7.986	8.200
SD	24.917	20.614	23.125
FL	14.617	11.957	11.975
FG	5.617	5.271	5.475
NFPP	23.800	18.157	20.600
AFW	13.767	11.493	12.300
FWPP	329.483	209.221	252.275
DTFM	6.250	7.371	6.800
FS	76.917	64.450	69.200
PC	14.100	12.593	12.850
VC	0.270	0.241	0.243
FT 6^{th}	2.123	2.726	2.373
FT 8^{th}	3.133	3.959	3.625
FT 10^{th}	4.498	5.855	5.023
FT 12^{th}	5.553	8.227	7.338

Table 6. D^2 statistics exhibiting genetic divergence between the constructed clusters for okra genotypes.

	Cluster I	Cluster II	Cluster III
Cluster I	0		
Cluster II	123.970	0	
Cluster III	79.106	45.099	0

Conclusion

Wide variation existed for most of the studied traits, particularly fruit related traits including yield, fruiting span, and fruit tenderness. Significant positive correlation of days to flowering and average fruit weight with fruit yield and tenderness indicated that these traits can be used in assessment of germplasm for breeding purpose. Cluster analysis indicated that genotypes from cluster I and III can be crossed to get hybrid vigour for yield and related traits. Some of the superior performing genotypes/lines, for example Ikra-02 and Ikra-04, can be further assessed in multi-locational trials to be released as a variety. Moreover, okra breeding program should also include fruit tenderness, besides other yield and other fruit related quality traits, because most of the population in South East Asia prefer tender okra fruit.

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