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Characterization of Okra (*Abelmoschus esculentus* (L.) Moench) Germplasms Collected from Western Ethiopia

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ABSTRACT

Although Ethiopia is considered as the likely origin and center of diversity for okra, characterization and cultivar improvement of okra is very limited yet. Fifty accessions of okra germplasm were collected from four major production regions in Ethiopia and were evaluated under field conditions at Melkassa Agricultural Research Center during main cropping seasons of 2015, with the objective of characterization of the germplasms. The International Plant Genetic Resources Institute descriptor list for okra was used as a guide for data collection. Variations were observed among the different accessions based on their vegetative traits, inflorescence and fruit characteristics. There was a wide variation in plant height among the accessions; flowering and fruiting periods varied considerably among all accessions based on the output of the correlation and cluster analyses. There was a strong positive correlation between total fruit number and yield per plant (r = 0.84); first fruit producing node and plant height (r = 0.39); and number of seeds per fruit and the length of commercial fruit (r = 0.44). The observed variability in the traits studied strongly indicate the possibility of selecting plants with suitable morphology when considering integration into any improvement program towards preservation and conservation of okra genetic diversity in Ethiopia. The distant relatedness among the various accessions could also be considered and incorporated into hybridization program in breeding for different consumer preferences and market demands.

Keywords: Okra, Cluster analysis, Correlation analysis, Genetic diversity, Ethiopia

INTRODUCTION

Okra (*Abelmoschus esculentus* (L) Moench) is an economically important vegetable crop grown in tropical and sub-tropical parts of the world which belongs to the family Malvaceae. It is apparently originated in Ethiopia, higher parts of the Anglo-Egyptian Sudan [1]. It is widely distributed from Africa to Asia, in Southern Europea, the Mediterranean and all of the America [2]. Okra, commonly known as “lady finger” is primarily suitable for cultivation as a garden crop as well as on large commercial farms. The crop grows well in hot weather, especially in the regions with warm nights (>20^{0}C) [3]. It is sensitive to frost, water logging and drought conditions. There is no any clear record on production area and productivity of the crop under Ethiopian condition. However, okra has great diversity in different parts of the country particularly in the Western lowlands (550-650 masl) regions. Okra is a multipurpose crop due to its various uses of the fresh leaves, buds, flowers, pods and stems, pods and seeds [4]. For generation, communities in Gambella and Beneshangul gumuz have been cultivating for its fruit and leaf to use as a food and medicine of different diseases. Nearly 10% of the recommended levels of vitamin B6 and folic acid are also present in a half cup of cooked okra [5].

Although okra has multidirectional importance and utilization, technology development regarding variety development and crop management practices are very limited. Ethiopian Institute of Biodiversity (IBC) has collected okra germplasms from Western lowland regions of Ethiopian. There are also an attempt of collection by Pawe, Gambella and Assosa Agricultural Research Center. However, little has been previous attempted by breeders in improving the crop in terms of developing core collections for higher yield and quality. The accessions under cultivation, over the years in the various regions across the country are landraces.

The value of germplasm collection depends not only on the number of accessions it contains, but also upon the diversity present in those accessions [6]. Characterization and quantification of the genetic diversity and information on the genetic diversity within and among closely related crop varieties is essential for a rational use of plant genetic resources. Diversity based on phenotypic and

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morphological characters usually varies with environments and evaluation of traits requires growing the plants to full maturity prior to identification. High degree of wide morphological variation exists among accessions of okra especially in West African type [7]. Although the great value of the crop, information on characterization is either not accessible or simply unavailable. Characterization and evaluation of crop is done to provide information on diversity among crops. This permits the identification of unique entries (accession) necessary for curators of gene banks and plant breeders.

In okra, all growth, earliness and yield associated traits are quantitative in nature. Such characters are controlled by polygene and are much influenced by environmental fluctuations. Pod yield of okra is a complex quantitative trait, which is conditioned by the interaction of various growth and physiological processes throughout the life cycle [8]. In general, plant breeders commonly select for yield components which indirectly increase yield since direct selection for yield may not be the most efficient method for its improvement. Indirect selection for other yield related characters, which are closely associated with yield, will be more effective. The appropriate knowledge of such interrelationships between pod yield and its contributing components can significantly improve the efficiency of a breeding program through the use of appropriate selection indices.

Correlation analyses are pre-requisites for improvement of any crop including okra for selection of superior genotypes and improvement of any trait. In plant breeding, correlation analysis provides information about yield components and thus helps in selection of superior genotypes from diverse genetic populations. The correlation studies simply measure the associations between yield and other traits. Usefulness of the information obtained from the correlation coefficients can be enhanced by partitioning into direct and indirect effects for a set of a pair-wise cause-effect inter relationships [9]. In okra, correlation analyses have been used by several researchers to measure the associations between yield and other traits and to clarify interrelationships between pod yield and other traits, respectively.

Morpho-agronomical characters and diversity analysis of crops is also very essential in order to pave way for genetic improvement. It is the first step in any crop improvement program. Adequate characterization for agronomic and morphological traits is necessary to facilitate utilization of germplasm by breeders. Characterization of genetic resources, therefore, refers to the process by which accessions are identified, differentiated or distinguished according to their character. It provides information on diversity within and between crop collections. This enables the identification of unique accessions essential for curators of gene banks [6]. Moreover, information obtained on genetic association among genetic resources of crop plants is useful, both for breeding and for the purposes of germplasm conservation. Morphological characterization is therefore a highly recommended primary step that should be undertaken before more in-depth biochemical or molecular studies are employed in any diversity studies. Therefore, it is imperative to study the variability among the collected accessions. Hence, the objective of the study was to determine the range variability and association of quantitative and qualitative characters among okra collection with the ultimate goal of providing a basis for varietal improvement and conservation.

In this study, an attempt was made to study the inter-relationship among characters and the direct and indirect effects of some important yield components on pod yield in germplasm lines by adopting cluster and correlation analysis.

MATERIALS & METHODS

Description of the Study Area

The study was conducted at Melkassa, Ethiopia in 2015 main cropping season (rainy season). Melkassa is located $8^0$24'59.20" N latitude and $39^0$19'15.19" E with an altitude of 1548 m.a.s.l. The area is characterized by low and erratic rainfall with mean annual rainfall of 796 mm with peaks in July and August. The dominant soil type of the center is andosol of volcanic origin with pH that ranges from 7 to 8.2. The mean annual temperature is 21.2^0C with a minimum of 14^0C and maximum of 28.4^0C [10].

Data Collection

Data of quantitative and qualitative traits were recorded using International Plant Genetic Resources Institute [11] descriptor list for okra species. These includes: Plant growth habit, stem color, petiole color, degree of branching, leaf blade size, depth of leaf lobing, dentations of leaf margin, color between veins, flower size, stem pubescence, leave pubescence, fruit pubescence, number of epicalyxes segments, time of flowering, time of commercial harvest, mature fruit color, immature fruit color, number of ridges per fruit, number of locules, surface between ridges, Fruit length at maturity, fruit diameter at maturity, first fruit producing node, plant height, length of immature fruit, diameter of immature fruit, number of seed per fruit, fruit number on branches, total fruit number per plant, yield per plant.

Data Analysis

These were further separated into qualitative and quantitative characters and subjected to statistical analyses. Cluster analysis was done to assess extent of relatedness among the accessions using R-software (version 3.2.2) and correlation analyses were done on the quantitative characters with SPSS (version 23) to determine percentage contribution of each character to total diversity and degree of association among these characters.

RESULTS & DISCUSSION

Growth Habit and Degree of Branching

The growth habit and degree of branching of okra germplasms are highly variable. About 59% of accessions are erect type while 24.7 and 16.4 % of accession characterized with medium growth and procumbent type of growth habits, respectively. Regarding the branching habit of accessions 41.1% are strong branching habit but 25% are without branches. These all indicate that the germplasms are variable by vigorousity and branching.

Pubescence on Stem, Leaf and Fruit

Occurrence of pubescence varies across the okra germplasms on leaves, stems and fruits and also strongly correlated to each other. As indicated table 2, 30.1% of the germplasms are smooth glabrous stem while 54.1% of the okra collections have slight pubescence and 15.1% characterized with conspicuous pubescence on stems. Similarly the extent of pubescence varies on leaves and fruits of okra. Thirty percent of okra accessions are smooth while the 35% and 35% of the germplasms are characterized with slightly rough and prick type of pubescence.

Table2. *Percent share and variability of okra accession to different traits*

Variables	*values*	*Percent*	*Variables*	*values*	*Percent*
Plant growth habit	Erect	58.9	**Fruit pubescence**	Downy	29.6
	Medium	24.7		Slightly rough	35.2
	Procumbent	16.4		Prickly	35.2
Stem color	Green	31.5	**Number of epicalyxes**	8-10 (many)	17.2
	Green with red	50.7		10 (very many)	82.8
	Red	17.8	**Time of flowering**	Early	24.3
Petiole color	Small	8.7		Medium	28.6
	Medium	50.7		Late	47.1
	Large	40.6	**Time of commercial harvest**	Early	22.9
Degree of branching	Week	25.7		Medium	30.0
	Medium	32.9		Late	47.1
	Strong	41.4	**Mature fruit color**	Yellowish green	42.1
Leaf blade size	Small	8.7		Geen	1.8
	Medium	50.7		Green with red	38.6
	Large	40.6		Dark green	14.0
Depth of lobing	Shallow	30.9		Dark red	3.5
	Medium	32.4	**Immature fruit color**	Yellowish green	56.1
	Deep	36.8		Green	25.8
Dentations of margin	Week	5.9		Green with red	12.1
	Medium	39.7		Dark green	3.0
	Strong	54.4		Dark red	3.0
Color between viens	Green	60.3	**Number of ridges per fruit**	Smooth(none)	1.6
	Red	13.2		Few (5-7)	35.9
	Green with red	26.5		Many (8-10)	59.4
Flower size	Small	33.3		Very many (10)	3.1
	Medium	42.4	**Number of locules**	Five	5.9
	Large	24.2		More than five	94.1
Stem pubescence	Glabrous	30.1	**Surface between ridges**	Concave	27.3
	Slight	54.8		Flat	36.4
	Conspicuous	15.1		Convex	36.4
Leave pubescence	Glabrous	19.2			
	Slight	67.1			
	Conspicuous	13.7			

Color of Stem, Leaf, Veins and Fruits

Variability of colors on different parts of okra plant observed across okra accessions. For instance, 31.5% of germplasms have green stem color while 17.8% have red stem color. The rest 50.7% of germplasms have green with red patches on stems. Similarly, petiole color is highly variable among germplasms.

Earliness of Flowering and Harvest

The okra accessions vary in flowering and commercial harvesting time from one another. According to the category; 24%, 30% and 47% of okra accessions are early, medium and late type of for flowering and pod setting, respectively. These indicate that phenotypic and genetic variability are pertinent among okra collections.

Cluster Analysis

Table 1 displays the identities of the 50 accessions, the geographical collection sites and specific localities in Ethiopia. The largest collection of the accessions was made in the Beneshagul Gumuz region. This is to be expected as the region has a large number of farmers engaged in okra production and utilization.

Table1. Okra *(Abelmoschus esculentus (L) Moench) accessions and their area of collection*

No	Accession	Region	Specific District		No	Accession	Region	Specific District
1	23632-A	Beneshagul	Guba		26	240601-A	Gambella	Abobo
2	240201-A	Beneshagul	Mandura		27	240602-A	Gambella	Abobo
3	240201-B	Beneshagul	Mandura		28	240609-A	Gambella	Gambella
4	240201-C	Beneshagul	Mandura		29	240609-B	Gambella	Gambella
5	240203-A	Beneshagul	Mandura		30	240615-A	Gambella	Gambella
6	240203-B	Beneshagul	Mandura		31	240615-B	Gambella	Gambella
7	240203-C	Beneshagul	Mandura		32	240784-A	Beneshagul	Dangur
8	240203-D	Beneshagul	Mandura		33	240784-B	Beneshagul	Dangur
9	240203-E	Beneshagul	Mandura		34	240786-A	Beneshagul	Dangur
10	240203-F	Beneshagul	Mandura		35	240786-B	Beneshagul	Dangur
11	240583-A	Gambella	Akobo		36	240786-C	Beneshagul	Dangur
12	240583-B	Gambella	Akobo		37	240786-D	Beneshagul	Dangur
13	240585-A	Gambella	Akobo		38	242444-A	Beneshagul	Menge
14	240586-A	Gambella	Akobo		39	242444-B	Beneshagul	Menge
15	240586-B	Gambella	Akobo		40	242448-A	Beneshagul	Assosa
16	240587-A	Gambella	Akobo		41	242448-B	Beneshagul	Assosa
17	240587-B	Gambella	Akobo		42	242448-C	Beneshagul	Assosa
18	240591-A	Gambella	Abobo		43	242451-A	Beneshagul	Assosa
19	240591-B	Gambella	Abobo		44	242451-B	Beneshagul	Assosa
20	240591-C	Gambella	Abobo		45	242451-C	Beneshagul	Assosa
21	240592-A	Gambella	Gog		46	245157-A	Beneshagul	Guba
22	240599-A	Gambella	Abobo		47	245157-B	Beneshagul	Guba
23	240599-B	Gambella	Abobo		48	245157-C	Beneshagul	Guba
24	240599-C	Gambella	Abobo		49	245161-A	Beneshagul	Pawe
25	240600-A	Gambella	Abobo		50	245162-B	Beneshagul	Pawe

Cluster Analysis based on quantitative characters grouped 50 germplasm accessions into 4 distinct clusters(Fig.1) in which the first cluster considered of 25 accession(50%), the second cluster consisted of 13 accessions (26%), the third clusters consisted 8 accessions (16%) and the fourth cluster contained only 4 accessions (8%) from the total accessions. The distribution pattern of genotypes into 4 clusters confirmed the existence of diversity among the germplasms.

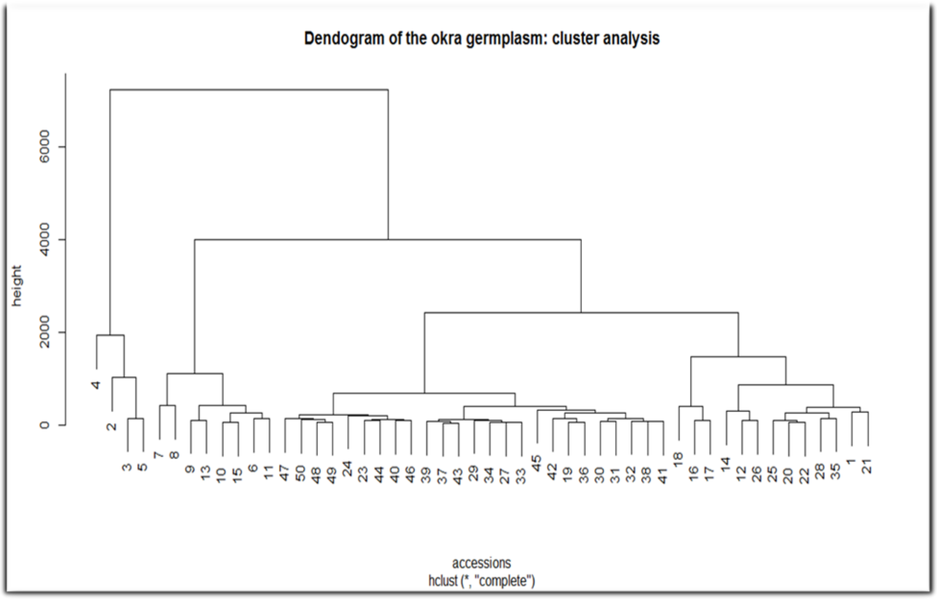

Fig1. *Cluster analysis among okra germplasms*

Correlation Analysis

Table 3 shows the correlation coefficients among the eleven (11) quantitative traits in the accessions of okra studied. Selection for a single character may increase the trait values of positively correlated characters and decline the values for negatively correlated traits. Mature fruit length had positive and significant correlation (P ≤ 0.05) with fruit length of immature fruit (r = 0.78) and number of seed per fruit (r = 0.443); but negatively correlated with first fruit producing node (r = -0.299) and mature fruit diameter (r = -0.027). This is also supported with other findings of [12] that component breeding would be very effective in the event of strong positive associations of major yield characters as evidenced in this study.

Table3. *Phenotypic and genotypic correlation among eleven quantitative traits of okra accessions*

	FLM	FDM	FFPN	Ph	LIF	DIF	NSPF	FNMS	FNB	TFN	YLD
FLM											
FDM	-0.027										
FFPN	-0.299*	-0.028									
Ph	-0.052	0.176	**0.394****								
LIF	**0.780****	-0.092	-0.342**	-0.115							
DIF	0.100	0.207	0.079	0.199	0.121						
NSPF	**0.443****	0.101	-0.217	-0.123	**0.440****	0.296*					
FNMS	0.006	-0.050	-0.187	-0.159	-0.034	-0.109	-0.069				
FNB	-0.127	0.283*	0.108	0.182	-0.191	-0.120	-0.207	**0.504****			
TFN	-0.076	0.141	-0.087	-0.045	-0.133	-0.108	-0.188	**0.854****	**0.863****		
YLD	0.102	0.125	-0.104	-0.019	0.120	0.224	-0.039	**0.816****	**0.579****	**0.837****	

(*), (**) Significant at 5 and 1% levels of probability, respectively.

***FLM**-Fruit length at maturity, **FDM**-fruit diameter at maturity, **FFPN**-first fruit producing node, **Ph**-plant height, **LIF**-length of immature fruit, **DIF**-diameter of immature fruit, **NSPF**-number of seed per fruit, **FNMS**-fruit number on main stem, **FNB**-fruit number on branches, **TFN**-total fruit number per plant, **YLD**-yield per plant.*

First fruit producing node (FFPN) and maximum plant height had the strongest positive association(r=0.394). But FFPN was highly significantly negatively correlated with immature fruit length(r=-0.342) (Table 3). Number of seeds per fruit illustrated highly positive correlation with mature fruit length (r=0.443) and commercial fruit length (r=0.44) but negative association with first fruit producing nodes(r=-0.207). Fruit yield had strong positive correlation with fruit numbers (r=0.86) but negatively correlate with other parameters. There has been a reported negative correlation among these traits. Hence, total fruit production, first fruit-producing node and number of fruits per plant should be given more attention when selecting for higher yield and high dry matter in okra [6].

Mean Values of Some Important Characters

Number of fruits per plant, mean fruit weight and total fruit production had the greatest variability among the quantitative traits measured (Table 4). Similarly there are reported greater coefficients of variations in these traits [13]. This gives credibility to the relevance of these characters in selecting accessions for yield improvement since they possess greater variability for exploitation of desirable traits for overall yield and productivity.

Wide range of flowering periods among the accessions were observed which implies varying maturity periods even on the same plant making it difficult for harvesting and practically unfeasible for mechanization. However, these type of cultivars appropriate for home gardening for continuous harvest. Majority of the accessions exhibited compact growth habit (Table 4). This trait might have been selected by farmers over the years as such plants are able to combine high number of fruit per plant per unit space, an economic indicator for yield [14]. Height of plant can potentially affect yield as plants with higher heights are usually prone to windstorms in the events of heavy downpour. Intense variation was observed in the fruiting and maturity periods of the various accessions of okra. Accessions with late maturity periods were at poor in quality and full of insect and pest infestations. Heights are of particular interest for breeding programs because tall, thin stems increase rate of lodging near harvesting and this could culminate in loss of dry matter and a subsequent decrease in fruit yield [15]. There were also intense variations in first fruit setting node, number of seeds per fruit, total number of fruits per plant, stem pubescence, fruit shape, average fruit weight and plant height (Table 4). These agree with results found in okra morphological diversity studies by [16].

Table4. *Mean value of eight quantitative traits of okra accessions*

Accession no	First fruit producing node	Plant height (cm)	Fruit length (mm)	Fruit diameter (mm)	seeds per fruit	Total fruit no	Yield per plant (g)	Average fruit weight
23632-A	10	167	51	16	59.7	208	1345.1	6.47
240201-A	9	78	193	24	102.7	24	1160	48.33
240201-B	15	197	140	27	102.3	65	2491.7	38.33
240201-C	9	177	83	33	95.7	25	916.7	36.67
240203-A	12	198	90	32	62	68	2488.8	36.60
240203-B	12	225	87	27	62.3	30	814	27.13
240203-C	13	258	143	23	81	37	1147	31.00
240203-D	10	184	86	29	88.3	33	880	26.67
240203-E	7	116	107	30	73.7	12	444	37.00
240203-F	18	176	80.9	33	95.7	14	382.7	27.34
240583-A	5	169	118	24	120.3	91	2912	32.00
240583-B	3	82	120	22	97	69	1886	27.33
240585-A	8	205	152	32	120.3	15	925	61.67
240586-A	12	197	116	22	80.3	120	3040	25.33
240586-B	18	202	96	27	99	38	1152.7	30.33
240587-A	7	177	112	29	87.7	130	5763.3	44.33
240587-B	6	127	93	31	115	32	917.3	28.67
240591-A	8	164	112	33	105.7	70	2916.7	41.67
240591-B	10	158	113	30	102	38	1380.7	36.33
240591-C	8	83	115	27	70	11	326.3	29.66
240592-A	11	180	98	29	108.3	18	480	26.67
240599-A	12	231	183	43	101.7	75	3125	41.67
240599-B	17	246	127	27	106.7	16	586.7	36.67
240599-C	9	214	62	28	87.3	28	905.3	32.33
240600-A	5	133	107	28	109.3	142	4922.7	34.67
240601-A	25	185	73	30	84.7	30	778	25.93
240602-A	5	202	142	27	82.3	17	702.7	41.34
240609-A	5	127	155	22	102.3	114	3876	34.00
240609-B	6	187	127	30	79.7	8	333.3	41.66
240615-A	22	227.8	140	25	46	95	3515	37.00
240615-B	21	209	92.5	29.5	94.7	23	747.5	32.50
240784-A	6	106	136	25	89	11	370.3	33.66
240784-B	13	128	151	22	78.5	10	313.3	31.33
240786-A	11	186	62	21	31	48	608	12.67
240786-B	15	236	131	23	73.3	71	1727.7	24.33
240786-C	15	194	127	30	94	49	2123.3	43.33
240786-D	18	183	74	21	36	38	430.7	11.33
242444-A	5	85	58	21	35.5	38	354.7	9.33
242444-B	6	64	139	25	115.3	32	1280	40.00
242448-A	12	141	100	31	94.3	90	3270	36.33
242448-B	9	210	132	28	21.3	35	1677.7	47.93
242448-C	15	189	123	30	136.7	22	887.3	40.33
242451-A	8	165	129	30	89.7	69	3261.4	47.27
242451-B	5	160	133	22	87.5	28	765.3	27.33
242451-C	5	96	185	25	105.5	13	662.1	50.93
245157-A	13	191	128	25	112.3	39	1170	30.00
245157-B	7	175	136	31	108	23	950.7	41.33
245157-C	17	225	74	31	63	24	608	25.33
245161-A	14	145	110	36	54	157	6698.7	42.67
245162-B	12	209	130	27	64.7	156	5876	37.67

CONCLUSION

It was concluded that genetic variation existed among the germplasms in all the characters studied. Accessions 245161-A, 240587-A and 245162-B showed greater potential in terms of yield attributes as they outperformed the other germplasms, indicating their usefulness as promising genotypes. The crosses among the other clusters would probably exhibit high heterosis and may also produce new okra recombinants with the desired characters.

This present investigation has assessed the morphological variations and relationships among all okra accessions and suggests similarities within species. Variability observed in this study for traits may be indicative of differences in the genetic make-up of the germplasms considered.

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