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Variability, Heritability and Genetic Advance in Ethiopian Okra [*Abelmoschus esculentus* (L.) Monech] Collections for Tender Fruit Yield and Other Agro-morphological Traits

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Authors' contributions

This work was carried out in collaboration between all authors. Author DM design study, data collection, data analysis and wrote first draft of the manuscript. Author MW managed and gave correction study design, complete data analysis and gave correction. Author GE managed and gave correction for the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Okra is grown as a wild plant in Ethiopia. However, the variability of the crop is not well studied. Therefore, this study was initiated with the objectives of estimating variability, heritability and genetic advance for tender fruit yield and yield related traits of Ethiopian okra collections.

Design: Experiment was conducted at Werer Agricultural Research Center in 2014 growing season. Treatments consisted of 23 local okra collections and two exotic varieties using a simple lattice designs with five incomplete blocks. Data were recorded from 25 quantitative and 10 qualitative traits.

Results: Results revealed the presence of significant differences (p<0.05) among genotypes for all traits except for internode and peduncle length and number of epicalyx. All Ethiopian okra collections except one exhibited tender fruit yield advantages up to 28.67 t ha^{-1} (144.8%) over the

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introduced variety, which performed below the local collections for all traits except 100 seed weight. Genotypic coefficient of variation ranged from 3.08 (number of epicalyx per flower) to 27.19% (primary branches per plant), while phenotypic coefficient of variation values ranged between 5.5% (number of epicalyx per flower) and 34.14% (mature pod per plant). Heritability in broad sense and genetic advance ranged from 12% (internodes length) to 85.89% (fruit ridges) and 2.3% (internode length) to 47.69% (number of primary branches per plant), respectively. Both heritability and genetic advance values were high for tender fruit yield, fruit length and fruit weight and other yield related traits. Genotypes also varied in their qualitative traits except flower color.

Conclusion: This study results showed Ethiopia has wide variation among local and exotic okra genotypes. Therefore it is necessary to conduct other collection, characterization and evaluation study to determine the genetic variability within Ethiopian okra collections and exotic genotypes for variety development and further breeding program.

Keywords: Genotypic; phenotypic; coefficient of variation.

1. INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Monech] belongs to the family Malvaceae [1,2]. It is an annual plant, propagated by seeds and has duration of 90-100 days. It is grown in tropical and sub-tropical parts of the world [3]. Okra is a warm season vegetable [4,5] but severe frost damage pods [2]. It has high nutritive value [6] grown for fresh Table use or for processing [4], [5], its leaves might be cooked in a similar way to the greens beet root (*Beta vulgaris*), or dandelions (*Taraxacum officinale*) [2]. It possesses export potential [6]. Okra is native to North Eastern Africa in the area of Ethiopia and Sudan [7] flourished before date palm in the tropical climate of Ethiopia [8]. It is cultivated since ages and extensively disseminated from Africa to Asia, Southern Europe and America and currently grown in many countries [9]. In developing countries, it has crucial contribution for food security and income diversification [10].

Ethiopian has high genetic diversity in okra [11]. Moreover, breeders attempt in improving the crop in terms of developing high yielder and quality varieties from core collections is negligible. Even though, the potential contribution of okra for food security and export purpose is very well, under cultivation in Ethiopia are landraces. This finding will help to exploit the existing variations in breeding program and develop high yielding varieties with desirable quality attributes. There is no information about the variability of Ethiopian landraces or improved okra varieties of other countries. Therefore, it is necessary to generate genetic variability of okra landraces and morphological differences between okra landraces of Ethiopia and other countries' improved okra varieties. The objectives of this study were to estimate variability of tender fruit and various agro-morphological traits in Ethiopian okra collections and to estimate heritability and genetic advance of tender fruit and various agro morphological traits in Ethiopian okra collections.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted at Werer Agricultural Research Center (WARC) in 2014 growing season. The site is located in the Afar National Regional State which is 280 km in the northeast of Addis Ababa at an altitude of 740 m.a.s.l. The center is characterized by total annual rainfall of 564 mm, total annual average evapotranspiration of 2050 mm and light textured alluvial and black soil with a pH of 8.4. The mean annual temperature is 34.1℃ with a minimum of 18.9℃ and maximum of 38℃ [12].

2.2 Treatments and Experimental Design

Treatments consisted of 23 okra genotypes obtained from Ethiopian Biodiversity Institute (EBI) and two introduced varieties from Melkassa Agricultural Research Center. Genotypes were evaluated on field experiment at Werer Agricultural Research Center in simple lattice design with 5 x 5 in complete blocks and spaced 2 m between blocks. Three seeds per hill was sown at 1 x 0.60 m and thinned to one plant per hill when plants reached 3-4 leaves stage.

2.3 Data Collection

International Plant Genetic Resources Institute [13] descriptor list for okra species were used to record the quantitative and qualitative traits. Quantitative traits were recorded from 12 plants per row leaving the two plants grown as boarder plants. Mature fruit from two plants next to border plant in each row were used to estimate mature fruits characters and 100 seeds weight while the remaining 10 plants grown at each row used to record growth, phenology and tender fruits characters and to estimate tender fruit yield. Fruits were harvested two times per week and tender fruits characters were recorded in each harvest. Five randomly selected tender fruits from each harvest in each plot were used to record tender fruit characters.

2.4 Quantitative Traits

Phenology and growth traits recorded from days to 50% emergence, days to first flowering, days to 50% flowering, days to maturity, plant height (cm), stem diameter (mm), number of primary branches per stem, number of internodes, internodes length (cm), leaf length (cm), leaf width (cm) and number of epicalyxes. Fruit and yield traits were recorded from peduncle length (cm), fruit length (cm), fruit diameter (mm), average fruit weight (g), number of tender fruits per plant, number of ridges on fruit, yield per plot (kg), yield per hectare (t/ha), number and weight of matured pods per plant, dry weight of matured pods per plant (g/plant), number of seeds per pod and hundred seed weight (g).

2.5 Qualitative Traits

Such as plant habit, flower color, leaf color, leaf petiole color, pod color, stem color, leaf shape, fruit position on main stem, fruit pubescence and fruit shape were recorded according to International Plant Genetic Resources Institute [13] descriptor list for okra species.

2.6 Data Analysis

2.6.1 Analysis of variance

Data of 25 quantitative characters were subjected to analysis of variance (ANOVA) using SAS version 9.1 [14] to test the presence of significant differences among. Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad-sense heritability (H^2) and expected genetic advance as percentage to mean (GAM) were computed. Duncan's Multiple Range (DMRT) was employed to identify genotypes that are significantly different from each other. Descriptive statistic was used for qualitative traits data.

2.6.2 Phenotypic and genotypic variability

The variability of each quantitative trait was estimated by using mean, range, standard deviation, phenotypic and genotypic variances and coefficients of variation. The phenotypic and genotypic coefficient of variation was computed using the formula suggested [15]. PCV and GCV values were categorized as low, moderate, and high values as indicated [16].

2.6.3 Heritability and genetic advance

Broad sense heritability values were estimated using the formula adopted [17]. The heritability percentage was categorized as low, moderate and high as suggested [18]. Genetic advance in absolute unit (GA) and percent of the mean (GAM), assuming selection of superior 5% of the genotypes were estimated in accordance with the methods illustrated [19]. Genetic advance as percent of mean was estimated categorized as low, moderate and high as suggested [19].

3. RESULTS AND DISCUSSION

3.1 Quantitative Characters

3.1.1 Analysis of variance

Mean square of most of the characters studied revealed that genotypes showed highly significant ($P< 0.01$) differences on days to pod formation, days first flowering, days to 50% flowering, days to maturity, plant height, stem diameter, number of branch, leaf length, leaf width, number of epicalyx, fruit length, fruit diameter, fruit weight, fruit ridge, fruit yield, number of mature pod, fresh weight of mature pod and dry weight of mature pod. On other hand, genotypes exhibited significant ($P<0.05$) differences for days to 50% emergency, number of fruit per plant, number of seeds per pod and hundred seed weight. However, non-significant differences among genotypes were observed for internode length, number of number of epicalyx per flower and peduncle length characters. The analysis of variance result indicated the presence of variability among Ethiopian okra collections and introduced exotic varieties for most of the characters studied. This variability can be exploited through selection to improve the crop for desired traits. This result is in agreement with [20-24] who reported that significant differences among the tested okra genotypes for most of the studied traits.

3.1.2 Mean performances of genotypes and range

In this study result okra genotypes showed wide range of variability for most of the crop phenology, growth and fruit characters (Table 1).

The two exotic okra varieties had the lowest value phenology traits in this study indicating the varieties are early genotypes as compared to Ethiopian okra genotypes. Ethiopian okra collections exhibited higher mean values than the two exotic okra varieties on growth traits. This result suggested Ethiopian okra collections are vigorous growth and late mature genotypes as compared to the two introduced exotic okra varieties.

Mean values of genotypes were in the range of 25.65 and 71.67 g for fruit weight and 17.5 and 48.47 t ha^{-1} tender fruit yield. The genotypes had 50.02 g and 30.38 t ha^{-1} overall mean values for fruit weight and tender fruit yield per hectare, respectively. The highest mean values for fruit length, fruit diameter and fruit weight were recorded for the okra genotype collected from Gambella while highest number of fruit per plant and tender fruit yield per hectare exhibited for okra accessions obtained from Oromia (Wellega) and Benishangul (Metekel) regions respectively. The lowest tender fruit yield per hectare was obtained from introduced exotic variety. This result is supported [11] who reported that wide range of mean values for 20 quantitative traits of the okra accessions collected from Gambella Regional State of Ethiopia. This finding indicated that Ethiopia had wide okra genetic potential across different regions in the country and local collection genotypes showed wild nature of the crop indicating originated in Ethiopia. The observed high number of mature pods and pod weight as well as number of seeds per pod higher and 100 seed weight suggested that the higher chance of improving seeds yield of okra to produce high amount of edible oil quite at about 40% and seed also used as a substitute for coffee [25,26].

3.1.3 Estimates of variability components

Estimated variability components viz. phenotypic and genotypic variance, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), heritability in broad sense and genetic advance as percent of means (GA%) for 25 okra characters are presented (Table 1).

3.1.3.1 Phenotypic and genetic variances

The highest phenotypic variances were calculated for tender fruit yield ha^{-1} (6794.95) followed by plant height (2512.41) and number of seeds per pod (369.41) while the lowest value was recorded for days to emergence (0.2) followed by peduncle length (0.29) and number of epicalyx per flower (0.31). The genotypic variance ranged from 0.03 (internode length) to 4175.64 (tender fruit t ha^{-1}). Phenotypic variances were higher than the corresponding genotypic variances indicating predominance of environmental effects on the expression of these characters [27]. The phenotypic coefficient of variation (PCV) ranged between 5.5 % (number of epicalyx per flower) to 34.14 % (number of mature pod per plant) while genotypic coefficient of variation (GCV) ranged between 3.08 (number of epicalyx per flower) to 27.19 % (number of primary branches per plant). Traits exhibited phenotypic variances higher than their respective genotypic variances thus revealing the great significant influence of environmental factors in the expressions of the traits in okra genotypes and the apparent variation is not only due to the genotypes but also due to the influence of environment [28,22,29,27,30]

According to [16] PCV and GCV values greater than 20% are regarded as high, values between 10% and 20% to be medium whereas values less than 10% are considered to be low. Based on this delineation PCV and GCV recorded in this study, days to 50% emergence, inter node length, leaf length, leaf width and number of epicalyx had low values (<10%) for both phenotypic and genotypic coefficient of variations. The low PCV and GCV value of traits suggests the higher influence of environment on these traits thus; selection on the phenotypic basis would not be effective for the genetic improvement [31-34,29,27]. Contrarily, days to first flowering, days to 50% flowering, days to maturity, stem diameter, number of internodes per plant, peduncle length, fruit diameter, fruit ridges, number of seeds per pod and 100 seed weight had medium values for both coefficient of variations. Medium PCV and GCV value suggests that these characters are controlled more of by the genetic factors. Hence, these characters amenable to selection for further improvement [31,33,29,27]. On the other hand, number of branches per plant, fruit length, fruit yield ha^{-1}, number of mature pods per plant and fresh weight of mature pod per plant had high values (>20%) both PCV and GCV and the magnitude of the differences between the two were low. [27] who reported a narrow range of difference between PCV and GCV value of two traits while [11] who reported wide range difference between PCV and GCV value for most of these traits. [21,32,22,35] who suggested that the high phenotypic and genotypic coefficient of variation is an indication of the less influence of environmental factors in the expression of such traits and the higher possibility to improve them through selection breeding. The high PCV and GCV value with low magnitude of differences between the two genetic parameters indicates that the less environmental influence on the phenotypic expression. Hence, selection of desired character uses phenotypic value may be effective in improving the characters.

3.1.3.2 Estimate of broad sense heritability

This study estimate of heritability in broad sense ranged from 12% for internodes length to 85.89% for fruit ridges (Table 1). According to [18] heritability is categorized as low (0-30%), moderate (31-60%) and high > 60%. Accordingly, heritability estimate in broad sense was highest (>60%) for fruit ridges, fruit length, fruit weight, days to maturity, fruit diameter, days to 50% flowering, plant height, number of primary branches per plant, fresh weight of mature pod per plant, days to pod formation, leaf length, stem diameter and tender fruit yield from high to low. If heritability of a character is very high around 80% or more, selection for such character is fairly easy. This is because there would be a close correspondence between the genotypic and phenotypic variations due to relatively small contribution of the environment to the phenotype expression of the trait [36].

Moderate heritability values (31- 60%) were registered for number of mature pod per plant, days to first flowering, leaf width, dry weight of mature pod, number of seeds per plant, number of fruit per plant, number of inter nodes per plant, days to emergence, peduncle length, 100 seed weight and number of epicalyx. On the other hand, low broad sense heritability value was recorded for inter node length. When the heritability of a trait is medium to high, selection based on the individual level of performance allows relatively rapid rate of improvement. Very low heritability reveals the ineffectiveness of direct selection for the improvement of the traits while moderate heritability suggests improvement through selection [37,38].

3.1.3.3 Estimate of expected genetic advance

The genetic advance as the percentage of the mean (GAM) at 5% selection intensity is presented (Table 1). In this study, genetic advance ranged between 2.3% for internode length to 47.69% for number of primary branches per plant. Different result [22] who reported genetic advance had ranged from 15.13% for pod width at maturity to 66.30% for pod weight per plant, [39] also reported genetic advance in the ranged between 5.94% for number of epicalyxes to 198.15% for number of primary branches. The observed differences in results of different studies may be due to the different genotypes used in each experiment and the environmental differences where the genotypes were grown.

Genetic advance as percent mean was categorized as high (≥20%), moderate (10-20%) and low (0-10%) [19]. As per this suggestion, the highest (≥20%) genetic advance was observed for number of branches, fresh weight of mature pod, number of mature pod per plant, fruit length, fruit weight, plant height, fruit yield ha^{-1}, dry weight of mature pod, number of fruit per plant, days to 50% flowering, days to maturity and number of seeds per pod. This indicated that these traits are controlled more of by additive genes [40]. Moderate genetic advance (10-20%) were registered for days to pod formation , days to first flowering, stem diameter, number of internode, leaf length, leaf width, peduncle length, fruit diameter, hundred seed weight and fruit ridges. On the other hand, low (<10%) genetic advance was recorded for days to 50% emergence, inter node length, and number of epicalyx per flower. Similar result was reported by [23] for the traits that exhibited low genetic advance. This study result disagreed with finding [27] for the traits that exhibited moderate and low genetic advance for different traits.

Johnson et al. [19] Suggested that heritability estimates along with genetic advance were more useful in predicting the effect of selecting the best individual. High heritability along with high genetic advance as percent of the mean was obtained for days to 50% flowering, days to maturity, plant height, number of primary branches per plant, fruit length, fruit weight, tender fruit yield t ha^{-1}, and fresh weight of mature pod per plant. High heritability estimates along with genetic advance were more useful in predicting the effect of selecting the best individual. It provides better information than each parameters alone and also an expression of additive gene action and amenable for selection [19,40,6,41]. High heritability along with moderate genetic advance in days to pod formation, stem diameter, leaf length, fruit diameter, and fruit ridges while moderate values for both heritability and genetic advance for days to first flowering, leaf width, 100 seed weight and peduncle length. This result is supported by the finding [42-45] who reported that traits showed moderate values both of heritability and genetic advance might be amenable for selection and improvement of such traits.

This result revealed that moderate heritability coupled with low genetic advance was observed for days to 50% emergence, number of internode and number of epicalyx while both heritability and genetic advance values were low for internode length. This study result agreed with [42-44] who reported that selection is hardly possible to improve traits which exhibited low values both for heritability and genetic advance or moderate and low values combinations. This may be due to the higher influence of environment on the expression of the characters and limit the scope of improvement by selection due to the presence of non-additive (dominant and/or epistatic) type of gene action. Characters those possessing low heritability in association with low genetic advance special approaches i.e. hybridization or recurrent selection should be followed [34,45].

3.2 Qualitative Characters

This study result revealed the variations among okra accessions were noted for most of the qualitative morphological characters assessed (Table 2). Qualitative descriptors for okra are grouped into three main types; color, shape and other features. These descriptors tend to be highly subjective [46]. Okra genotypes characterized in this study showed a broad variation of traits which allows for the identification of promising accessions for okra breeding in Ethiopia (Table 2).

3.2.1 Growth Habit

This result showed that almost all genotypes had similar growth habits i.e. densely branched base (DBB) characters except accession T240609 and T240586 which had densely branched over and none branched growth habit respectively. Densely branched base (DBB) characters were 92% in frequency, densely branched over and non-branched growth habit 4% for each. Different result was reported [47] that 60% in occurrence for unique orthotrop axis (UOA) and densely branched all over (DBO) and densely branched base (DBB) characters were 20% in frequency. This variation in branching may be due to accession's has the ability of exhibiting different growth habit, which could be the result of selection or a natural adaptation mechanism. This result in agreement with [48] erect plant habit protects pods from decayed by irrigation water and from soil disease causing pathogen. Moreover, chance for a fruit to touch the ground is less and thus reduces fruit rot and it allows maximum and uniform exposure or distribution of all leaves and other vegetative parts for better interception of sunlight, and would also result in an increase in dry matter production and a subsequent increase in yield.

3.2.2 Stem color

Okra accessions showed three distinct stem color scored as '1' (Green), '2' (Green with red patch), "3" (red) and '4' (Purple). This result revealed that, 36% of the accessions had green stem, 48% had Green with red patch and 16% had purple stem color. Similar result was reported by [47] who found that, 56% green, 36% green with red veins and 10% purple. This result disagreed with finding [49] who reported that stem color ranged from green to red and red to purple color, [50] who reported that 60% purple and 40% green stem color.

3.2.3 Leaf characteristics

This study results showed two distinct leaf colors, totally green and green with red vein. In all, 80% of the okra accessions showed green leaf while 20% had green with red veins. Similar result was reported by [47] and [51] while disagreed with [28] who reported that uniform green leaf color for all the accessions. [52] who reported 3 color of leaf; light green, green and deep green. Genotypes showed three leaf petiole colors scored as '1' (Green), '2' (Red above only) and '3' (Red on both sides). From 25 accessions 16% produced green petiole, 76% produced red above only and 8% produced red on both sides. Different result reported [47] who reported that purple, green and green with red veins petiole color representing 48%, 44% and 8% respectively among the okra accessions, [28] who reported that 91.4% purple and 8.6% had green petiole color within 35 accessions. Okra accessions in this study showed four distinct leaf shape types among the 25 accessions scored as '2' (heart-shaped), '3' (broadly ovate),'4' (star shaped), and '7' (palmately lobed with serrated margins). This result revealed that accessions produced 48% heart shapes, 28% broadly ovate shape, 16% star shaped and 8% palmate 7. Similar result was reported by [47] for '2' (heart 2), '3' (heart 3),'4' (heart 4), and palmate '7' okra leaf shape.

Table 1. Estimates of range, mean and variability components of 25 okra genotypes evaluated at Werer in 2014

Traits	Range	Mean	SE	σ2g	σ2e	σ2p	GCV%	PCV%	H %	GA	GA%
Dem	5.0-6.0	5.28	0.34	0.09	0.11	0.20	5.67	8.51	44.33	0.41	7.77
DPF	25-44.5	39.32	2.37	14.13	5.63	19.76	9.56	11.30	71.50	6.55	16.65
DFF	37-65	53.34	5.11	36.82	26.12	62.94	11.38	14.87	58.50	9.56	17.92
DFPF	41.5-85	70.04	5.24	95.62	27.46	123.08	13.96	15.84	77.69	17.76	25.35
DM	49.7-100.97	82.84	5.23	121.87	27.30	149.17	13.33	14.74	81.70	20.55	24.81
PH	110.5-302.13	218.27	25.84	1844.70	667.71	2512.41	19.68	22.96	73.42	75.81	34.73
StD	19.78-37.19	31.65	2.99	14.95	8.93	23.88	12.22	15.44	62.60	6.30	19.91
NBr	2.6-13.61	7.45	1.25	4.10	1.55	5.65	27.19	31.93	72.51	3.55	47.69
NIn	24.55-51.36	40.95	5.06	20.78	25.58	46.36	11.13	16.63	44.82	6.29	15.35
InLe	4.16-6.64	5.36	0.77	0.03	0.59	0.25	3.23	9.32	12.00	0.12	2.30
LL	18.27-26.91	22.58	1.26	2.93	1.58	4.51	7.59	9.41	64.98	2.84	12.60
LWd	23.32-36.54	32.30	1.95	5.31	3.80	9.11	7.13	9.35	58.28	3.62	11.22
NEp	9.1-11.32	10.19	0.46	0.10	0.22	0.31	3.08	5.50	31.34	0.36	3.55
PL	1.94-3.71	2.79	0.43	0.10	0.18	0.29	11.56	19.22	36.21	0.40	14.33
FL	6.95-20.73	14.86	1.38	9.07	1.91	10.98	20.26	22.29	82.58	5.64	37.92
FD	19.96-36.44	29.15	1.52	9.30	2.30	11.60	10.46	11.68	80.15	5.62	19.29
FW	25.65-71.67	50.03	4.58	96.07	21.00	117.07	19.59	21.63	82.06	18.29	36.56
NFP	36.17-96.5	64.17	12.12	141.25	146.95	288.21	18.52	26.46	49.01	17.14	26.71
FR	5.21-8.54	7.64	0.32	0.62	0.10	0.73	10.34	11.16	85.89	1.51	19.75
FY	17.5-48.47	303.77	51.21	4175.64	2619.31	6794.95	21.27	27.14	61.45	104.35	34.35
NMP	20.05-59.75	32.08	6.98	71.15	48.75	119.91	26.30	34.14	59.34	13.39	41.73
FWMP	26.67-104.35	53.03	8.53	187.75	72.82	260.57	25.84	30.44	72.05	23.96	45.19
DWMP	6.01-20.58	14.60	2.58	8.25	6.66	14.91	19.67	26.45	55.32	4.40	30.14
NSP	48.9-122.3	99.99	13.30	192.62	176.79	369.41	13.88	19.22	52.14	20.65	20.65
SW	4.55-7.9	6.49	0.67	0.46	0.45	0.91	10.42	14.72	50.15	0.99	15.21

*Dem= Days to 50% Emergence, DPF= Days to first Pod Formation, DFF= Days to first flowering, DFPF = Days to 50 % flowering, DM= Days to maturity, PH= Plant height, StD= Stem diameter, NBr= No. of branch, NIn= No. of inter node, InLe= Inter node length, LL = Leaf length, LWd = Leaf width, NEp = No. of epicalyx, PL= Peduncle length, FL= Fruit length, FD= Fruit diameter, FW= Fruit weight, NFP= No. of fruit/plant, FR= Fruit ridge, FY= Fruit yield, NMP= No. of mature pod, FWMP= Fresh weight of mature pod, DWMP= Dry weight of mature pod,NSP= No. of seed/plant, SW= Seed weight, ,C.V. = Coefficient of variation **, *=Significant at 1% and 5%, respectively, NS= non-significant difference, SE=Standard error, phenotypic variance (σ2p) genotypic variance (σ2g) and environmental variance (σ2e), phenotypic coefficient of variations (PCV) and genotypic coefficient of variations (GCV), broad sense heritability (H%), expected genetic advance (GA) and genetic advance as percent of the (GA %) mean*

Table 2. Ten qualitative characters variations among 25 okra genotypes evaluated at Werer in 2014

No.	Genotypes	PHa	FC	LC	LPC	PC	SC	LSh	FPo	FSh	FPu
1	T240591	2	2	2	2	1	1	3	1	4	1
2	T245162	2	2	1	2	3	1	4	2	4	2
3	T240207	2	2	2	2	1	4	3	1	12	1
4	T242443	2	2	1	2	1	1	2	1	3	1
5	T240615	2	2	2	2	1	2	4	2	3	2
6	T240204	2	2	2	3	1	4	2	2	4	1
7	T240587	2	2	2	2	1	2	2	1	4	2
8	T245157	2	2	2	2	3	4	4	1	4	2
9	T242433	2	2	2	3	1	4	3	2	12	1
10	T240609	3	2	2	2	1	1	3	2	1	1
11	SOH714	2	2	2	2	1	2	7	1	3	2
12	T240786	2	2	1	2	1	1	3	2	14	1
13	T240599	2	2	2	1	1	2	2	1	3	1
14	T242448	2	2	2	2	3	1	2	1	15	1
15	T240583	2	2	1	2	1	2	2	1	3	1
16	T240592	2	2	2	2	3	2	2	2	1	2
17	SOH701	2	2	2	2	1	2	7	1	3	2
18	T240209	2	2	2	2	3	2	2	1	4	2
19	T240784	2	2	2	2	1	2	3	1	3	2
20	T242445	2	2	2	2	1	2	2	1	14	1
21	T240602	2	2	2	2	1	1	2	1	2	2
22	T92203	2	2	2	2	3	2	2	2	14	1
23	T240586	4	2	2	1	1	1	2	1	4	1
24	T2420203	2	2	2	1	3	2	4	1	4	2
25	T242451	2	2	1	1	1	1	3	1	12	1

PHa = Plant habit, FC = Flower color, LC= Leave color, LPC=Leave petiole color, PC= color, SC = color, LSh = Leave shape, FPo = Fruit position, FSh = Fruit shape, FPu= Fruit pubescence

3.2.4 Flower color

Okra accessions showed uniform in color of flowers. Flower color for all accessions scored as '2' was red color at both sides. Different result was reported by [47] from golden yellow to yellow, 60%, which represents more than half of the okra bore golden yellow-colored petals while the remaining 40% bore yellow-colored petals.

3.2.5 Fruit characteristics

Fruit color displayed two distinct variations that ranged from common green to green yellow colors. This study result revealed that, 72% of the accessions produced green fruits while 28% displayed green yellow fruits. Different result was reported by [47] showing that 72% of the accessions produced green fruits while 8% displayed green-with-red-spotted fruits, dark green to black fruits and green to yellow-fruits and small portion 4% of the accessions had tinged purple fruits, [28] reported that three distinct fruit color 42.85% green, 48.57% purple and 8.57% green yellow fruit color, [51] who reported that fruit color yellowish green was the most predominant fruit color while green and green with red patches were least observed among the accessions. Fruits' position on the main stem of the accessions showed 68% fruits positioned erect and 32% fruits positioned intermediate. Different result was reported by [47] who reported, 60% intermediate, 20% erect (upright) position, 12% horizontally while only 4% slightly falling and drooping (fruits in an almost upside down position), [28] who reported that 40% horizontal and 60% erect fruit position, [51] who reported erect, horizontal or pendulous. Fruit showed seven different types of shape from short and triangular to long straight or long curve. Its fruits with shape scores of 1, 2, 3, 4, 12, 14 and 15, according to the descriptor [13].

This study result showed accessions' bored, 8% fruit shape scored as '1', 4% fruit shaped scored as '2', 28% fruit shaped scored as '3', 32% fruit shaped scored as '4', 12% fruit shaped scored as '12', '14' respectively and 4% fruit shaped scored as '15'. Similar result was reported by [47]. Fruit pubescence showed two variations among the okra accessions. Fruit pubescence scored as '1' (smooth) and '2' (rough) among okra accessions. In this study 56% of all accessions bored smooth fruit and 44% of accessions bored rough fruit. Different result was reported by [47]. Results obtained in this study show that the majority of okra accessions had smooth fruits (scored as '1'), [28] who reported that three types 80% downy, 14.29% rough and 5.71% prickly fruit pubescence, [51] who reported that from prickly, slightly rough (smooth), downy to little hairs on fruits but with the majority having smooth fruits.

4. CONCLUSION

Analysis of variance revealed that genotypes had significant ($P< 0.05$) differences for all quantitative traits except for internodes length, number of epicalyx and peduncle length. Generally, the local collections had higher mean values for all quantitative characters than exotic varieties except that the introduced varieties were performing better than local collection for 100 seed weight. The okra genotypes showed a broad variation for qualitative traits. This observed morphological difference among genotypes will allow breeder to use as a marker to identify promising accessions for okra breeding in Ethiopia. The result of this study revealed a possibility of improving the crop through selection of high performing local collections because local collections performed better than higher performing improved exotic varieties (check) for all economically important traits considered except seed weight. This suggested the importance of further collection, maintaining and study of Ethiopian okra collections and varieties from different countries to exploit the genetic variability between Ethiopian okra collections and exotic varieties as well as for variety development of okra genotypes in the country.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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