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Morphological Characterization and Yield Traits Analysis in Some Selected Varieties of Okra (*Abelmoschus Esculentus* L. Moench)

Anwanobong Jonathan Eshiet[1*] and Ebiamadon Andi Brisibe[1,2,3]

[1]Plant Genetic Resources and Cell and Tissue Culture Research Laboratory, Department of Genetics and Biotechnology, University of Calabar, Calabar, Nigeria

[2]Department of Biological Sciences, Niger Delta University, Wilberforce Island, P.M.B. 71 Yenagoa, Nigeria

[3]Department of Pharmaceutical Microbiology and Biotechnology, Niger Delta University, Wilberforce Island, P.M.B. 71 Yenagoa, Nigeria

Abstract

Okra (*Abelmoschus esculentus* L. Moench) is an important all-season food crop widely grown throughout the tropical and semi-temperate regions of the world, for its tender green pods and leaves. Unfortunately, the crop rarely reaches its yield potential in most of these areas, primarily due to the use of unimproved cultivars and limited utilization of fertilizers and irrigation inputs. In addition, investments in breeding programmes that are aimed at enhancing its yield in the field are very limited. In the current study, therefore, some agronomic traits and yield components of four cultivars of okra (NHAe-47-4, V35, LD88 and a local variety), were compared in a field plot to aid in the development of selection strategies that could be used for okra improvement. The experiment was laid out in a completely randomized design with each accession, which served as the main factor, replicated five times and grown to maturity. Data collected from the four varieties included number of days to seedling emergence, number of days to flowering, plant height at flowering, number of leaves at flowering, mean number of pods per plant, pod length, mean number of seeds per pod, and mean weight of one hundred seeds, which were individually subjected to analysis of variance (ANOVA) test. The results demonstrated that the okra varieties differed significantly ($p<0.05$) in number of days to flowering (71.75-112 days), plant height at flowering (49.75-128 cm), number of leaves at flowering (7.50-19.33), pod length (3.23-6.83 cm) and one hundred seed weight (3.87-4.42g). There were, however, no significant ($p>0.05$) differences between the cultivars in terms of certain yield characters including average number of pods and average number of seeds per pod per plant. Taken together, the findings from this study will certainly be useful to okra breeders for appropriate selection strategies in cultivar improvement programmes.

Keywords: Accessions; Morphological traits; Okra yield; Selection; Variability

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is one of the most important and widely grown crops found throughout the tropical and sub-tropical regions of the world. It is an annual, erect growing, high yielding crop with numerous cultivars varying in plant height, degree of branching and pigmentation of the various parts, period of maturity, and pod shape and size. It is mainly grown for its tender green pods and leaves, which are cooked and commonly consumed as boiled vegetables [1]. The total commercial production of okra in the world was estimated at 4.8 million tons, with India and Nigeria being the predominant producers [2]. Other minor producers include Pakistan, Ghana, Egypt, Ethiopia, Iran, Iraq, Turkey, Brazil, Guyana, Japan and USA.

Okra constitutes a major economic crop in the West African sub-region owing to its vital importance as a component of various recipes in many local cuisines and delicacies. It has a considerable area under cultivation in Nigeria, for example, where it is traditionally cultivated as a rainy season crop by women often on a wide range of habitats including marginal land along roadsides, backyard gardens, and wastelands [3].

Nutritionally, tender green pods of okra are important sources of vitamins A, B_1, B_3, B_6, C and K, folic acid, potassium, magnesium, calcium and trace elements such as copper, manganese, iron, zinc, nickel, and iodine [4], which are often lacking in the diet of people in most developing countries. The young green pod is a nutritious vegetable containing 86.1% moisture, 9.7% carbohydrate, 2.2% protein, 0.2% fat, 1.0% fiber and 0.8% ash [5]. The tender green pods are also popular in most tropical countries due to their medicinal values as they contain very high levels of antioxidants including β-carotene, xanthin and lutein [6]. The mucilage substance derived from the wall of tender okra pods has been found to have a good alkaline pH, which contributes to its relieving effect in gastrointestinal ulcer by neutralizing digestive acids [7]. Okra also stabilizes blood sugar levels and helps to control the rate at which sugar is absorbed in the body. In addition, okra mucilage has also been reported as an effective tablet binder [8], plasma replacement and blood volume expander with enormous potential to improve renal function, alleviates renal diseases, and reduces proteinuria [9]. Mature seeds of okra on the other hand contain about 20% protein, with an amino acid profile similar to their composition in soybean. The seeds also contain about 20% oil that is similar in fatty acid composition to cotton seed oil [10] such that a very high potential presently exists for wide cultivation of okra for edible oil production [11].

In spite of its enormous economic benefits, okra rarely reaches its maximum yield potential due to several constraints. Some of the major factors limiting okra production, amongst several others, include the use of locally unimproved varieties, high incidence of pest and disease

***Corresponding author:** Anwanobong Jonathan Eshiet, Plant Genetic Resources and Cell and Tissue Culture Research Laboratory, Department of Genetics and Biotechnology, University of Calabar, Calabar, Nigeria E-mail: andibrisibe24@gmail.com

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burden, a narrow genetic base of existing varieties and sub-optimal planting densities [12-14]. As okra production plays a significant role in the rural economies of most tropical countries, for example, in Africa, where it is cultivated, more attention needs to be directed to the selection of high yielding cultivars for edible fruits and seeds as no serious effort has been paid to its improvement in international research programmes in the past. Meanwhile, a high degree of wide morphological variation is known to exist among various accessions of the crop, especially in the West African sub-region [15] where several landraces have been identified.

Improvement of okra requires a broad spectrum of genetic variability from which useful characters can be selected for developing broad-based populations to be used in hybridization programmes towards improvement. Therefore, to harness and utilize useful traits in okra genetic resources, it is essential to assemble, characterize and evaluate many useful varieties in order to maximize their utilization in any crop improvement programme [16], which is highly dependent on the amount of genetic variability that is available in the gene pool. Expectedly, any successful selection programme can only be achieved when there is valid information about the genetic variability of the traits of interest in the crop population. In other words, the availability of genetically based variations for morphological traits and yield-attributing characters is a prerequisite for the development of new cultivars. Driven by the desire to identify genetically good parents to utilize for hybridization to expand genetic variation for selection of superior genotypes in okra, the current study was conducted to investigate variability in some morphological traits and yield characteristics as a precursor to exploring the gene pool in order to formulate a suitable breeding strategy for the development of new cultivars.

Materials and Methods

Plant materials

Three cultivars of okra (NHAe-47-4, V_{35}, and LD88) were obtained courtesy of the National Institute of Horticultural Research (NIHORT), Ibadan, Nigeria. In addition, a local variety was procured from a subsistence farmer in Calabar, Nigeria (4.95° N, 8.32° E, 99 m.a.s.l.) and used in the experiment.

Experimental site, study design and agronomic operations

Seeds of the four okra accessions were soaked in water for 24 h and thereafter planted out in field plots at the Teaching and Research Farm, University of Calabar, Calabar, Nigeria, during the rainy season between June and August in 2012 and 2013, respectively, in a completely randomized design and their performance evaluated at various stages of growth. The different okra varieties served as the main factor with each treatment having 30 plants at a spacing of 100 cm × 30 cm in a plot that was replicated five times. Plots were detached from one another by path distance of 1 m within and 2 m between replications.

The area where the experimental plots were situated features lowland humid tropical conditions that is affected by two opposing air masses, with a bimodal pattern of rainfall with a rainy, wet season between April and October and a dry season from November to March that is characterized by a cold dry dusty wind (harmattan), which blows from the Sahara towards the western coast of Africa, especially in January and February. Temperatures within the experimental site were relatively constant throughout the year, with average highs usually ranging between 22 and 28°C (Table 1). There was also little variance in temperature between daytime and nighttime, as temperatures at night were generally only a few degrees lower than the high temperature that was typically observed during the daytime. In addition, the experimental site in Calabar averages about 3,900 mm of precipitation annually with a relative humidity (60-82%) that varies directly with the peaks of the bimodal rainfall. Radiation is fairly high and varies according to different periods of the year with values above 1,600 h per year being common [16].

Soil samples collected from different locations of the experimental site were oven-dried, ground and sieved through 2 mm sieve. The particle size distribution of the soil into sand, clay and silt contents was evaluated by a simplified soil size determination method [17]. The soil pH was determined using a potable pH metre in a 1:2.5 soil/water ratio while total nitrogen content was determined using the micro-kjeldahl method [18], and total phosphorus according to Bray 1 method [19]. Calcium and magnesium were determined using an atomic absorption spectrophotometer (model 372, Perkin Elmer) while potassium and sodium were evaluated by flame emission photometry. Organic carbon was determined according to Walkey and Black [20] and the present organic matter was estimated by multiplying the percent organic carbon with a factor 1.724.

Standard agronomic practices such as weeding, using a simple hoe, during the experimental period were adopted. Plants were tended carefully at the different stages of growth until maturity after which twenty stands were chosen at random from the central rows of each plot for the purpose of data collection on the following agronomic parameters:

(i) Number of days to seedling emergence

(ii) Number of days to flowering

(iii) Plant height at flowering (cm)

(iv) Number of leaves at flowering

(v) Number of pods per plant

(vi) Pod length (cm)

(vii) Average number of seeds per pod

(viii) Mean weight of one hundred (100) seeds (g)

Statistical analysis

Data on parameter means for each plot were pooled and subjected to analysis of variance (ANOVA) test for determination of significant differences among the four okra varieties evaluated. The least significant difference (LSD) test was used to separate significantly different means.

Results

Climatic and edaphic conditions

The intensity of rainfall during the study period (between June and August in 2012 and 2013, respectively) was quite heavy. The highest amount of rainfall and highest number of rainy days were usually recorded in July of either of the two years (Table 1). The average monthly temperature during the study period ranged between 22.1 and 28.7°C while the average relative humidity ranged from 76.3 to 77.2% for the two years (Table 1).

The physic-chemical properties of the soil at the experimental site are given in Table 2. While total nitrogen level was low (0.13 and 0.18%), however, the soil had a moderate level of phosphorus (5.9ppm and 5.8ppm) and a correspondingly low level of potassium (0.20 and

	Average monthly precipitation (mm)	Average monthly temperature (°C)		Average relative humidity (%)
2012		**Maximum**	**Minimum**	
June	3945 (18)*	27.0	22.1	78.4
July	4450 (20)	26.8	24.3	78.9
August	3940 (14)	26.0	22.4	76.3
2013				
June	3940 (17)	27.2	23.0	77.2
July	4390 (21)	28.1	22.4	77.5
August	3925 (12)	28.1	23.2	79.2

* Values in parentheses indicate number of rainy days.
Source: Teaching and Research Farm, University of Calabar, Calabar, Nigeria Meteorological Station

Table 1: Meteorological data for the experimental site in Calabar, Nigeria between June and August, 2013 and 2013.

0.29%) during the study period in 2012 and 2013, respectively. In addition, relatively moderate amounts of calcium and magnesium were also present in all the soil units examined. During the two years, organic matter was low (2.8 and 3.1%), while the pH in water was near neutral (Table 2).

Number of days to seedling emergence

Having noted the prevailing weather and soil conditions at the experimental site, attention was thereafter shifted to the growth parameters of the four okra varieties evaluated. First, there were no significant differences (p>0.05) in the mean number of days taken for seedlings of the four varieties of okra to emerge. Cultivars NHAe-47-4 and V_{35} took a mean number of 4.33 days to emerge while LD88 and the local variety took a mean of 4.20 and 3.25 days, respectively. These results are presented in Table 3.

Number of days to flowering

Number of days to flowering differed significantly (p<0.01) among the four varieties of okra evaluated. While NHAe-47-4 took the highest mean number of days (112) to flowering, LD88 and the local variety flowered at statistically the same mean number of days (91.8 and 71.75 days, respectively). As shown in Table 3, the local variety may be considered to have matured first and therefore stands a better chance of earlier returns than NHAe-47-4, V_{35} or LD88.

Plant height at flowering

The growth parameters were significantly affected by the okra variety. For example, plant growth measured as plant height (in cm) was different among the four okra varieties (Table 3) evaluated. The tallest plants at flowering were recorded for LD88, with a mean value of 128 cm. This was closely followed by those of NHAe-47-4 and V_{35} with a mean height of 119.67 cm and 118.15 cm, respectively, which were greater than that produced by plants from the local variety with a mean height of 49.75 cm. Mean square estimates for plant height at flowering showed significant (p <0.05) differences amongst the four okra varieties evaluated in the current study.

Number of leaves at flowering

Number of leaves also differed significantly (p <0.001) among the okra varieties at flowering. NHAe-47-4 had the highest mean number of leaves (19.33) at flowering, followed by V_{35} and LD88 with a mean value of 17.09 and 8.2, respectively, while the local variety had the least mean (7.5) number of leaves at flowering. NHAe-47-4 and V_{35} also produced significantly larger sizes of leaves.

Average number of pods per plant

The four varieties of okra evaluated in the current study had statistically the same (p >0.05) average number of pods per plant. NHAe-47-4, V_{35}, LD88 and the local variety had a mean number of 5.67, 4.45, 3.20 and 4.0 pods, respectively, per plant. Though there was no statistical difference in fresh fruit yield/plant between NHAe47-4 and V_{35}, however, NHAe47-4 and V_{35} in 2012 and 2013 produced more fruits than LD88 and the local variety. Comparatively, yields of NHAe47-4 and V_{35} did not differ significantly.

Pod length

Pod length differed significantly (p <0.01) among the four okra varieties. Pods of NHAe-47-4, V_{35} and LD88 were longer (6.38, 6.23 and 6.83 cm, respectively) than those of the local variety with a mean length of 3.23 cm.

Average number of seeds per pod

There were no significant (p >0.05) differences in the average number of seeds per pod among the four varieties of okra evaluated. NHAe-47-4, V_{35}, LD88 and the local variety had mean values of 34, 36.20, 33.4 and 43.50 seeds, respectively, per pod.

Parameter	Year (2012)	Year (2013)	Analytical method used
Organic matter (%)	2.8	3.1	Walkley-Black
Nitrogen (%)	0.13	0.18	Micro-Kjeldahl
P_2O_5 (ppm)	5.9	5.9	Flame photometer
K (%)	0.20	0.29	Oxidation
Ca (meq/100g)	4.84	5.20	AAS
Mg (meq/100g)	3.36	2.84	AAS
pH (H_2O)	6.7	6.6	pH meter
pH ($CaCl_2$)	5.8	5.8	pH meter
Soil particle size distribution (%)	sand 81, clay 8 and silt 11	sand 80, clay 8 and silt 12	Kettler *et al.*

ppm = parts per million; AAS = Atomic Absorption Spectrophotometer

Table 2: Physico-chemical properties of the soil at the experimental site in 2012 and 2013.

	Variety			
Parameter	**NHAe-47-4**	**V_{35}**	**LD88**	**Local variety**
Number of days to seedling emergence	$4.33^a \pm 0.67$	$4.33^a \pm 0.12$	$4.20^a \pm 0.48$	$3.25^a \pm 0.25$
Number of days to flowering	$116.45^a \pm 7.21$	$112.00^a \pm 8.33$	$91.80^b \pm 5.80$	$71.75^b \pm 4.71$
Plant height at flowering (cm)	$119.67^a \pm 8.21$	$118.15^a \pm 2.18$	$128.00^a \pm 23.84$	$49.75^b \pm 5.76$
Number of leaves at flowering	$19.33^a \pm 2.60$	$17.09^a \pm 1.12$	$8.20^b \pm 0.37$	$7.50^b \pm 0.65$
Average number of pods per plant	$5.67^a \pm 1.20$	$4.45^a \pm 1.20$	$3.20^a \pm 0.49$	$4.00^a \pm 0.41$
Pod length (cm)	$6.38^a \pm 1.13$	$6.23^a \pm 0.19$	$6.83^a \pm 0.60$	$3.23^b \pm 0.13$
Average number of seeds per pod	$34.00^a \pm 3.06$	$36.20^a \pm 0.05$	$33.40^a \pm 2.62$	$43.50^a \pm 7.17$
One hundred seed weight (g)	$4.25^b \pm 0.10$	$4.22^b \pm 0.82$	$4.42^a \pm 0.02$	$3.87^c \pm 0.02$

*Means with same superscript letters in each horizontal array are not significantly (P>0.05) different from one another

Table 3: Growth components and yield attributes in four varieties of okra (*Abelmoscus esculentus*).

Mean weight of one hundred seeds

The four varieties differed significantly (p <0.05) in 100 seed weight. While LD88 had the highest weight of 100 seeds (4.42 g), followed by NHAe-47-4 (4.25 g), V_{35} (4.22 g) the local variety had the least weight of a 100 seeds at 3.87 g. These results are presented in Table 3.

Discussion

The results of this study are indicative of the fact that the four varieties of okra evaluated were significantly different in some of the morphological traits but definitely not in most of the yield attributes except for one hundred (100) seed weight. The observation of significant differences in some of the traits is an indication that genetic diversity do exist among the varieties, thereby providing a basis for selection. This is in consonance with what has been reported earlier [21-23], where it was demonstrated that such genetic variability existed amongst okra varieties evaluated in the respective studies on genetic diversity among some okra germplasm.

In this study, the four varieties differed significantly in the number of days to flowering. It has been demonstrated that on a general basis, early flowering is detrimental for overall productivity in okra as the source to sink ratio will be potentially limited for effective photosynthesis [24]. Differences in flowering periods among the varieties in the current study imply that their maturity periods vary. Depending on the desire of the breeder or farmer, appropriate selection can thus be made for either early or late maturing plants.

Plant height of the varieties evaluated was also significantly different. The height of the plant can potentially affect yield as those that are taller are usually more prone to windstorms in the event of heavy seasonal or monsoonal rains. Plant height at flowering and fruiting are of particular interest for breeding programmes because the presence of plants with tall and thin stems will increase the rate of lodging near harvesting and this could lead to loss of dry matter and subsequent decrease in fruit yield. Number of days to bud emergence and plant height at maturity, among other agronomic characters, are some of the most variable traits that are necessary for selection programmes aimed at improving desirable traits in okra [25]. It is suggestive from this that number of days to and plant height at flowering are controlled by the same genetic variables [26,27]. Consequently, selection for dwarf stature may thus be made on the local variety as it was shorter than the other three varieties evaluated in the current study (Table 3).

Variation was also observed in the number of leaves, pod length and one hundred seed weight of the cultivars. Since leaves serve as the sites for photosynthetic activities in any plant, an increase or a decrease in their number may have very serious implications for production of assimilates in the crop. Consequently, a greater number of them in any particular variety would be assumed to produce a better crop yield due to the higher photosynthetic capacity that is brought to bear by an increased leaf area index and a resultant higher fraction of intercepted radiation and its utilization efficiency [21]. The better performance of NHAe47-4 and V_{35} in the current study, amongst other reasons, can thus be attributed to the higher number of leaves as well as their larger leaf sizes (Table 3), which may have enabled these cultivars to produce greater assimilates during their photosynthetic activities. This position is reinforced by the suggestion that NHAe47-4 is a variety bred by NIHORT in Nigeria, which is characterized by early flowering with thick fresh pods, short to medium plant height, deeply lobed leaves and profuse branching [28]. This suggestion is further supported when the published data is examined for the reasons behind the yield increases that have been reported for this variety. Strictly speaking, NHAe47-4 is very often known to produce higher yield than most local and exotic varieties including V_{35} (an exotic variety that has the same morphological features as those of NHAe47-4), as it is well suited to the local environment in Nigeria. Also one hundred seed weight is usually associated with pod yield and other yield attributes in a seed bearing plant. An increased number of leaves and a higher seed weight would thus be important selection criteria in the improvement of okra accessions.

The tender green pod is often considered as the most important and economical part of okra production since it is utilized as vegetable throughout the world. Consequently, fruit length in consonance with pod number and pod weight are the most important determinants of production or yield. Thus, selection based on these characters will be quite beneficial in okra breeding programmes, especially since three amongst the four cultivars evaluated in this study showed identical results for fruit length, which were statistically similar (Table 3). A similar pattern has been identified earlier, where it was reported that the Sabz pari variety of okra had the most promising result for maximum pod length in that study [29]. These results are also in conformity with others reported earlier[25,30-33] , where statistically different results for pod length amongst the different okra cultivars evaluated were observed.

Overall, there were no significant variations in the number of days to seedling emergence, average number of pods per plant and average number of seeds per pod amongst the four okra varieties evaluated. This might be on account of the genetic characteristics of the cultivars. It is most probable that the genes controlling these character traits are dominant in all the varieties, which could have accounted for the absence of variation expressed amongst them. Consequently, these three traits cannot be considered as effective strategies while formulating selection indices for the improvement of okra.

Conclusion

It is apparent on the basis of the findings from this study that NHAe-47-4 and V_{35} okra varieties will be useful in breeding programmes where a higher crop yield is the dominant desire. Conversely, the local okra variety would be preferable where shorter and early maturing plants are desired since it had a comparatively shorter stature and an earlier flowering date than NHAe-47-4, V_{35} or LD88. However, further studies need to be conducted with a wider range of local and exotic okra varieties to enable a more robust selection of useful accessions for breeding programmes, especially on yield improvement.

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