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Selection and Genetic Variation in Okra (*Abelmoschus esculentus L.*) Genotypes in a Rainforest Agroecology

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ABSTRACT

Okra is a very essential crop, particularly for culinary purpose and as a source of bioactive metabolites of medical significance. However, genotypic influence and environmental factors affect the production and accessibility of okra. Hence, this study was conducted to investigate genetic variation in okra and determine its effect on growth and yield characteristics of okra genotypes in a rainforest agroecology. The field experiment was carried out at the Organic Farm of Federal College of Agriculture, Ibadan, Nigeria. Ten okra varieties were laid out in a Randomized Complete Block Design (RCBD) replicated three times. Data were collected on growth and yield components and subjected to correlation and Principal Component Analyses (PCA) to determine the extent of genetic variation and relevance for selection indices. The results revealed that N42/F5/32 had the highest height (56.67 cm), HNIKU had the highest number of leaves (12.00), NHAC 47-4 expressed highest pod weight/fruit (6.17 g) while N42/F5/32 recorded the highest fruit yield/hectare. Plant height, pod weight/fruit and 100-seed weight expressed strong positive correlation among the parameters studied, and they positively correlated with fruit yield per hectare. The PCA revealed maximum genetic diversity among okra genotypes; PC-1, PC-2, PC-3 and PC-4 had eigenvalues more than 1 with variability scores of 3.00, 1.27, 1.18 and 1.01, respectively. Overall, variety N42/F5/32 expressed superior okra yield and should be selected for farmers in rainforest agroecology or similar environment.

Keywords

Agroecology, Genetic variation, Okra, Growth and yield components.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a self-pollinating crop belonging to the family Malvaceae. Nigeria is the second largest producer of okra in the world accounting for about 15.4% of the world production [1,2]. They are cherished as important sources of dietary minerals and vitamins, and its consumption has extended to countries in Europe and North America. Okra seeds contain 18-20 percent oil and 20-23 percent crude protein while the leaves serve as feeds for animals [1]. It is rich in dietary fiber, minerals (Sodium, Calcium, Sodium, Potassium, Zinc, and Iron), vitamins (A, B, and C), seed oil and folate [3]. It has also been reported that okra fruits are excellent sources of mucilage, antioxidants as well as other bioactive metabolites [4] and as such, have several medicinal, health and industrial applications [5].

Production and accessibility of okra has recently been on the decline [6]. This is not unconnected to complex interactions between biotic and abiotic stressors, as well as scarcity of improved okra genotypes with superior performance and more desirable end-user traits than available varieties [7]. Most of the okra produced and consumed in Africa are grown in intercrop systems as a measure to augment its low productivity and production is predominantly in the hands of peasant farmers. Therefore, low yield associated with okra production may be largely attributable to the poor yielding genotypes used by these farmers [8,9].

The screening or development of new varieties with better adaptation and yield potential is crucial for sustainable production of okra. Genetic variation in okra is a necessary requirement to improve the crop [9]. Classification of a range of genetic variability among genotypes is pivotal to the maintenance and further acquisition of germplasm resources, especially, as accessions from diverse origins are needed as parents' stocks for improved varieties [8]. Crop improvement through successful selection programme is only achieved using valid information about the correlation and genetic variability of traits of interest, which is dependent on the degree of genetic variability in plant population [10].

Fruit yield in okra is a complex trait governed by several interrelated yield components. The significance of number of pods per plant, early flowering and fruit weight in determining fruit yield has been widely reported [11,12]. To mitigate poor yield, enhance accessibility and optimize okra production to meet industrial demand, improved okra genotypes are recurrently developed by research institutes and agricultural facilities globally [13]. However, these genotypes sometimes perform below expectation when adopted by local farmers, owing to environmental influence, genetic diversity, paucity of follow-up data on the yield potentials of released cultivars and reports on genetic diversity among okra genotypes [7,10]. Consequently, this study aims to investigate genetic variations in okra and select superior genotype based on the influence of genetic differences on growth and yield characteristics of okra in a rainforest agroecology.

Materials and Methods

Source of Planting Materials and Experimental Site

Ten varieties of okra seeds, proposed for cultivation in derived savannah and rainforest agroecology, were acquired from the National Horticultural Research Institute (NIHORT), Ibadan (Table 1). This included the NHOLAK genotype, officially released by NIHORT for farmers in Ibadan. Field experiment was conducted in May 2024 at the Organic Farm of Federal College of Agriculture, Ibadan (OF-FCAIB), Nigeria. The experimental site lies between latitude 7°24′3″ and longitude 3°51′9″. The mean annual rainfall was 250 mm and classified under the sub-humid tropical zone. The rainfall pattern is bimodal, soil type of OF-FCAIB was sandy and sufficient in nutrient for okra production. The maximum temperature was 30.50°C while the minimum was 21.02°C.

Agronomic Practices and Experiment Design

The land was ploughed mechanically and subsequently harrowed manually. Seed beds were prepared for okra seedlings weeding was carried out fortnightly until crop maturity. The experiment was designed in a randomized complete block (RCBD) with 10 treatments (genotypes) in 3 replications (blocks). The plot size was 15 m × 7 m with 0.5 m inter row spacing, 0.3 m between the plots and a sowing depth of 1 - 2 cm.

Data Collection

Data was collected on plant height at maturity (cm), number of leaves per plant, Days to 95% maturity, number of fruits per plant, pod weight per fruit (g), pod weight per plant (g), hundred seed weight (g) and fruit yield per hectare (kg/ha) [12,14].

Table 1: List of the ten okra varieties used for the study.

S/N	Variety	Source
1	N42/F5/32	NIHORT
2	NHOLAK	NIHORT
3	HNIKU	NIHORT
4	NHB1	NIHORT
5	FS/P13	NIHORT
6	NA21/F5/28	NIHORT
7	NH21/F5/40	NIHORT
8	NH21/F5/25	NIHORT
9	NHAC 47-4	NIHORT
10	LD88	NIHORT

NIHORT: National Horticultural Research Institute.

Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) and the means were separated using Duncan Multiple Range Test (DMRT) at 5% probability level. The relationship among the characters evaluated for all the varieties was also studied using correlation coefficients [15], which were generated through correlation analysis. Principal Component Analysis (PCA) was also used to determine the extent of genetic variation and percentage similarity within the varieties [16]. Eigenvalues and factor scores obtained from PCA were used to determine the relative discriminative power of the axes and the associated characters.

Results and Discussion

Agronomic Performance of Okra Varieties

As presented in Table 2, N42/F5/32 had the highest plant height (56.67 cm), this was however comparable to the height recorded for other varieties but significantly higher ($p<0.05$) than the height (30.00) expressed by NH21/F5/40. Number of leaves ranged from 12.00 – 8.33, HNIKU had the highest number of leaves (12.00) while NA21/F5/28 produced the least number of leaves (8.33). The genotypes produced similar number of fruits per plant, however, HNIKU had the highest number of fruits per plant (5.33). Days to 95% maturity ranged from 96.00 – 79.67; NHB1 (96.00), LD88 (93.33), N42/F5/32 (91.67), NH21/F5/25 (91.33) and HNIKU (90.67) all expressed longer days to maturity than other varieties.

NHAC 47-4 expressed the highest pod weight per fruit (6.17g), which was not significantly higher than the pod weight of N42/F5/32. Also, pod weight/plant ranged from 83.10g – 36.33g. N42/F5/32 had the highest pod weight per plant (83.10g), and this was significantly higher than pod weight per plant expressed by other okra varieties. LD88 had the highest 100-seed weight (8.87g), which was followed by (and not significantly different from) seed weight (8.73g) of NHOLAK. Six of the 10 genotypes produced low fruit yield, less than 3.00 kg/hectare. However, N42/F5/32 expressed an outstanding yield performance with the highest fruit yield per hectare of 5.82kg (Table 1). This was significantly higher than the yield observed for other genotypes considered in this study.

The result suggests that dissimilar okra genotypes exhibited significantly different growth and yield characteristics. This observation disagrees with the report of Umeri et al. [2] who investigated growth and yield of seven varieties of okra in a freshwater swamp forest agroecology. The local varieties performed better than other varieties, but the overall agronomic properties were not significantly different [2]. This difference in outcomes could have been as a result of environmental distinctions between a freshwater swamp forest and rainforest agroecology. Locations and weather variability could interfere with genomic expressions in plant and significantly affect both growth and yield performances of crops [17].

Sheferie et al. [18] demonstrated, through a single-year field study, that the inherent range of genetic differences in okra could significantly influence seedling emergence (especially, days to attain 50% seedling emergence) and performance of okra in the field. Okra genome codes for seed hardness, a peculiar feature that significantly affects emergence and performance, this could necessitate seed priming to establish okra seedlings for better performance [18]. Adediran et al. [15] also underscores the influence of agroecology in the adoption of crop genotypes by local farmers.

Correlation Coefficient among Characters Evaluated in Okra Varieties

There was positive, significant correlation between plant height and pod weight per fruit (0.00365), as well as 100-seed weight (0.071) (Table 3). This indicates that there was strong positive relationship among the three characters and hence, indicative of significant interaction between the development of okra pod as well as their seed mass and final height at which the entire crop life cycle was completed. Number of leaves positively correlated to pod weight per fruit (0.00605), pod weight per plant (0.04467), 100-seed weight (0.01643) and fruit yield (0.04826). Consequently, these parameters appeared to have promoted the development of one another through the growth and yield phases of okra genotypes.

In a similar study, 75 okra genotypes were examined by Kumar et al. [19] for genetic divergence for fruit yield and its contributing traits. The path coefficient study revealed that okra fruit weight exhibited the highest impact on fruit yield per plant; this was followed by number of fruits produced per plant. In addition, days to 50 per cent flowering, first fruiting node, hundred seed weight and leaf width also correlated with fruit yield [19]. In another study investigating growth and seed yield responses of okra to different rates of compost in a tropical environment, correlation analysis also showed that there was a strong, positive and significant relationship between seeds production and total seed yield [20]. However, negative correlation was observed between days to 95 maturity and weight of hundred seeds, this showed that varieties with shorter days to maturity tend to produce more yield in terms of seed mass. Although, negatively correlated characters are rarely selected for hybridization of desirable traits, those with insignificant correlations are generally disregarded in selection for crop or variety improvement [21].

Principal Component Analysis of Characters Evaluated in Okra

Principal Component Analysis (PCA) showed maximum genetic diversity among okra genotypes (Table 4). The analysis unveiled that PC-I to PC-4 had eigenvalues more than one and exhibited 2.9989, 1.2661, 1.1759 and 1.0053 variability respectively: consequently, establishing these traits as inter-correlated, quantitative dependent variables. Interestingly, it was revealed that in cumulative proportion of measured traits, involvement of PC-1 and PC-2 was 4.26; both contributing over 53% variance. PC-I exhibited negative factor loadings for all the measured traits. Factor loading in PC-2 was positive for four of the important loaded parameters.

It was equally evident (in PC-2) that maximum contribution for factor loadings was recorded for day to 95% maturity, followed by number of leaves. Highest positive contributor in PC-3 was plant height. The only character that contributed in PC-4 was 100-seed weight. Moreover, association between eigenvalue and PC was elaborated using a scree plot (Figure 1). The scree plot highlights a graphical representation of overall variance contribution of each principal component. The variance contribution declined from PC-2 to PC-8, with PC-1 having the highest eigenvalue, while PCs 5 to 8 expressed values lower than 1.

Table 2: Agronomic performance of the evaluated okra varieties.

Varieties	Plant height (cm)	Number of leaves	Number of fruit	Days to 95% maturity	Pod weight per fruit (g)	Pod weight per plant (g)	100 seed weight (g)	Fruit yield per hectare (kg)
N42/F5/32	56.67^{a}	9.33^{bc}	4.00^{a}	91.67^{ab}	5.00^{ab}	83.10^{a}	8.47^{a}	5.82^{a}
NHOLAK	38.67^{ab}	10.33^{abc}	3.67^{a}	86.33^{bc}	4.20^{b}	38.53^{d}	8.73^{a}	2.70^{d}
HNIKU	49.00^{ab}	12.00^{a}	5.33^{a}	90.67^{abc}	4.37^{b}	47.13^{cd}	6.00^{d}	3.30^{cd}
NHB1	34.33^{ab}	10.33^{abc}	4.00^{a}	96.00^{a}	4.60^{b}	41.90^{cd}	6.93^{bcd}	2.91^{cd}
FS/P13	45.33^{ab}	10.00^{abc}	3.67^{a}	86.00^{c}	3.57^{b}	36.33^{d}	6.93^{bcd}	2.56^{d}
NA21/F5/28	41.00^{ab}	8.33^{c}	3.33^{a}	87.00^{bc}	4.73^{ab}	36.43^{d}	7.60^{abc}	2.55^{d}
NH21/F5/40	30.00^{b}	10.00^{abc}	4.00^{a}	86.33^{bc}	4.37^{b}	38.97^{d}	6.50^{cd}	2.73^{d}
NH21/F5/25	52.00^{ab}	11.67^{ab}	4.00^{a}	91.33^{abc}	3.70^{b}	36.53^{d}	8.07^{ab}	2.55^{d}
NHAC 47-4	35.67^{ab}	11.33^{ab}	4.67^{a}	79.67^{d}	6.17^{a}	53.70^{bc}	8.07^{ab}	3.76^{cb}
LD88	44.00^{ab}	11.33^{ab}	4.33^{a}	93.33^{a}	4.60^{b}	66.43^{b}	8.87^{a}	4.65^{b}
LSD	23.84	2.37	2.02	5.63	1.47	13.19	1.50	0.92

Means followed by the same alphabet along the column for each character are not different from one another at 5% level of significance.

Table 3: Correlation coefficient among characters evaluated in Okra varieties.

Characters	Plant height	Number of leaves	Number Fruit/plant	Days to 95% maturity	Pod weight Per fruit	Pod weight Per plant	100 seed weight	Fruit yield
Plant height	-	-0.20414	0.27728	0.06784	0.00365*	0.29965	0.07108*	0.2984
Number of leaves			-0.12711*	0.17729	0.00605*	0.04467*	0.01643*	0.04826*
Number of Fruit/plant				-0.01489*	0.44062	0.38000	0.08678*	0.37566
Days-95%- maturity					-0.14858	0.26887	-0.04664*	0.26678
Pod Weight/fruit						-0.052155	0.22628	0.51824
Pod Weight/plant							-0.40982	0.99986
100 seed weight								-0.41137
Fruit yield								

Similar finding was reported by Chernet et al. [22], who showed positive association of morphological and yield traits in different principal components evaluated in tomato germplasm. Abhilash *et al*. (2023) also investigated yield-attributing traits in 55 okra accessions and reported first six principal components with eigenvalues above 1, which accounted for over 75.52% of the total variability observed in the considered traits. The variance contribution of principal components could be used as a foundation for defining and implementing subsequent okra breeding initiatives for the genotypes used in this study.

Table 4: Principal component analysis of characters evaluated in okra.

Statistics	PC1	PC2	PC3	PC4
Standard deviation	1.7317	1.1252	1.0844	1.0026
Proportion of variance	0.3749	0.1583	0.147	0.1257
Cumulative proportion	0.3749	0.5331	0.6801	0.8058
Eigenvalue	2.9989	1.2661	1.1759	1.0053
Plant height (cm)	-0.2208	-0.2024	**0.6534**	-0.26
Number of leaves	-0.0387	**0.5941**	**-0.4685**	-0.2285
Number of fruit/plant	**-0.3364**	-0.1022	-0.1153	-0.6456
Day to 95% maturity	-0.1244	**0.7013**	**0.3647**	0.0288
Pod weight/fruit (g)	**-0.3813**	-0.2713	**-0.4159**	-0.1464
Pod weight/plant (g)	**-0.5452**	0.0945	0.0666	0.1395
100-seed weight (g)	-0.2868	-0.1101	-0.1604	**0.6334**
Fruit yield/hectare (t/ha)	**-0.5443**	0.0962	0.0652	0.1432

Bolded characters recorded significant contribution to the variation with values above 0.300.

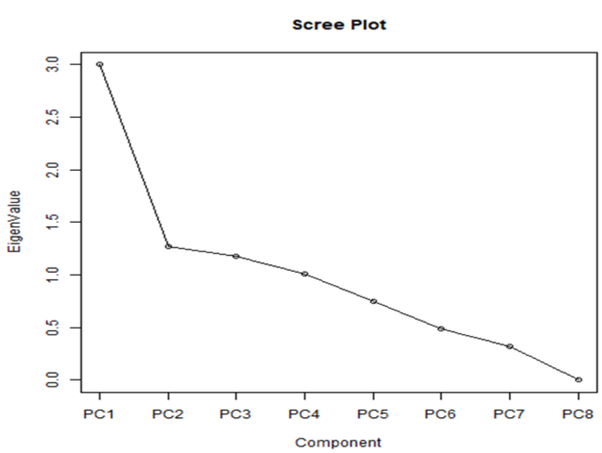

Figure 1: Association between eigenvalue and Principal Component (PC).

Principal component analysis (PCA) of 25 qualitative and quantitative traits in another 260 okra accessions revealed four distinct clusters, indicating a broad genetic base [23]. These observations provide significant insights for breeding programs targeting improved okra varieties with enhanced growth, yield and resilience, thereby contributing to sustainable, environment-specific production of okra.

Conclusion

This research investigated genetic variations among 10 okra genotypes and determined the influence of genetic peculiarities on the growth and yield characteristics of okra in a rainforest agroecology. Variance analysis revealed highly significant differences in plant height, number of leaves, number of fruit, days to 95% maturity, pod weight per fruit, pod weight per plant, 100-seed weight and fruit yield per hectare. This suggests that the characters should be considered in okra improvement programme. Positive correlation among days to 95% maturity, number of leaves per plant and 100-seed weight indicated direct effect on okra fruit yield. The outcome contributes to the importance of screening crop genotypes released for farmers in each environment, to identify best performing genotypes for subsequent improvement programme. The genotype, N42/F5/32, expressed superior yield performance and would be selected for disease resistance studies, fortification of nutrient composition through precision cultivation, stability assay and subsequent breeding programmes at the Federal College of Agriculture, Ibadan. Recommendation of stable, resistant, high-yielding genotypes to farmers in different agroecological zones will significantly improve okra production, its accessibility and industrial utilization.

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