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Genetic variability and heritability in cultivated okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract

Twenty-nine okra accessions from different agro-ecological regions in Nigeria were grown during the rainy and dry seasons, between 2006 and 2007 at Abeokuta (derived savanah) and Ilishan (rainforest) and assessed to determine their genetic variability, heritability and genetic advance from eight yield related characters. The experiment was laid out in a Randomized Complete Block Design with five replications. There was high genotypic coefficient of variability, % broad-sense heritability and genetic advance in traits such as plant height (26.2, 90.7, 51.5), fresh pod length (23.9, 98.5, 48.8), fresh pod width (23.9, 98.5, 48.8), mature pod length (28.6, 98.5, 52.3), branching per plant (29.3, 82.3, 54.8) and pod weight per plant (33.9, 90.0, 63.3), suggesting the effect of additive genes and reliability of selection based on phenotype of these traits for crop improvement. The positive and significant phenotypic and genotypic correlation between plant height at maturity, fresh pod width, seeds per pod and pods per plant, branches per plant with seed weight per plant and pod weight per plant, suggests that selection on the basis of the phenotype of these characters will lead to high seed and pod yield in okra.

Additional key words: accession; derived savannah; genetic advance; genotypic correlation; Nigeria; phenotype.

Resumen

Variabilidad y heredabilidad genética en quingombó [*Abelmoschus esculentus* (L.) Moench] cultivado

Se cultivaron 29 accesiones de quingombó de diferentes regiones agro-ecológicas en Nigeria durante las estaciones lluviosas y secas de 2006 y 2007 en Abeokuta (derivada de la sabana) y Ilishan (selva) y se evaluaron para determinar la variabilidad genética, heredabilidad y avance genético de ocho caracteres relacionados con el rendimiento. El experimento fue en bloques completos al azar con cinco repeticiones. Hubo un alto coeficiente de variabilidad genotípica, % de heredabilidad en sentido amplio y avance genético en caracteres como altura de planta (26,2; 90,7; 51,5, respectivamente), longitud de vaina fresca (23,9; 98,5; 48,8), ancho de vaina fresca (23,9; 98,5; 48,8), longitud de vaina madura (28,6; 98,5; 52,3), ramas por planta (29,3; 82,3; 54,8) y peso de vaina por planta (33,9; 90,0; 63,3), lo que sugiere un efecto aditivo de genes y fiabilidad de selección basada en el fenotipo de estos caracteres para mejorar los cultivos. La correlación positiva y significativa, fenotípica y genotípica entre la altura de la planta en la madurez, el ancho de la vaina fresca, las semillas por vaina, las vainas por planta y las ramas por planta, con el peso de las semillas por planta y el peso de las vainas por planta, sugiere que la selección en el quingombó basada en el fenotipo de estos caracteres conducirá a un alto rendimiento en semillas y vainas.

Palabras clave adicionales: accesión; avance genético; correlación genotípica; fenotipo; Nigeria; sabana.

Introduction

Okra, [*Abelmoschus esculentus* (L) Moench] is a Dicotyledonae, belonging to the order Malvales, family Malvaceae and genus *Abelmoschus* (syn. *Hibiscus*) (Schippers, 2000). It is an important vegetable crop widely grown in the tropical and subtropical regions of the world (Tindall, 1983). The plant is a robust, erect, annual herb, ranging 1-2 m in height, with simple leaves, which are alternate and palmately veined.

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In West Africa, the plant is cultivated as a vegetable crop and the leaves, buds and flowers are often eaten. The leaves and fruit produce a mucilaginous substance, which makes most African delicacies especially soup, slimy and thick, thereby making consumption of bulky food such as eba, pounded yam (fufu) etc. easy. The leaves are sometimes used as cattle feed. Fresh okra fruit contains 2.1 g protein, 0.2 g fat, 8 g carbohydrate, 36 calories, 1.7 g fiber, 175.2 mg minerals, and 88 mL of water per 100 g of edible portion (Tindall, 1983; Berry *et al.*, 1988). Its edible leaf per 100 g contains about 81 mL water, 56 calories, 11 g carbohydrate and 4.4 g protein. In addition to its usefulness as a vegetable crop, okra fruit is useful medicinally, in curing ulcers and suppressing the pains and effects of haemorrhoids. The mucilage has been used as a plasma replacement or blood volume expander (Siemonsma & Kouame, 2004). Reports from research in China revealed that an alcohol extract from *Abelmoschus* leaves can eliminate oxygen free radicals, alleviate renal tubular-interstitial diseases, improve renal function and reduce proteinuria (Siemonsma & Kouame, 2004).

Okra is a high yielding crop under a good cropping system, with yield varying from 4,480 to 5,500 kg ha^{-1} of green pods (Ayodele, 1993). Its usefulness has enhanced world production to an estimated 6 million tons per year (Siemonsma & Kouame, 2004). However, the yield potential of okra has been grossly affected by poor cropping system, use of crude implement, poor soil, pests and diseases (Siemonsma & Kouame, 2004).

Generally the success of any crop improvement program largely depends on the magnitude of genetic variability, genetic advance, character association, direct and indirect effects on yield and yield attributes. Genetic diversity is important for selection of parents to recover transgressive segregants (Kiran Patro & Ravisankar, 2004). Genetic variability and heritability studies have been done in a wide range of crops in other breeding programs, *e.g.* okra (Bisht *et al.,* 1996), kenaf (Mostofa *et al.,* 2002), roselle (Ibrahim & Hussein, 2006), tomato (Foolad *et al.,* 2006), cowpea (Aremu *et al.,* 2007) or eggplant (Islam & Uddin, 2009). Determination of heritability estimates, using different methods (Obilana & Fakorede, 1981; Wray and Visscher, 2008) will provide information on the proportion of phenotypic variance that is due to genetic factors for different traits but heritability estimate alone is not a sufficient measure of the level of possible genetic progress that might arise not even when the most outstanding individuals are selected in a breeding programme. The value of heritability estimates is enhanced when used together with the selection differential or genetic advance (Ibrahim & Hussein, 2006). Information on the amount and direction of association between yield and yield related characteristics is important for rapid progress in selection and genetic improvement of a crop (Asish *et al.,* 2008). This will indicate the interrelationship between two or more plant characters and yield, providing suitable means for indirect selection for yield. This study is aimed to determine which of traits associated with the fruit and seed yield in okra have high heritability and high genetic advance so they can be used for indirect selection to improve okra pod and seed yield.

Material and methods

The current study was conducted between 2006 and 2007, in two seasons (rainy and dry season) each at the teaching and research farms of University of Agriculture Abeokuta and Babcock University Ilishan-Remo (Ikeja, Lagos, Nigeria located on 7º9'N, 3º30'E and 6º5'N, 6º43'E, respectively). Each experiment was laid out in a Randomized Complete Block Design (RCBD) with five replications. Each replication consisted of 29 single rows of each genotype. Each row was 8 m long with intra-row spacing 30 cm and inter-row spacing of 60 cm. Each row contained 25 plants.

Data collection

Data was collected on the following traits and scored according to the descriptors for okra (Charrier, 1984):

— Days to flowering (day): determined as the average number of days to flowering of competitive plants in the inner row.

Abbreviations used: IAR&T (Institute of Agricultural Research and Training, Ibadan); BU (Babcock University Ilishan-Remo); GA (Genetic Advance); GCV (Genotypic Coefficient of Variation); NACGRAB (National Centre for Genetic Resources and Biotechnology); NIHORT (National Horticultural Research Institute, Ibadan); PCV (Phenotypic Coefficient of Variation); RCBD (Randomized Complete Block Design); UNAAB (University of Agriculture, Abeokuta).

— Plant height at maturity (cm): measured from soil level to the tip of the plant when more than half of the pods per plant begin to dry.

— Branches per plant: 1-3 (weak), 4-5 (medium), 6-7 (strong).

— Mature pod width (cm): measured as circumference of mature pod.

— Mature pod length (cm): measured from the tip of pod to the pedicel attachment when pods attain physiological maturity.

— Seeds per pod: determined at maturity by counting the total number of seeds in ten randomly selected pods.

— Number of pods per plant: average number of pods from nine randomly selected competitive plants from inner plants.

— Pod weight per plant (g): average value of the summation of the weighed mature harvested pods from nine inner plants at seed stage.

— Seed weight per plant (g): determined by bulking and weighing of the dry seeds as sample from the bulk of accessions.

Data analysis

The plot means for each character in each environment was subjected to analysis of variance using the method of Steel & Torrie (1980). The yield and its component from each of the environment were used to determine the genotypic and phenotypic variances according to Prasad *et al*. (1981). The variance components was used to compute the genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV), broadsense heritability and expected genetic advance, according to the methods of Burton (1952), Johnson *et al*. (1955) and Kumar *et al*. (1985).

Results

Combined mean performance and range of twenty-nine genotypes of okra in four environments

The combined mean performance of the 29 okra accessions in nine yield related traits in four environments indicated that there were significant differences among the 29 okra accessions with respect to all the measured characters except in mature pod width (Table 1). Days to flowering ranged between 43.8 for Ila gidi and 58 days for NH88/82. For plant height at maturity, NH99/28 maintained the highest values of 132.55 cm, while CCN2005/1 had the least values 38.56 cm. Plant height at maturity ranged between 38.56 cm and 132.55 cm. The number of branches per plant ranged between 1.2 for Clemson spineless and 3.40 for V45-2 and LD88/1-8-16-2. For mature pod length, NH99/9 recorded the shortest mean values of 7.45 cm, while CCN2005/1 recorded the highest value of 20.42 cm. Mature pod width ranged from 2.86 cm for CCN2005/1 and 3.88 cm for V-35. Seeds per pod varied significantly amongst genotypes and was highest in NH88/1-8-16-2 (100.35), followed by OLA K2005 (99.4), LD88/1-8-11-1 (99.20), LD88/1-8-5-2 (96.74), NH47-4 (97.85), 45-4-5(96.75), whereas the least value was recorded for Ila Gidi (69.15). Pod per plant was highest in OSADEP Purple tail with mean value of 5.20, while the least value was 2.45 for CCN2005/1. The highest yielding genotype in terms of pod weight per plant was Jokoso with mean value of (40.83 g), while the least was Clemson spineless with mean value of (14.97 cm). Meanwhile, seed weight per plant ranged from (22.18 g) for OSADEP Purple tail and 7.74 cm for Clemson spineless.

Means, estimates of genotypic and phenotypic variance, genotypic and phenotype coefficient of variation, broad-sense heritability and genetic advance

Expectedly, phenotypic variances were generally higher than the genotypic variances in all the characters studied (Table 2). The highest phenotypic and genotypic variances in all the characters considered were recorded in plant height at maturity (1,242.95 and 1,127.00 respectively). High phenotypic and genotypic variances were also observed in seeds per pod (138.06 and 91.50) and pod weight per plant (94.34 and 84.92 respectively). The PCV generally ranged between 8.49% for mature pod width and 35.76% for pod weight per plant respectively. Similarly, the GCV ranged between 7.90% for mature pod width and 33.927% for pod weight per plant. Generally heritability in the broad-sense estimate varied from 65.57% for seed weight per plant and 98.51% for mature pod length. Similarly genetic advance had a general range between 15.13% for pod width at maturity and 66.30% for pod weight per plant. A joint consideration of genotypic coefficient of variability,

Table 1. Combined mean performance of twenty-nine okra accessions for fruit and seed yield related characters from the four environments

Accession	Days to flowering	Plant height at maturity (cm)	Branches per plant	Mature pod length (cm)	Mature pod width (cm)	Seeds per pod	Pods per plant	Pod weight per plant (g)	Seed weight per plant (g)
Lady's finger	55.05	97.61	3.05	7.67	3.67	89.95	4.25	38.27	19.42
Ola-Kg 1-6-5	55.65	118.81	3.20	8.02	3.39	99.25	3.95	28.74	16.33
OLA V1	49.70	82.27	2.65	9.86	3.25	88.75	4.15	34.68	19.46
OLA K2005	54.80	128.82	2.80	9.72	3.09	99.40	4.20	31.12	17.58
Ila Gidi	43,80	65.82	2.45	9.50	3.08	69.15	4.10	30.51	16.15
LD88/1-8-11-1	55.70	103.58	3.00	7.98	3.06	99.20	4.40	30.02	21.26
LD88/1-8-5-2	56.75	107.45	3.05	8.35	3.14	96.74	4.55	35.71	21.64
Short mouth Ibarapa	45.30	81.71	1.95	9.73	3.07	72.75	4.45	31.54	17.51
Clemson spineless	45.30	53.41	1.20	11.60	3.80	74.25	2.65	14.97	7.74
V45-2	45.30	62.09	3.40	10.27	3.41	95.90	4.60	38.88	21.25
NH99/DA	46.95	109.17	3.00	7.67	3.21	89.05	4.80	32.42	19.14
LD88/1-8-16-2	54.00	108.18	3.40	8.07	3.13	96.25	4.55	27.96	17.69
OLA 99/13	56.10	109.94	2.40	7.90	3.16	95.70	4.20	35.57	20.81
OSADEP purple tail	50.45	127.78	2.50	7.86	3.32	79.45	5.20	39.12	22.18
45-4-5	53.05	97.13	2.85	8.62	3.53	96.75	3.80	33.30	18.21
Enugu 1	51.90	63.02	3.10	9.09	3.24	93.75	4.70	32.08	17.98
47-4	54.55	104.50	2.70	8.21	3.25	97.85	4.15	33.27	19.86
V_2-OYO	50.35	73.45	2.35	7.77	3.25	86.90	3.55	27.59	14.91
V-35	56.85	83.74	2.85	8.88	3.88	94.05	3.60	29.54	15.78
OLA 3 Local	47.5	90.05	2.25	8.49	3.01	88.35	3.90	26.96	16.11
OK 20	54.34	97.32	2.75	8.20	3.05	94.80	4.10	24.71	15.82
NH 99/28	52.85	132.55	2.35	10.85	2.30	95.25	3.90	35.48	19.65
Dajofolowo	50.05	92.02	2.70	9.01	3.25	91.35	3.95	35.06	19.14
CCN 2005/2	53.60	70.07	2.25	9.47	3.00	83.45	3.70	26.45	15.76
NH88/1-8-16-2	50.05	102.38	2.85	7.87	3.08	100.35	4.65	32.40	20.32
NH88/82	58.00	79.21	2.35	8.60	3.15	94.84	4.25	34.64	20.11
NH99/9	51.25	94.13	2.65	7.45	3.20	95.00	4.80	33.78	20.69
Jokoso	54.25	93.36	3.00	8.34	3.54	90.40	3.50	40.83	19.76
CCN2005/1	44.00	38.56	1.35	20.42	2.86	91.35	2.45	23.12	10.92
Mean	51.74	91.83	2.63	9.15	3.25	91.046	4.11	31.68	18.04
LSD	2.23	12.13	0.62	0.54	0.66	8.21	0.93	9.28	5.24

broad-sense heritability estimates and genetic advance revealed that plant height at maturity (26.2, 90.7, 51.5%, respectively), pod length at maturity (25.6, 98.5, 52.3%), number of branches per plant (29.3, 82.3, 54.8%), and pod weight per plant (33.9, 90.0, 66.3%) combined high GCV, heritability and high genetic advance, whereas days to flowering (10.8, 95.7, 21.3%) combined high heritability with moderate GCV and genetic advance.

Correlation between characters

Phenotypic and genotypic correlation was estimated on accessions from nine characters of okra and presented in Table 3. Generally the inter-character association followed the same trend except for character association with mature pod length. The results show that estimates of genotypic correlation coefficients were generally higher than their corresponding phenotypic correlation coefficients. At the phenotypic and genotypic level, high and significant positive association was observed between seed weight and all other characters except mature pod length which had a non-significant phenotypic correlation and a significant genotypic correlation. Similarly, at the phenotypic and genotypic levels significant and positive association was also observed between pod weight and all other characters except mature pod length which showed non-significant correlation. However, at the phenotypic and genotypic levels significant and positive

Table 2. General mean, estimate of phenotypic and genotypic variance, phenotypic and genotypic coefficient of variability, broad sense heritability and genetic advance expressed for twenty-nine okra accessions

Character	Grand mean	Phenotypic variance	Genotypic variance	Environmental variance	Phenotypic coefficient of variability	Genotypic coefficient of variability	Broad-sense heritability	Genetic advance %
Days to flowering	68.17	56.90	54.60	2.30	11.06	10.84	95.96	21.87
Plant height at maturity (cm)	127.98	1,242.95	1,127.00	115.95	27.55	26.23	90.67	51.45
Mature pod length (cm)	9.8	6.38	6.28	0.10	25.77	25.58	98.51	52.30
Mature pod width (cm)	3.26	0.08	0.07	0.01	8.49	7.90	86.48	15.13
Seeds per pod	99.51	138.06	91.50	46.56	11.81	9.61	66.27	16.12
Pods per plant	3.88	0.43	0.31	0.12	16.90	14.40	72.60	25.28
Branches per plant	3.22	1.09	0.90	0.19	32.33	29.33	82.28	54.80
Pod weight per plant (g)	27.16	94.34	84.92	9.42	35.76	33.92	90.01	66.30
Seed weight per plant (g)	17.72	24.54	16.09	8.45	27.96	22.64	65.57	37.77

association was observed between branches per plant and the remaining characters except mature pod length which showed negative significant correlation. Similarly, at phenotypic and genotypic levels significant positive association was also observed between pods per plant and all other characters except mature pod length which showed a negative significant correlation. At the phenotypic and genotypic levels seeds per pod also showed significant positive correlation with all the characters except mature pod length which also showed a non-significant correlation. Mature pod width also showed a positive and significant correlation with all other characters except mature pod length at the phenotypic and genotypic levels. However, at the phenotypic and genotypic levels mature pod length also had negative and significant correlation with days to flowering and plant height at maturity. Meanwhile, plant height at maturity showed a significant and positive correlation with days to flowering at phenotypic and genotypic level.

Discussion

The PCV was higher than the GCV in all the characters across the four environments. The difference between PCV and GCV is probably accounted for by the environmental effects. Generally, the high PCV and GCV observed in number of branches per plant, total number of fruits per plant, total weight of fruits per plant is an indication of high variability for these traits (Vijay & Manohar, 1990). There was high heritability estimates for days to flowering, plant height at maturity, mature pod length, pod weight per plant. This suggests that the genotypic factor had greater effect on the phenotypic performance of these traits. Hence selection based on the phenotypic performance of these characters will be reliable and effective.

Similarly, days to flowering, plant height at maturity, mature pod length, pod weight per plant, and number of branches per plant, with high estimates of heritability, GCV and GA, may be good predictors of seed yield in crops according to Murtadha *et al*. (2004). This agrees with the finding of Ibrahim & Hussein (2006). Furthermore, the high estimates of heritability, GA and GCV recorded in plant height at maturity, days to flowering, mature pod length, number of branches per plant and pod weight per plant, could be explained by additive gene action, hence their improvement can be done through mass selection (Randhawa & Sharmar, 1972; Ibrahim & Hussein, 2006). For inter-character association estimates to be repeatable such character must have both significant genotypic and phenotypic correlations and any selection based on this is reliable (Ibrahim & Hussein, 2006). The higher genotypic correlation coefficient over phenotypic correlation coefficient observed in almost all the characters suggests very strong inherent association between various characters at genetic level. This is similar to the report of Ibrahim & Hussein (2006) on roselle (*Hibiscus sabdariffa*). The positive and significant phenotypic and genotypic correlation between plant height at maturity, seeds per pod and pods per plant, days to flowering and branches per plant with seed weight per plant and pod weight per plant, across the environments is a strong indication that these traits are major factors in relation to seed yield per plant and pod yield per plant. This suggests that selection directed towards these characters will be effective in ensuring seed and pod yield in okra. This also agrees partly to the report of Adeniji & Aremu (2007).

Table 3. Phenotypic and genotypic correlation coefficients among eight characters of 29 okra accessions

Character[1]		Plant height at maturity	Mature pod length	Mature pod width	Seeds per pod	Pods per plant	Branches per plant	Pod weight per plant	Seed weight per plant
Days to flowering	P	0.57**	–0.38**	0.48**	0.65**	0.28**	0.36**	0.48**	0.56**
	G	0.61**	–0.39**	0.53**	0.83**	0.33**	0.40**	0.53**	0.71**
Plant height at maturity	P		–0.53**	0.36**	0.47**	0.49**	0.47**	0.19*	0.42**
	G		–0.57**	0.37**	0.60**	0.55**	0.54**	0.17*	0.53**
Mature pod length	P			–0.22**	–0.08	–0.39**	–0.26**	0.07	–0.13
	G			–0.25**	–0.10	–0.47**	–0.28**	0.06	–0.18*
Mature pod width	P				0.23**	0.29**	0.40**	0.39**	0.29**
	G				0.28**	0.32**	0.47**	0.44**	0.37**
Seeds per pod	P					0.15	0.31**	0.35**	0.46**
	G					0.17*	0.43**	0.39**	0.56**
Pods per plant	P						0.57**	0.47**	0.59**
	G						0.69**	0.43**	0.66**
Branches per plant	P							0.55**	0.58**
	G							0.63**	0.77**
Pod weight per plant	P								0.78**
	G								0.88**

[1] P = Phenotypic correlation; G= Genotypic correlation. *, ** significant at 5% and 1% level of probability, n = 144, Degree of freedom = n – 2 = 142.

However, the negative correlation at the phenotypic and genotypic level between seed weight per plant, pod weight per plant and mature pod length suggests that any selection to improve okra seed and pod yield directed towards the phenotype of mature pod length will not be effective. The negative correlation between seed yield and pod length (mature) may be due to the direct negative relationship between pod length and pods per plant and suggests the influence of environmental factors limiting the yield (Ibrahim & Hussein, 2006). This agrees with the report of Malik *et al.* (2000). Furthermore, the strong positive significant genotypic and phenotypic correlations between days to flowering and seed weight per plant suggests that selection based on late flowering of okra will lead to increase in seed yield.

This study therefore concludes that plant height at maturity, number of branches per plant and pod weight per plant with high heritability, genetic advance and significantly and positively associated to seed yield at the phenotypic and genotypic level should be considered during selection for okra pod and seed yield.

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