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VARIATION AND HERITABILITY OF SIXTEEN CHARACTERS IN WEST AFRICAN OKRA, *ABELMOSCHUS CAILLEI* (A. CHEV.) STEVELS

ABSTRACT

Genotypic and phenotypic variances, genotypic and phenotypic coefficients of variation, heritability and genetic advance were estimated for 16 agronomical characters in West African okra for two seasons, using 25 West African okra lines of diverse origin. Considerable differences were observed for some characters in the two seasons. Number of days to flowering, number of leaves at flowering, plant height at flowering and number of pods at branches showed seasonal differences. The estimates of genotypic coefficients of variation (gcv) in the two seasons were close in many cases. The gcv values ranged from 1.41 for number of days to flowering in the early season to 68.63 for number of branches per plant in the late season planting. Heritability estimates ranged from 5.02% for number of leaves at flowering in the early season to 99.54% for weight of matured pod during the early season. This study highlighted the significance of genotype-environment interaction in the breeding programmes of West African okra. The relatively large genotypic coefficient of variation, heritability estimates and genetic advance for number of pods at stem, number of pods per plant, number of branches per plant, weight of matured pods and seed yield per plant, were indicative of likely effectiveness of selection for such characters.

Key words: West African okra; heritability; Genetic variability; Cultivars; Seasons.

INTRODUCTION

West African okra (*Abelmoschus caillei* (A. Chev.) Stevels) is a self pollinated an allopolyploid hybrid between *Abelmoschus esculentus* and *Abelmoschus manihot* (Sinnadurai, 1977). It is an important vegetable crop in Nigeria and many tropical and sub-tropical countries. On a worldwide basis, okra pro-

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duction as fresh fruit vegetable was estimated at 4.8 million tonnes, but most of the production was in India (70%) followed by Nigeria (15%), Pakistan (2%), Ghana (2%) and Iraq (1.7%) (Gulsen *et al.,* 2007). According to Grubben and Denton (2004), A *esculentus,* the conventional okra account for 90-95% of the global production while West African okra contributes the remaining 5-10%. Also according to the estimates of the authors, okra production in West and Central Africa has reached about 500,000 – 600,000 tonnes annually with West African okra making up half of this amount. The potential of the seeds as a new source of plasma replacement or blood volume expender was emphasized by Siemonsma and Kouame, (2004)

Although, West African okra is a popular vegetable in Nigeria, most of the okra pods available are harvested from wild, unselected plants with associated low pod yields and poor pod qualities. Whether West African okra will become major source of medicinally useful compounds in the tropics depends largely on the breeding and selection

Progress in breeding for economic characters that are quantitative in inheritance and therefore subject to environmental variability are determined by the nature and magnitude of genetic variability. Such characters presents difficulty in selection programmes since heritable variation is often masked by non heritable variation. Hence, the need to partition overall variability into heritable and non heritable components with the aid of genetic parameters such as genotypic and phenotypic coefficients of variation and heritability.

Considerable variation has been reported in some West African okra characters by some authors such as Ariyo (1993), Omonhinmin and Osawani (2005), Adeniji *et al.,* (2007) and Aladele *et al.,* (2008). Heritability estimates have been observed for length and width of pods by Adeniji *et al.,* (2007) and for pod and seed yield by Ariyo (1993). The present study estimated the variation heritability and genetic advance from 16 characters by utilizing data from single row plots. The work was conducted at the Federal University of Agriculture, Abeokuta, Nigeria during the early and late season of 2006/2007.

MATERIALS AND METHODS

Germplasm collection

Twenty-five West African okra accessions were collected from the genebank of National Center for Genetic Resources and Biotechnology (NACGRAB), Centre for Environment, Renewable Natural Resources Management, and Development (CENRAD), Ibadan and from several locations in Ekiti and Ondo states of Nigeria as listed in Table 1

Table 1

Code names, Source and specific morphological characters of the accessions used

Genotype Code Names	Source	Stem colour	Stem pubescence	Pod colour	Pod pubescence	Pod position
CEN 010	CENRAD	LP	Glabrous	DG	Downy	Erect
NGAE-96-012-2	NACGRAB	Purple	Conspicuous	LG	Pricky	SE
NGAE-96-012-3	NACGRAB	Green	Glabrous	GwR	Downy	SE
CEN 016	CENRAD	Purple	SP	DG	Prickly	SE
CEN 012	CENRAD	Purple	Conspicuous	Green	Prickly	Horizontal
CEN 007	CENRAD	Green	Glabrous	YwG	Downy	SE
NGAE-96-04	NACGRAB	Green	Glabrous	Green	SP	SE
CEN 015	CENRAD	LP	Glabrous	DG	Downy	SE
OAA96/175-5328	NACGRAB	Green	SP	DG	Prickly	Horizontal
AGA79/066-5780	NACGRAB	Purple	Glabrous	DG	Downy	Horizontal
ADO-EKITI-1	Ekiti state	Green	Glabrous	DG	Prickly	Horizontal
CEN 001	CENRAD	Purple	Glabrous	GwY	Prickly	Horizontal
CEN 009	CENRAD	LP	Glabrous	Green	Downy	Horizontal
NGAE-96-0062-2	NACGRAB	Purple	Glabrous	Green	Downy	Horizontal
NGAE-96-0066	NACGRAB	Purple	Glabrous	Green	SP	Horizontal
NGAE-96-0061	NACGRAB	LP	Glabrous	GwR	SP	SE
NGAE-96-0060	NACGRAB	Purple	Glabrous	Green	Downy	Horizontal
NGAE-96-0064	NACGRAB	PwG	SP	GwR	Prickly	Horizontal
NGAE-96-0063	NACGRAB	DR	SP	Green	Prickly	Erect
CEN 005	CENRAD	GwP	Glabrous	YG	SP	Horizontal
NGAE-96-0065	NACGRAB	PwG	Glabrous	Green	Downy	Horizontal
OJA OBA-2	Ondo state	Green	Glabrous	YG	SP	Horizontal
OJA OBA-3	Ondo state	Green	Glabrous	Green	SP	Erect
ADO-EKITI-3	Ekiti state	Purple	Glabrous	Green	Downy	ST
NGAE-96-0067	NACGRAB	GwP	Glabrous	GwR	SP	Horizontal

LG-Light Green, ***GwP***-Green with Purple, ***PwG***- Purple with Green, ***DG***- Dark Green, ***LP***- Light Purple, ***GwR*** - Green with Red, ***YG***-Yellowish Green, ***GwY***-Green with Yellow, ***DGwR***-Dark Green with Red, ***SP***- Slightly prickly, ***SE***-Semi-Erect

Experimental sites:

The field trial was conducted at the Teaching and Research Farm and Seed Laboratory of the Federal University of Agriculture, Abeokuta (FUNAAB). Geographically, FUNAAB is situated in the derived savanna zone on latitude $7^{0}9^{1}$N and the longitude $3^{0}21^{1}$E. It experiences approximately eight months (March-October) of bimodal rainfall and has about five months (November-March) of dry season each year with slight irregularity in rainfall distribution pattern. The soil of the experimental soil is classified as an underlain basement complex rock with quartz schist, coarse grained and fine grained granite and gneiss as parent material (Aiboni, 2001)

Land preparation was done mechanically using the tractor and plough for soil tillage. For upland planting, Ploughing was done twice followed by harrowing while at the Inland valley site, land preparation was done manually. The first planting was done in July 2006; the second planting was done in December 2006. Each of the plantings was laid out in a Randomized Complete Block Design (RCBD) with three replications and in single row plots. A block consisted of 25 rows of all the genotypes and each row was 6m long. The rows were 1m apart while the between plant distance in each row was 0.6m. A total of twelve plants were maintained per row and data were taken on ten plants within each row leaving the two border plants for border effect.

Seeds were sown three per hole to a depth of about 1cm into the soil and later thinned to one plant her hill on establishment. Weeding was carried out manually at 3 weeks after planting and as necessary to keep the plot weed free. Following thinning, fertilizer application of a compound fertilizer in the form of NPK 20:10:10 was applied by drilling at the recommended rate of 60kg/ha to enhance the growth of the crop.

In each of the sites, Cypermethrin (Cymbush at the rate of 50 ml/10 litre of water) was applied from 4 weeks after planting (WAP) and subsequently carried out fortnightly. Pyretroid (karate EC) was applied twice during the reproductive phase at 20 ml/15 l to reduce the damage on the crop by insect pests. The fruits collected per experimental row had their seeds extracted and air dried.

Data collection and analysis

From ten competitive plants in each row, data were collected on the following characters

i. Days to Flowering: This was determined as the average of the number of days to flowering of ten plants in the inner rows.
ii. Plant height at flowering [cm]: This was measured from the soil level to the tip of the plant.
iii. Number of pods on the branches: Number of pods on the branches was determined by counting.

iv. Number of pods on the main stem: Number of pods on the main stem was determined by counting.
v. Number of pods per plant: Average value of the total of pods from ten competitive plants from inner rows was obtained.
vi. Number of leaves per plant: Average value of number of leaves on the main stem and all the branches in the plants in the inner rows.
vii. Number of branches per plant: Number of branches on the main stem was counted.
viii. Matured plant height [cm]: This was taken by measuring the plant from the soil level to the tip of the main stem when the plants had shed their leaves and other floral parts and the shoot had dried up.
ix. Length of matured pod [cm]: This was measured by randomly harvesting ten pods per plant. This was measured from the tip of the pod to the point of attachment of the pedicle, when the pods turned brown and woody on the plants.
x. Width of matured pod [cm]: This was measured by randomly harvesting ten pods per plant. This was measured as the widest circumference of the matured harvested pods.
xi. Weight of matured pods per plant [g]: Average value of the total weight of matured harvested pods from 10 inner plants.
xii. Number of ridges per pod: This was determined at maturity by counting the number of the ridges in ten randomly selected pods.
xiii. Number of seeds per ridge: This was determined at maturity by counting the number of seeds in each of the ridges of ten randomly picked pods and dividing by the total number of ridges in the ten pods.
xiv. Number of seeds per pod: This was determined at maturity by counting the number of seeds in ten randomly picked pods and averaging over ten.
xv. 250-seed weight [g]: This was determined by weighing 250 dry seeds at 14% moisture content
xvi. Seed weight per plant [g]: This was determined by bulking the weight of the dry seeds of ten inner plants and dividing by ten.

Yield and yield component data were subjected to analysis of variance according to the procedures outlined by Steel and Torrie (1980). Genotypic and phenotypic variances were determined according to Prasad *et al.* (1981):

$$Genotypic\ variance(\delta^2 g) = \frac{(MSG - MSE)}{r}$$

$$Phenotypic\ variance(\delta^2 ph) = \frac{(MSG + MSE)}{r}$$

$$Error\ variance\ (\delta^2 e) = \frac{MSE}{r}$$

where:

MSG — Genotype mean square
MSE — Error mean square
r — Number of replication

The variance components were used to compute the genotypic coefficient of variability, phenotypic coefficient of variability and heritability (in broad sense), according to the procedure of Johnson *et al.* (1955) thus:

$$Genotypic\ coefficient\ of\ variability = 100 \times \frac{\delta g}{X}$$

$$Phenotypic\ coefficient\ of\ variability = 100 \times \frac{\delta ph}{X}$$

where

δg and δph are the genotypic standard deviation and phenotypic standard deviation, respectively
and X is the grand mean for the character under consideration.

Broad sense heritability and the genetic advance expected under selection,, assuming a selection intensity of 5% were estimated according to the formula of Allard (1960) as follows:

$$Heritability(broad - sense) = \frac{\delta g}{(\delta^2 g + \delta^2 e)}$$

where

($\delta^2 g$) is the estimate of genotypic variance
($\delta^2 e$) is the estimate of environmental variance

$$(GA) = (K) \times \sigma_A \times (H^2)$$

where:

GA — Expected genetic advance
K — Selection differential (2.06 at 5% selection intensity)
σ_A — Phenotypic standard deviation

RESULTS

The analyses of variance for the 16 characters considered using the average of the two season's data, showed significant differences among the lines (Table 2).

Moderate to low character variation was observed as measured by coefficients of variation (CV). The CV values ranged from 3.03% for 250 seed weight to 62.04% for number of pods on the branches. All the pod and seed characters had very low CV with seed yield per plant leading the group with 9.17%.

Table 2

Mean squares, analysis of variance of plot means and coefficients of variation (CV) of sixteen characters studied in 25 genotypes of *Abelmoschus caillei* averaged over two seasons

Character	Blocks	Lines	Error	CV [%]
Days to 50% flowering	12.12	56.02**	10.68	3.65
Number of leaves at flowering	163.03	192.24**	71.40	25.31
Plant height at flowering	14.06	1236.81**	21.91	5.35
Final plant height	53.04	2558.06**	31.88	3.35
Number of branches per plant	0.02	12.82**	0.11	12.16
Number of pods per branch	12.34	24.68**	7.59	62.04
Number of pods at stem	0.06	13.32**	0.11	6.91
Number of pods per plant	0.42	40.06**	0.64	8.60
Number of ridges per pod	0.04	2.46**	0.10	3.68
Number of seeds per ridge	0.08	5.42**	0.13	4.03
Number of seed per pod	5.72	902.48**	10.71	3.99
250 Seed weight	0.26	7.63**	0.17	3.03
Pod length	0.17	10.47**	0.20	4.89
Pod breadth	0.18	6.17**	0.92	9.13
Weight of matured pod	5.19	1495.17**		6.79
Seed yield per plant	0.44	212.97**	2.59	9.17

** = Significant P≤ 0.01; Degree of freedom: Block,2: Line, 24: Error

The means, genotypic and phenotypic variances and coefficients of variation of all the characters studied are presented in Table 3. The West African okra lines showed considerable variability for most characters in both seasons, the variation exhibited by final plant height, number of pods per plant and weight of matured pods per plant differed between seasons. Plant height at flowering and number of days to flowering seemed to have responded to seasonal changes. Among the fruit and seed characters, only number of pods per plant and matured pod weight per plant appeared to have been influenced by seasons as variances for other characters in respect of the two seasons were quite close.

Table 3

Means, phenotypic and genotypic variances of sixteen characters studied in 25 genotypes of *Abelmoschus caillei*

Character	Seasons	Mean	Phenotypic variance	Genotypic variance
Flowering Characters				
Days to 50% flowering	ES	99.3	3.38	1.95
	LS	79.7	25.3	19.61
Plant height at flowering	ES	98.3	301.93	294.28
	LS	76.6	198.79	191.83
Vegetative Characters				
Number of leaves at flowering	ES	39.9	33.11	1.66
	LS	26.9	42.97	26.82
Final plant height	ES	175.1	706.33	702.54
	LS	161.7	769/30	751.84
Number of branches per plant	ES	3.2	3.52	3.48
	LS	2.2	2.25	2.21
Fruits and seed characters				
Number of pods per branch	ES	4.8	5.90	2/02
	LS	4.1	3.27	2.09
Number of pods at stem	ES	5.6	3.09	3.05
	LS	4.1	2.15	2.12
Number of pods per plant	ES	10.0	13.09	12.79
	LS	8.6	5.67	5.54
Number of ridges per pod	ES	8.9	0.42	0.39
	LS	8.2	0.53	0.50
Number of seeds per ridge	ES	9.3	1.75	1.70
	LS	8.5	0.69	0.65
Number of seed per pod	ES	87.2	144.62	140.44
	LS	77.0	179.39	176.48
250 Seed weight	ES	13.6	1.18	1.16
	LS	13.3	1.43	1.35
Pod length	ES	9.7	1.74	1.66
	LS	6.8	2.55	2.50
Pod breadth	ES	11.0	1.35	0.91
	LS	10.0	0.95	0.77
Weight of matured pod	ES	48.5	319.49	318.01
	LS	37.1	205.85	201.61
Seed yield per plant	ES	18.1	35.39	34.03
	LS	17.0	39.27	38.91

ES, Early season. LS, Late season

Table 4

Phenotypic and genotypic coefficients of variability, broad sense heritability and genetic advance for some characters of twenty five West African okra accessions

Character	Seasons	Phenotypic coefficients of variation pcv [%]	Genotypic coefficients of variation gcv [%]	Heritability [%]	Genetic advance [%]
Flowering Characters					
Days to 50% flowering	ES	1.85	1.41	57.64	2.20
	LS	6.31	5.56	77.52	10.08
Plant height at flowering	ES	17.69	17.46	97.47	35.31
	LS	18.40	18.07	96.50	36.57
Vegetative Characters					
Number of leaves at flowering	ES	14.42	3.23	5.02	1.49
	LS	24.40	19.27	62.40	31.36
Final plant height	ES	15.18	15.14	99.46	31.11
	LS	17.15	16.96	97.73	34.53
Number of branches per plant	ES	57.99	57.68	98.93	118.19
	LS	69.16	68.63	98.47	140.29
Fruits and seed characters					
Number of pods per branch	ES	50.61	29.61	34.23	35.69
	LS	44.29	35.42	63.96	58.36
Number of pods at stem	ES	31.57	31.35	98.60	64.13
	LS	35.70	35.44	98.55	72.48
Number of pods per plant	ES	36.19	35.78	97.71	72.85
	LS	27.55	27.24	97.71	55.46
Number of ridges per pod	ES	7.25	6.94	91.71	13.70
	LS	8.96	8.69	94.18	17.38
Number of seeds per ridge	ES	14.26	14.03	96.92	28.46
	LS	9.76	9.54	95.41	19.19
Number of seed per pod	ES	13.79	13.59	97.11	27.59
	LS	17.39	17.24	98.35	35.23
250 Seed weight	ES	8.03	7.93	97.53	16.13
	LS	8.98	8.72	94.30	17.45
Pod length	ES	13.57	13.23	95.16	26.59
	LS	18.54	18.36	98.05	37.45
Pod breadth	ES	10.52	8.66	67.77	14.69
	LS	9.77	8.80	81.13	16.32
Weight of matured pod	ES	36.86	36.78	99.54	75.59
	LS	38.64	38.25	97.98	77.99
Seed yield per plant	ES	32.90	32.26	96.15	65.16
	LS	36.90	36.73	99.08	75.31

The phenotypic and genotypic coefficient of variation (CV), broad sense heritability (h^2B) estimates and genetic advance of the sixteen characters evaluated are presented in Table 4. Although the magnitude of the variances differed from season to season with respect to each character, the estimates of the *gcv* in the two seasons were close in many cases. The *gcv* values ranged from 1.41 for number of days to flowering in the early season to 68.63 for number of branches per plant in the late season planting.

Heritability estimates ranged from 5.02% for number of leaves at flowering in the early season to 99.54% for weight of matured pod during the early season. Number of leaves at flowering and number of pods per branch exhibited low heritability estimates during the early season. The remaining characters gave very high heritability estimates. The expected genetic advance for sixteen characters of West African okra genotypes revealed that progress that could be expected from selecting the top 5% of the genotypes ranged from 1.49% for number of leaves at flowering in the early season to 140.29% for number branches per plant in the late season.. Comparatively, the highest genetic advance as percent of mean was recorded for number of branches per plant (140.29) followed by weight of matured pods per plant (77.99) and seed yield per plant (75.31).

DISCUSSION

The significant variations among the 25 West African okra genotypes with respect to the 16 traits that were observed may be regarded as a reflection of their diverse eco-geographical backgrounds. This gives high possibility of improvement of these characters through selection either directly or following recombination through hybridization of desirable genotypes. The moderate to low CV obtained for all characters except number of pods per branch is expected because most of these genotypes had undergone some levels of selection.

The higher relative value of phenotypic variation to its genotypic counterpart implies environmental influence on the characters. This view was also buttressed by Briggs and Knowles (1967) who were of the opinion that if environmental variability is negligible compared to genetic variability, selection will be effective in improving the character if such character has high genotypic variability and also easily measurable. Therefore character with moderate to high values of genotypic coefficient of variation such as number of branches per plant, number of pods per branch, number of pods per stem, pod weight and seed yield might be further improved through varietal selection. Different estimates of varietal variability have been reported in West African okra (Ariyo, 1993).

Although, genotypic coefficient of variability gave information on the genetic variability present in the various quantitative characters, it is not enough to determine the amount of genetic gain that is heritable. Siddique and Gupta (1991) described the heritable portion of the total phenotypic variability as the total heritability estimates. Heritability estimates alone indicate the extent with which selection of genotypes can be based on phenotypic appearance. However, Assefa *et al.* (1999) suggested that genetic coefficient of variation together with heritability estimates would give the best picture of genetic advance to be expected from selection. In addition, Johnson *et al.* (1955) reported that heritability estimates show only the extent with which selection of genotypes could be based on phenotype but its utility increased when used along with estimates of genetic advance. High heritability values for most of the characters suggest the effectiveness of direct selection for such characters. That the heritability estimates for the characters differed between seasons suggests different responses of various characters to changing environmental conditions, thus showing the influence of environments on the estimation of genetic parameters. Subsequent study (Ariyo and Ayo-Vaughan, 2000) sees the need to breed for specific environments because the response of most characters to environments was nonlinear. Number of days to flowering, number of leaves at flowering and plant height at flowering are often affected by the length of the growing season. Late season was shorter than the early season, a situation which favoured early maturing varieties during the late season. This partly accounted for seasonal response of these three characters. Number of pods per branch appeared to have been influenced by seasons, yet other fruits and seed characters appeared to have response very little or not at all. This might be partly to duration of flowering, a character that determines the number of pods produced and hence the pod yield per plant. According to Sahao *et al.* (1990), gcv along with heritability and genetic advance will provide better information than single parameter alone. The high heritability estimates together with high gcv and relatively high genetic advance for number of pods at stem, number of pods per plant, number of branches per plant, weight of matured pods and seed yield per plant indicated that these characters, are highly heritable. Therefore, selection for these characters on the basis of phenotypic performance is likely to be dependable and effective. This result was in agreement with previous studies of Ariyo (1990c), Adeniji *et al.* (2007) and Osekita and Akinyele (2008).

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