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Interrelationships among Characters and Path Analysis for Pod Yield Components in West African Okra (*Abelmoschus caillei* (A. Chev) Stevels)

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Abstract: Correlation, stepwise multiple regression and path coefficient analysis were used to determine the relationships, direct and indirect effects of agronomic and reproductive characters on pod and seed yield. Eighteen F₂ generation obtained from hybridization of West African okra were planted for evaluation in a randomized complete block design with two replications in a single locations. Data were collected on agronomic and reproductive characters. Significant differences were observed among the segregating population for pods/branch, seeds/pod, inter node distance, seeds/ridge branch length, height at flower bud initiation and height at flowering. A positive correlation ($p < 0.05$) was recorded for number of pods/plant and seed weight, height at maturity, ridges/pod and seeds/ridge. The seed weight recorded a positive correlation coefficient with edible pod width, seeds/ridge and pods/plant. The stepwise multiple regression analysis identified two characters (height at maturity and number of pods/plant) to have accounted for 31% of variation observed in seed weight. Mature pod length was responsible for 39% of variability in seed weight. The numbers of ridges per pod and plant height at maturity were responsible for 25% of variation due to regression in pod yield. The path analysis identified plant height at maturity, ridges/pod, pods/plant, mature pod length and seed/ridge as selection indicators for pod and seed yield improvement in West African Okra.

Key words: *Abelmoschus caillei*, stepwise regression, assimilate, F₂ generations, path coefficient analysis, yield indicators, correlation analysis

INTRODUCTION

West African Okra (*Abelmoschus caillei* (A. Chev) Stevels) is cultivated primarily for its fresh pods and leaves, which are consumed fresh as vegetables in most parts of tropical and sub-tropical regions of the world. It is photoperiod sensitive (short day) annual, relatively tolerant of insect pests and diseases. The cultivation of West African Okra traverses agro-climatic regions in Nigeria. Fresh pod production in West African Okra is enhanced by mono-modal and bimodal rainfall pattern. While the availability of lowland ecology (Fadama) has encouraged dry season cultivation of this crop in several parts of Sub Sahara Africa. The cultivation of West African Okra is pronounced in the savannah and in the high altitude areas of the north of Nigeria. Distinctively, West African Okra is hardy and has a potential for producing a high number of pods, when compared with *Abelmoschus esculentus*. This potential increase the awareness of this crop among farmers in this sub-region. In sub Sahara Africa, West African Okra is cultivated primarily for its fresh pods, the utilization of West African

Okra seeds for industrial and biomedical purposes are limited in this region as compared with Europe and Asia (Kehinde *et al.*, 2004).

Adeniji and Peter (2005) had noted that pod yield in West African Okra is a function of physiological and agronomic characters acting singly or in interaction with each other. The vegetative parts of West African Okra (including the roots) are the only sink for assimilate prior to flowering. During flowering and fruit set, the vegetative and reproductive parts could be competetory sink for assimilate. The proportion of assimilates allocated to the reproductive parts (pod and seed) during flowering and fruit set might be of importance in determining the number of pods, seed number and seed weight. The total variations observed in F₂ generation of an intervarietal population consist of within family variation and between family variations. Both variations are important in the estimation of genetic parameters. Evidently the progress in crop production is dependent on the magnitude of variability observed in the F₂ population. Genetic information on the inheritance pattern of quantitative and qualitative characters in *A. caillei* had been noted

(Adeniji, 2003). The knowledge of relationship among pod and seed yield component characters is pivotal for improvement in the physiology of this crop, particularly for direct selection of quantitative traits (such as pod and seed yield) that exhibit a low heritability.

Regression techniques have been used by many workers to obtain functional parameters, which can determine to a large extent the relationship among variables. While the stepwise multiple regression analysis on the other hand, determine the contribution of several independent variables in the dependent variable (Welsberg, 1980). In addition, correlation studies and stepwise regression analysis are of great value in determining the most effective breeding procedure in crops (Adeniji and Peter, 2005). The path coefficient analysis, which is an important analytical tool make use of standardized partial regression technique that determine interrelationship among all variables by partitioning and interpreting the cause and effect among variables (Dewey and Lu, 1959). More often plant breeder have some characters in mind, when carrying out selection. Therefore for improvement in characters of choice, selection is generally applied simultaneously to several characters that influence yield. Information on the inheritance of components characters in selection index is required. This study therefore seeks to employ correlation and regression techniques to identify plant characters that determine pod and seed yield in Okra. Also to evaluate the direct and indirect effects of characters on pod yield among segregating F_2 generations of West African Okra.

MATERIALS AND METHODS

Ten accessions of West African Okra (Table 1) that exhibit diversity for agronomic and reproductive characters were obtained from the germplasm collection of the University of Agriculture Abeokuta and have been maintained through selfing. Two seed of each accession were planted in polythene pots (25×36 cm) filled with sterilized soil in the screen house. Hybridization was carried among the accessions to produce F_1 seeds, a total of eighteen crosses were made (Table 2). Two seeds of each F_1 generation were planted in polythene pots and were allowed to self pollinate to produce F_2 seeds. Field evaluation of the eighteen F_2 generations was carried out at the lowland ecology the Teaching and Research farm, University of Agriculture Abeokuta (Lat. 7.33°N, 3.88° E 450 m asl) in 2003/2004 planting season. The experimental design was a randomized complete block design with two replications. Each plot consisted of a five rows of 10meter long and a between row spacing of 0.60 m. The plots

Table 1: List of accessions evaluated in the study

Acc1	Okiti pupa
Acc2	Asero, Abeokuta
Acc3	Asero, Abeokuta
Acc4	Ise Ondo State
Acc5	Ikene, Ogun State
Acc6	Omuo, Ondo State
Acc7	Abeokuta, Ogun State
Acc8	Omuo, Ondo State
Acc8	Abeokuta, Ogun State
Acc9	Ibara Abeokuta, Ondo State
Acc10	Ikere, Ondo State

Table 2: List of crosses evaluated in this study

Acc1×Acc2
Acc1×Acc3
Acc1×Acc4
Acc1×Acc8
Acc1×Acc6
Acc8×Acc9
Acc9×Acc10
Acc21×Acc10
Acc9×Acc2
Acc7×Acc2
Acc6×Acc9
Acc7×Acc9
Acc4×Acc5
Acc4×Acc7
Acc5×Acc7
Acc6×Acc7
Acc7×Acc10

received fertilizer equivalent NPK (15:15:15) at the rate of 60 kg ha⁻¹, 2-3 weeks after planting and at flowering. Cultural practices included ploughing, harrowing and weed control by hand weeding.

Data were consistently collected on 128 stands for each F_2 generation. At anthesis, seven flowers were tagged per stand for determination of edible pod length and width at seven days after anthesis. By randomly harvesting 15 pods/plant, pod length was measured at the longest point on the pod (cm), while the width was measured on the widest point (cm). By counting the number of seeds (damaged or undamaged), the number of seeds/pod and seeds/ridge were estimated. The leaf area was estimated from seventy leaves sampled from each F_2 generation according to Asif (1987) as $Y = 15 (X) - 1050$, where Y is the leaf area and X is the length of the midrib, described for *Abelmoschus esculentus* [L.] Moench. The height at flower bud initiation, flowering and at maturity was measured with a meter rule from the ground level to the top of the main stem at flowering at each growth stage. The number of days to flower bud initiation and flowering were estimated as the number of days from planting to the appearance of the flower bud and first flower. Weight of a hundred seeds were estimated on hundred clean seeds in grams, seed weight was measured on the total seed/plant in grammes. From the data collected, the means, standard deviation, range and

coefficient of variability (CV) were estimated. The plot means were subjected to combined analysis of variance (Snedecor, 1956). Linear correlations among the characters were done using SPSS version 7.5 software for windows. Important characters associated with seed/pod, pod/plant and seed yield were determined using the forward stepwise multiple regression analysis (Welsberg, 1980). The direct and indirect causes of pod yield were analyzed as specified by Dewey and Lu (1959).

RESULTS AND DISCUSSION

F₂ generations evaluated showed significant difference ($p < 0.05$) for pods/branch, seeds/pod, inter node distance, seed/ridge, branches/plant, edible pod length and width, mature pod length, peduncle length and height at maturity (Table 3). The significant level of variability ($p < 0.05$) observed among the F₂ generations revealed the magnitude of variation among the segregating population. Failure to detect significant difference among F₂ generations for characters could result from a nearly equal parental means. The number of seed/pod significantly correlated with mature pod length ($r = 0.51^*$), height at flowering ($r = 0.42^*$) and branches/plant ($r = 0.36$) (Table 4). This suggest these characters as components for improvement in seed yield. A significant positive correlation between seed/pod and branches/plant ($r = 0.36^*$) among the segregating population evaluated indicated an effective utilization of photosynthate manufactured in the leaves for seed growth and development. Therefore seed growth among the segregating population can be improved by selecting for a higher number of branches. Our finding corroborates

Ariyo (1993a,b) in *Abelmoschus esculentus*. Negative correlation coefficient between seed number and leaf area ($r = -0.17$) and pods/plant ($r = -0.10$) seed weight ($r = -0.05$), days to flower bud initiation ($r = -0.10$), branch length ($r = -0.03$), seeds/ridge ($r = -0.17$) and inter node distance ($r = -0.15$) recorded in the study, could be explained as a competition in the distribution and accumulation of photosynthate among these character. Therefore an independent selection of these character in selection process could be ideal for improvement in seed yield. In furtherance, a positive correlation between seed/pod and branches/plant may be related to substantial photosynthetic capacity provided by more leaves.

Table 3: Mean squares of nineteen characters in segregating F₂ generations of West African Okra

Characters	df	Genotypes	Error
Weight of hundred seeds	17	0.34	0.29
Pod/branch	17	1.01*	0.08
Seeds/pod	17	350.22*	81.64
Inter node distance	17	3.50	0.37
Seeds/ridge	17	5.76*	0.89
Mature pod length	17	2.56	1.36
Ridges/pod	17	2.23	0.63
Branch length	17	815.20*	43.10
Edible pod length	17	162.25	132.24
Days to first flowering	17	340.39*	117.59
Edible pod width	17	6.34*	1.77
Mature pod length	17	2.57*	0.21
Height at maturity	17	1.13*	0.23
Peduncle length	17	24944.96	23525.6
Height at flower bud initiation	17	128.89*	46.97
Seed weight	17	3820.37	2481.82
Pods/plant	17	20.45	26.34
Height at flowering	17	761.14*	182.12
Leaf area	17	125789.81	145393.08

* = Significant at 5% level of probability, ** = Significant at 1% level of probability

Table 4: Correlation coefficient among characters in segregating F₂ populations of West African Okra (*A. cailliei*) [A. Chev] Stevels

	Htfl	LA	Pd/plt	Sw	Dfini	Htini	Htmat	Pedl	Mpl	Dff	Epl	Brl	Rpp	Mpl	Spr	Intdist	Spp	Pd/br	100swt	Br/plt	Epw
Htfl	1.00																				
LA	0.06	1.00																			
Pd/plt	-0.03	-0.16	1.00																		
Sw	-0.01	-0.19	0.23	1.00																	
Dfini	0.18	0.14	-0.14	-0.02	1.00																
Htini	0.32	0.32*	0.23	-0.21	0.31	1.00															
Htmat	-0.07	-0.10	0.29	-0.42*	0.10	0.44*	1.00														
Pedl	0.11	-0.19	0.01	-0.29	0.47*	-0.06	-0.20	1.00													
Mpl	0.19	0.14	-0.07	-0.17	0.29	0.48*	0.29	-0.08	1.00												
Dff	0.07	0.13	-0.14	-0.02	0.64*	0.14	0.04	0.37*	0.32*	1.00											
Epl	-0.07	-0.09	0.08	0.27	-0.05	-0.07	-0.05	0.15	0.01	-0.04	1.00										
Brl	0.11	0.32	0.19	-0.25	-0.14	0.10	0.24	-0.17	0.29	0.09	-0.18	1.00									
Rpp	-0.30	0.001	0.26	0.07	-0.05	-0.01	0.14	-0.06	0.10	0.06	0.34	0.28	1.00								
Mpw	-0.06	-0.34**	-0.06	-0.25	-0.05	0.37*	0.20	-0.11	0.16	-0.15	-0.22	0.07	-0.26	1.00							
Spr	0.10	-0.04	0.23	0.27	0.21	-0.26	-0.30	0.53*	-0.10	0.11	0.07	0.09	0.22	0.57**	1.00						
Intdist	0.36*	-0.26	-0.12	-0.29	-0.08	0.57*	0.13	-0.08	0.08	-0.10	-0.06	0.18	-0.14	0.18	-0.10	1.00					
Spp	0.42*	-0.17	-0.10	-0.05	-0.10	0.26	0.009	-0.03	0.51*	0.21	0.12	-0.03	-0.32*	0.21	-0.17	-0.15	1.00				
Pd/br	-0.03	0.006	0.15	-0.004	0.10	0.10	0.10	-0.27	0.21	0.07	-0.06	0.11	0.41*	-0.17	0.19	0.30	-0.09	1.00			
100Swt	-0.15	-0.12	0.10	-0.05	0.05	0.08	0.05	0.15	0.24	0.25	-0.13	0.05	0.12	0.44*	0.04	-0.03	0.06	0.12	1.00		
Br/plt	0.21	-0.22	-0.07	0.02	-0.12	0.09	-0.12	-0.47**	0.24	-0.11	-0.08	0.04	0.04	0.06	-0.33*	-0.19	0.36*	-0.10	-0.27	1.00	
Epw	0.04	-0.24	0.09	-0.25	-0.45*	-0.32*	-0.16	-0.23	0.10	0.25	-0.06	-0.21	-0.12	-0.02	-0.13	-0.22	0.23	0.09	0.18	0.12	1.00

Htfl = Height at flowering; LA = Leaf area; Pd/plt = Pods/plant; Sw = Seed weight; Dfini = Days to flower bud initiation; Htini = Height at flower bud initiation; Htmat = Height at maturity; Pedl = Peduncle length; Mpl = Mature pod length; Dff = Days to flowering; Epl = Edible pod length; Brl = Branch length; Rpp = Ridges/pod; Mpw = Mature pod width; Spr = Seeds per ridge; Spp = Seeds/pod; Pd/br = Pods per branch; 100 swt = Weight of hundred seeds; Epw = Edible pod width. *Significant at 5% level of probability, **Significant at 1% level of probability

The study indicated a positive correlation coefficient in the association between pods/plant and seed weight ($r = 0.23$), height at flower bud initiation ($r = 0.23$) and height at maturity ($r = 0.49^*$). This association suggest a substantial complementation among these reproductive and physiological characters in the distribution and accumulation of photostynthate for pod yield among the segregating F_2 population evaluated. Meaning that the accumulation of photostynthate in these parts is an important determinant of pod yield. A positive correlation coefficient recorded in the association between seed weight and pods/plant ($r = 0.23$), seed/ridge ($r = 0.27$), edible pod length ($r = 0.27$), edible pod width ($r = 0.25$) ordinarily indicated that seed dry weight depend on the number of pod number and pod characters/plant. In addition, the length and width of pods and number of seeds/ridge could effectively influence seed yield among the segregating F_2 population. Conversely, a negative correlation between seed weight and leaf area ($r = -0.19$), height at maturity ($r = -0.42^*$), mature pod width ($r = -0.19$), branch length ($r = -0.25$), mature pod length ($r = -0.17$) and weight of hundred seeds ($r = -0.05$) identified these characters as independent in selection process for improvement in seed yield. Therefore a competition among these characters (vegetative and reproductive parts) in the distribution and accumulation of assimilate should be expected among the segregating generations evaluated.

The leaf area recorded a significant ($p < 0.05$) positive correlation coefficient with plant height at flower bud initiation ($r = 0.32^*$) and branch length ($r = 0.32^*$). This explains that a high efficiency in the manufacture and distribution of photostynthate in the leaves (source) will compensate for vegetative growth (plant height, branch length) in this crop. However a negative correlation ($p < 0.05$) between leaf area and pods/plant ($r = -0.16$), edible pod length ($r = 0.09$), mature pod width ($r = -0.34$), seed/ridge ($r = -0.04$), seeds/pod ($r = -0.17$) and branches/plant ($r = -0.22$) revealed an inverse relationship. Segregating population with a smaller leaf area may effectively manufacture and channel their photosynthate for a higher pod yield and seed number. A significant positive correlation between days to first flowering and days to flower bud initiation showed that early flowering generations must have developed flower buds early in the growth cycle. But a negative correlation coefficient between days to first flowering and number of pods/plant ($r = -0.14$) suggest that late flowering F_2 generations of West African Okra could provide more pods/plant. Hence a compromise in selection must be made for either for a high pod number or earliness among the population evaluated. Present findings corroborated Ariyo *et al.*

Table 5: Stepwise multiple regression analysis of agronomic characters on pod and seed yield

Characters	No	Seed weight	
		R ²	Change in R
Height at maturity	1	0.18	0.18*
Number of pods/plant	2	0.31	0.13
Seed/pod			
Mature pod length	1	0.26	0.26*
Ridges/pod	2	0.39	0.13*
Pod yield			
Height at maturity	1	0.18	0.18*
Ridges/pod	2	0.25	0.09*

* = Significant at 5% level of probability, R² = Multiple coefficient of determination

(1987). Generally, the correlation coefficients (r) among characters evaluated in this study were low. This may be ascribed to the fact that the population evaluated are highly segregating.

The results of the stepwise multiple regression analysis for seed weight returned two characters viz; height at maturity and number of pods/plant to have explained 31% of total variability observed in seed weight. The remaining characters did not meet a = 0.05 significance of entry into the model (Table 5). However this same analysis demonstrated that the height at maturity was responsible for 18% of the variation. By inclusion of number of pods/plant, 31% of the total variation was explained. However, these two characters correlated positively with seed weight, thus suggesting their relevance for genetic improvement in seed weight. In addition, the mature pod length and ridges/pod contributed 39% of the variability observed due to step wise regression analysis in seed/pod. Mature pod length alone was responsible for 23% of this variation, while ridges/pod contributed 13% of the variation as revealed in seed/pod. This suggest seed yield in West African Okra was highly influenced by pod length and ridges/pod. Similarly the mature pod length and ridges/pod showed a positive correlation with seed/pod. The stepwise contribution to pod yield identified height at maturity and ridges/pod to have accounted for 25% of the total variation pod yield among the segregating F_2 population. Plant height at maturity alone accounted for 18% of this variation, while ridges/pod accounted for a marginal increase of about 9%. The study identified height at maturity, ridges/pod and pods/plant as components for pod and seed yield improvement in West African Okra. The results of the correlation agree with that of the forward stepwise multiple regression analysis. Based on the results of the correlation and stepwise multiple regression analysis, ten characters that were found to have exhibited a positive association with pod yield were use in path analysis.

Table 6: The direct and indirect effects of ten characters on pod yield in West African Okra (*A. esculentus*)

	Swt	Htini	Ht mat	Epw	Epl	Brl	Rpp	Spr	Pb/br	100swt
Swt	0.10	-0.12	0.07	0.03	0.03	0.03	0.08	0.005	0.007	0.002
Htini	0.004	0.07	0.10	-0.03	0.01	-0.02	0.04	0.07	-0.007	-0.003
Ht mat	0.006	-0.10	0.32	-0.02	0.03	-0.007	-0.09	-0.02	0.007	0.003
Epw	0.006	0.08	-0.03	0.04	-0.02	0.02	-0.06	0.04	0.004	0.007
Epl	0.006	0.031	-0.02	-0.007	0.23	-0.03	-0.14	0.005	0.004	0.006
Brl	0.01	-0.11	0.006	0.002	-0.06	0.19	0.11	0.02	0.008	0.002
Rpp	0.01	0.03	0.02	-0.13	0.06	-0.05	0.24	0.04	0.02	0.005
Spr	0.001	-0.03	0.08	0.02	0.02	0.02	0.04	0.07	0.01	0.002
Pb/br	0.005	-0.03	0.01	0.004	0.02	0.02	0.04	0.03	0.05	0.003
100swt	0.002	-0.05	0.03	0.001	0.01	0.01	0.04	0.02	0.004	0.03

The diagonals are direct effects, Swt = Seed weight, Htini = Height at flower bud initiation, 100swt = Hundred seed weight, Ht mat = Height at maturity, Epw = Edible pod width, Epl = Edible pod length Br4l = Branch length, Rpp = Ridges/pod, Spr = Seed/ridge, Pd/br = Pods/branch, 100 seed weight = Weight of hundred seeds

All characters evaluated in Table 6 recorded a positive direct effect on pod yield. Meaning that these characters will increase pod yield. The plant height at maturity recorded the highest direct effect on pod yield ($p = 0.32$). The weight of hundred seeds recorded the lowest estimate of direct effect ($p = 0.03$) on pod yield. The path coefficient analysis further revealed that the adverse effect of seed weight on pod yield was largely due to the indirect effect of height at flower bud initiation. Present finding agrees with Agbo and Obi (2005) in Castor oil. The high direct effect of height at maturity on pod yield was lowered due to the indirect effect through masking action from edible pod width, height at flower bud initiation, branch length and seed/ridge. Similarly the direct of ridges/pod on pod yield was lowered by indirect effect of edible pod length and branch length. The direct effect of branch length on pod yield ($p = 0.19$) was equal to its correlation coefficient ($r = 0.19$). Suggesting that selection for this character among the segregating generations could be effective in identifying a genotype with improved pod yield.

The path coefficient analysis, stepwise multiple regression and correlation analysis identified height at maturity, ridges/pod edible pod length and seed weight as selection indicators for improvement in pod yield among the segregating population of West African Okra. Plant height at maturity among other characters seems to be an outstanding character for selection, whenever improvement is desirable for pod and seed yield.

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