Pertanika J. Trop. Agric. Sci. 37 (1): 39 - 49 (2014)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Correlation and Path Analyses of Seed Yield in Okra (*Abelmoschus esculentus* (L.) Moench) Grown Under Different Cropping Seasons

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ABSTRACT

Inter-character correlations and path coefficient analyses of yield related characters were evaluated in some quantitative traits of okra (*Abelmoschus esculentus* (L.) Moench) grown under different cropping seasons. Data collected were subjected to correlation and path coefficient analyses to determine the relationships among the characters, as well as the direct and indirect effects of some yield related characters to seed yield. Correlation coefficients among characters varied among seasons. Days to flowering, number of pods per plant, length of matured pod, weight of matured pods per plant, number of ridges per pod, number of seeds per pod and 100 seed weight had significant genotypic correlations with seed yield/plant across the seasons. Environmental correlation coefficients were generally low and non significant except for number of leaves per plant, length of matured pod, width of matured pod and weight of matured pods per plant in all the seasons of study. The genotypic correlation coefficients of eight selected characters with seed yield were partitioned into their direct and indirect effects. Weight of matured pods per plant had the largest direct effect on seed yield/plant in early rain 2005 (season 1) and off season 2006 (season 2), branch length in the early rain 2006 (season 3) and stem height at flowering in late rain 2006 (season 4). The residual effects of 0.16 in season 1, 0.74 in season 2, 0.55 in season 3 and 0.38 in season 4 respectively accounting for 84%, 26%, 45% and 62%, contributed by the characters under study.

ARTICLE INFO

Article history:
Received: 4 April 2011
Accepted: 21 August 2013

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ISSN: 1511-3701

Keywords: Yield-related characters, direct effect,interrelationship, path coefficients

INTRODUCTION

In tropical agriculture, production and conservation of okra is imperative due to the usefulness of its young leaves and immature pods for human food and animal feed. In Nigeria, okra (*Abelmoschus esculentus* (L.) Moench) is widely grown during both the dry and rainy seasons. The rainy season production is bimodal, where its early cropping usually begins as early as March/April and ends during a short dry spell in August, whilst the late cropping starts from August to October/November. The meteorological data, including rainfall and temperature, vary during the early and late seasons in ways that influence growth and yield of crop (Olasantan & Bello, 2004). The dry season cultivation is done in the dry month of the year spanning from December to March in swamps. Testing for the development of high performing genotypes in different environments is a continuous exercise to increase local production which in turn helps to boost the income of farmers.

Season of production is a parameter identified to be borne in mind in order to obtain maximum yields in okra (Adekoya, 2008). A number of okra varieties grown in Nigeria have low yield due to associated biotic and abiotic factors, lack of improvement, limited agro-inputs and low quality of seeds among others (Adekoya, 2008). Before yield improvement can be ascertained, appropriate selection criteria must be well established. One method to achieve this is to determine the extent of relationship between any given pair of traits (Obisesan, 1985; Adekoya, 2008; Adebisi, 2008). In addition, Falconer (1981) suggested that a plant breeder should also know whether the improvement of one character will result in simultaneous change in the other characters through estimates of inter-character correlation.

The use of simple correlation analysis cannot fully explain the relationships among characters. Therefore, path coefficient analysis has been used by many researchers for a more complete determination of the impact of an independent variable on a dependent one (Akinyele & Osekita, 2006; Lal, 2007; Zhao *et al*., 2008, Karademir *et al*., 2009; Majid *et al*., 2011; Udensi & Ikpeme, 2012; in okra, fennel, wheat, cotton, potato and *Cajanus cajan*, respectively). The path coefficient analysis helps the breeder to explain direct and indirect effects which have been extensively used in breeding works of different crop species by various researchers (Punia & Gill, 1994; Shalini *et al*., 2000; Ali *et al*., 2002; in rapeseed and sunflower). The knowledge of inter-character relationships is very important in plant breeding for indirect selection for characters that are not easily measured and for those that exhibit low heritability.

A path coefficient analysis simultaneously captures the effects of intricate relationship among various traits under investigation. Information obtained from correlation coefficients can be enhanced by partitioning them into direct and indirect effects for a set of a priori cause–effects interrelationship, as has been demonstrated in various crops (Kang *et al*., 1983; Gravois & Helms, 1992; Gravois & McNew, 1993; Board *et al*., 1997; Murtadha *et al*., 2004). However, there has been relatively little information on some of the newly collected genotypes of okra in Nigeria. A careful study of relationships among quantitative characters is necessary in order to ascertain the magnitude and direction of changes to be expected during selection in okra. This study was therefore designed to identify agronomic characters that determine the seed yield in okra using correlation and path coefficient analyses in twenty genotypes of okra grown under four different cropping seasons.

MATERIALS AND METHODS

Twenty genotypes of okra, *Abelmoschus esculentus* (L.) Moench were sown in four different seasons [early rain (last week in July) 2005, off season (second week in January), early rain (first week in June) and late rain (second week in September), 2006)]. The genotypes were obtained from different sources as listed in Table 1. These include four established genotypes which had been released to farmers and sixteen others that were still under evaluation for yield and stability. After ploughing and harrowing, the experiment was laid out in a randomized complete block design (RCBD) with three replications and in single row plot to minimize variation. A block consisted 20 rows of all the genotypes and each row was 4.5m long. The rows were 0.75m apart, while the between plant distance in each row was 0.45m, thus each row contained eleven plants.

Three weeks after sowing, plants were thinned to one plant per hole. From nine inner plants in each row, data were collected on the following characters:
days to flowering which was determined as the average of the number of days to flowering of the nine inner plants in each row; plant height at flowering was measured from the soil level to the tip of the plant and number of pod per plant, which was the average value of summation of pods from nine inner plants in each row. Number of leaves per plant (determined by counting the number of nodes on the main stem and all the branches from the inner plants in each row), while number of branches per plant was the number of branches on the main stem while branch length was determined as the average value of the summation of length of branches from nine inner plants.

Final plant height 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 shoots had dried up, length of matured pod was determined when pods turned brown and fibrous on the stem while width of matured pod was measured as the circumference of the matured harvested pods. Weight of matured pods per plant was taken as average value of the summation of the weighed matured harvested pods from nine inner plants. Meanwhile, number of ridges per pod was determined at maturity by counting the number of the ridges in ten randomly selected pods, number of seeds per pod was determined at maturity by counting the number of seeds in ten randomly selected pods, 100–seed weight was determined by weighing 100 dry seeds as sample from the bulk of each genotype and seed yield per plant was determined by bulking the yield of the dry seeds of nine inner plants and dividing by nine.

Data obtained were analyzed using SAS statistical package (SAS, 1999). Genotypic and phenotypic correlations were calculated from the mean values of the genotypes using the procedure outlined by Miller *et al.* (1958) as reported by Ariyo (1995). Environmental correlation coefficients were calculated according to the procedure of Falconer (1981). Path analysis to estimate the direct and indirect contributions of some characters to seed yield/plant was also conducted using the method described by Dewey and Lu (1959), as reported by Ariyo (1995). Fig.1 shows the cause and effect system between seed yield/plant and eight agronomic characters.

TABLE 1
Genotypes, sources and status of the accessions used for the study

Serial number	Genotypes	Sources	Status
1	NHAe 47-4	NIHORT	ESTABLISHED
2	NHAe 47- 4-5	NIHORT	ENTRANT
3	CLEMSON SPINELESS	NACGRAB	ESTABLISHED
4	LADY'S FINGER	UNAAB	ENTRANT
5	LADY'S FINGER (OUTCAST)	UNAAB	ENTRANT
6	LD 88/1 – 8 – 11 – 1	NIHORT	ENTRANT
7	NHAe88/82	NACGRAB	ENTRANT
8	NHAe99/28	NACGRAB	ENTRANT
9	NHAe99/DA	NACGRAB	ENTRANT
10	NIHORT ILAGIDI	UNAAB	ENTRANT
11	OK 20	NIHORT	ENTRANT
12	OLA 3 LOCAL	NIHORT	ENTRANT
13	OLA99/13	NIHORT	ENTRANT
14	OLA K 2005	NIHORT	ENTRANT
15	OLA KA 1 – 6 – 05	NIHORT	ENTRANT
16	OLA V_1	NIHORT	ENTRANT
17	OSADEP: PURPLE TALL	UNAAB	ENTRANT
18	SHORT MOUTH IBARAPA	UNAAB	ENTRANT
19	V_2 – OYO	UNAAB	ESTABLISHED
20	V – 35	IAR&T	ESTABLISHED

Status: Established – Accessions already released to farmers
Entrant – Accessions still undergoing evaluation on the field (not yet released to farmers)

NIHORT : National Institute of Horticultural Research and Training
NACGRAB : National Centre for Genetic Resources and Biotechnology
UNAAB : University of Agriculture, Abeokuta
IAR&T : Institute of Agricultural Research and Training

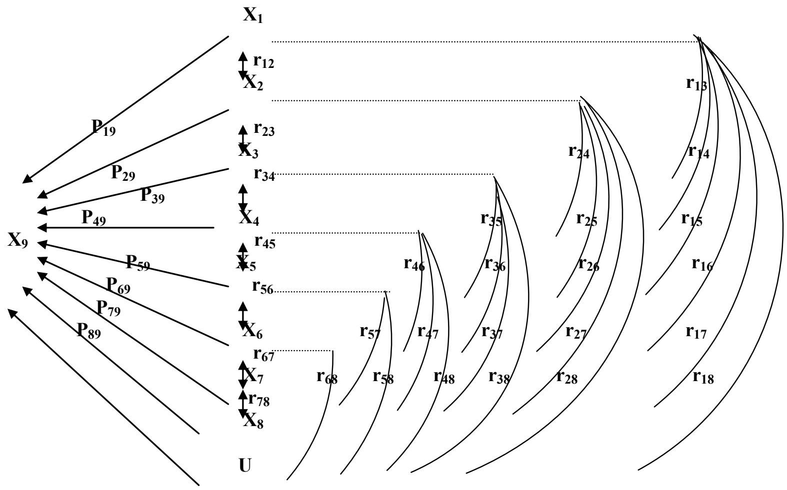

Fig.1: Causation diagram indicating the relationships between seed yield and yield related traits.

RESULTS

The genotypic correlation coefficients among sixteen characters in okra in four seasons are presented in Table 2. In early rain, 2005 (season 1), seed yield/plant exhibited significant positive genotypic correlations with all traits studied, except length of fresh pod, width of fresh pod, length of matured pod and 100 seed weight. In off season, 2006 (season 2), significant positive genotypic correlations were recorded between seed yield/plant and most of the characters evaluated except stem height at flowering, length of fresh pod and length of matured pod. In early rain, 2006 (season 3), seed yield/plant displayed significant positive genotypic correlations with all traits studied except length of fresh pod while in late rain, 2006 (season 4), it exhibited positive significant correlation with most characters except length and width of fresh pod, number of branches/plant and 100 seed weight.

From Table 3, the differences in both magnitude and direction of correlation coefficients were observed in the four different seasons for some of the characters. Positive significant correlation coefficients were observed for most traits except for the length of fresh pod in all seasons, 100 seed weight in seasons 1 and 4, and stem height at flowering and length of matured pod in season 2.

Environmental correlation coefficients between seed yield/plant and other agronomic characters in okra in four seasons are presented in Table 4. In all seasons, correlation coefficients ranged between 0.01 and 1 in the two directions. Negative significant correlation were recorded between seed yield/plant and number of branches/plant in season 1, length and width of matured pod in season 2, days to flowering, stem height at flowering, length of fresh pod, length and width of matured pod and number of ridges/pod in season 4.

TABLE 2
Genotypic correlation coefficients between seed yield per plant and other agronomic characters in okra in four seasons

Agronomic Characters	seed yield per plant			
	season 1	season 2	season 3	season 4
Days to flowering	1.23**	-0.09	0.94**	-0.08
Stem height at flowering	0.54**	-0.42**	0.92**	0.70**
Length of fresh pod	-0.47**	-0.44**	-0.43**	-0.62**
Width of fresh pod	-0.06	0.07	0.08	-0.41**
Number of pods /plant	0.89**	1.40**	1.14**	1.13**
Number of leaves/ plant	0.71**	-0.06	0.85**	0.02
Number of branches/ plant	0.26*	0.17	1.00**	-0.34**
Branch length	0.72**	-0.18	1.15**	0.85**
Final plant height	0.51**	0.25*	0.98**	0.60**
Length of matured pod	-0.35**	-0.67**	-0.06	-0.1
Width of matured pod	0.26*	0.52**	0.71**	0.46**
Weight of matured pods/plant	0.91**	0.72**	0.94**	1.12**
Number of ridges/pod	1.01**	0.27*	1.27**	0.68**
Number of seeds/pod	0.85**	4.83**	0.09	0.62**
100 seed weight	-0.69**	0.42**	0.75**	-0.54**

*, ** = significant at 5% and 1% level of probability respectively
n= 60, Degree of freedom = n-2=58

TABLE 3
Phenotypic correlation coefficients between seed yield per plant and other agronomic characters in okra in four seasons

Agronomic Characters	seed yield per plant			
	season 1	season 2	season 3	season 4
Days to flowering	0.76**	-0.08	0.49**	-0.14
Stem height at flowering	0.36**	-0.29**	0.55**	0.55**
Length of fresh pod	-0.29*	-0.25*	-0.25*	-0.60**
Width of fresh pod	-0.22	-0.13	0.09	0.21
Number of pods /plant	0.95**	0.53**	0.96**	0.90**
Number of leaves/ plant	0.56**	0.05	0.70**	0.25*
Number of branches/ plant	0.01	0.07	0.69**	0.33**
Branch length	0.57**	-0.13	0.78**	0.69**
Final plant height	0.36**	0.09	0.66**	0.54**
Length of matured pod	-0.09	-0.50**	0.24	-0.2
Width of matured pod	0.26*	0.29*	0.53**	0.26*
Weight of matured pods/plant	0.95**	0.58**	0.96**	0.97**
Number of ridges/pod	0.68**	0.19	0.52**	0.29*
Number of seeds/pod	0.83**	-0.03	0.41**	0.53**
100 seed weight	-0.36**	0.33**	0.49**	-0.36**

*, ** = significant at 5% and 1% level of probability respectively
n= 60, Degree of freedom = n-2=58

TABLE 4
Environmental correlation coefficients between seed yield per plant and other agronomic characters in okra in four seasons

Agronomic Characters	seed yield per plant			
	season 1	season 2	season 3	season 4
Days to flowering	0.02	-0.08	0.01	-0.76**
Stem height at flowering	-0.07	-0.07	0.29*	-0.57**
Length of fresh pod	-0.01	0.29*	-0.09	-0.52**
Width of fresh pod	-0.18	0.22	-0.08	0.62**
Number of pods /plant	1.01**	0.36**	0.92**	-0.1
Number of leaves/ plant	0.38**	0.31*	0.66**	0.83**
Number of branches/ plant	-0.27*	-0.04	0.53**	0.45**
Branch length	0.37**	-0.06	0.56**	0.32*
Final plant height	0.09	-0.23	0.48**	0.21
Length of matured pod	0.79**	-0.35**	0.55**	-0.82**
Width of matured pod	0.37**	-0.31*	0.47**	-1.10**
Weight of matured pods/plant	0.99**	0.44**	0.97**	0.45**
Number of ridges/pod	0.04	0.1	-0.02	-1.27**
Number of seeds/pod	0.81**	0.09	0.46**	0.23
100 seed weight	0.21	0.21	0.33**	0.25*

*, ** = significant at 5% and 1% level of probability respectively
n= 60, Degree of freedom = n-2=58

The direct and indirect path coefficients that estimated the extent of the relationships between seed yield/plant and eight yield related characters using the genotypic correlation values are presented in Table 5. Of the sixteen traits evaluated in this study, eight were genotypically significantly correlated with seed yield in the two directions. Path analysis partitioned these correlation coefficients into their components, thus giving an insight to which traits can be selected for improvement in seed yield. Number of pod/plant and final plant height had significant correlation coefficients in all seasons and large indirect effect through the branch length but had negative direct effects. This indicated that improvement in seed yield can be made indirect selection for branch length.

DISCUSSION

Phenotypic correlation is a composite of genotypic and environmental correlations. In this study, it was observed that the genotypic correlation coefficients were, in most cases, higher than their corresponding phenotypic correlation coefficients indicating that the inherent association between the characters is governed largely by genetic causes, although it could also be affected by environmental forces. Similar finding were earlier observed by Ariyo *et al*. (1987) and Scod *et al*. (1995) in okra.

The significant positive genotypic correlations between seed yield/plant and number of branches per plant in all the cropping seasons may be related to greater photosynthetic capacity provided by more leaves. Also more branches imply more

TABLE 5
Direct and indirect effect of some characters on seed yield in okra

Character	Environment	Direct effect	Days to flowering	Plant height at flowering	Number of pods per plant	Branch length	Final plant height	Width of matured pod	Weight of matured pods/plant	100 seed weight	Genotypic correlation coefficient
Days to flowering	1	0.06		-0.02	0.13	0.34	-0.01	0.11	0.60	0.02	1.23**
	2	-0.32		-0.07	0.15	0.16	-0.62	0.66	-0.41	0.36	-0.09
	3	0.57		0.06	-0.17	0.37	-0.55	0.12	0.67	-0.13	0.94**
	4	-0.79		0.37	-0.15	-0.86	0.80	0.02	-0.05	0.58	-0.08
Plant height at flowering	1	-0.11	0.01		0.06	0.28	-0.03	0.09	0.25	-0.01	0.54**
	2	-0.57	-0.04		0.70	0.19	-0.15	0.07	-0.56	-0.05	-0.42**
	3	0.26	0.13		-0.16	1.03	-1.04	0.11	0.81	-0.23	0.92**
	4	6.20	-0.05		-0.84	-2.55	-3.77	-0.05	1.05	0.70	0.70**
Number of pods per plant	1	0.19	0.04	-0.04		0.24	-0.04	-0.01	0.43	0.08	0.89**
	2	-0.56	0.09	0.71		-0.25	0.51	0.89	0.70	-0.68	1.40**
	3	-0.17	0.59	0.25		1.91	-1.77	0.25	0.73	-0.65	1.14**
	4	-1.10	-0.11	4.71		-2.62	-2.29	0.40	1.85	0.29	1.13**
Branch length	1	0.37	0.06	-0.09	0.12		-0.07	0.04	0.22	0.06	0.72**
	2	0.34	-0.15	-0.32	0.42		-0.43	0.34	-0.27	-0.10	-0.18
	3	1.41	0.15	0.19	-0.23		-1.16	0.10	0.91	-0.23	1.15**
	4	-2.40	-0.28	6.57	-1.20		-3.69	0.19	1.19	0.48	0.86**
Final plant height	1	-0.11	0.01	-0.03	0.07	0.22		0.07	0.29	0.01	0.51**
	2	-0.91	-0.22	-0.10	0.31	0.16		0.78	-0.10	0.32	0.25*
	3	-1.38	0.23	0.20	-0.21	1.19		0.11	0.96	-0.11	0.98**
	4	-4.01	0.16	5.83	-0.63	-2.21		-0.14	0.86	0.74	0.60**
Width of matured pod	1	0.16	0.04	-0.07	-0.02	0.10	-0.05		0.17	-0.08	0.26*
	2	1.23	-0.17	-0.03	-0.40	0.09	-0.57		0.25	0.13	0.52**
	3	0.34	0.21	0.08	-0.12	0.41	-0.46		0.79	-0.55	0.71**
	4	0.60	-0.02	-0.50	-0.73	-0.74	0.92		0.97	-0.04	0.46**
Weight of matured pods/ plant	1	0.59	0.06	-0.05	0.14	0.14	-0.05	0.05		0.04	0.91**
	2	1.37	0.10	0.24	-0.29	-0.07	0.06	0.22		-0.91	0.72**
	3	0.75	0.52	0.28	-0.16	1.72	-1.77	0.36		-0.76	0.94**
	4	1.59	0.02	4.09	-1.28	-1.80	-2.17	0.37		0.29	1.12**
100 seed weight	1	-0.08	-0.01	-0.01	-0.18	-0.29	0.01	0.16	-0.28		-0.69**
	2	-0.87	0.13	-0.03	-0.44	0.04	0.34	-0.18	1.44		0.42*
	3	-0.67	0.11	0.09	-0.16	0.48	-0.22	0.28	0.84		0.75**
	4	-0.74	0.61	-5.83	0.43	1.56	4.01	0.04	-0.62		-0.54**

Residual effect: Early rain 2005 (season 1) = -0.16; Dry season 2006 (season 2) = 0.74; Early rain 2006 (season 3) = -0.55; late rain 2006 (season 4) = -0.38
*, ** Significant at 5% and 1% level of probability, respectively

fruit bearing nodes. The positive significant association of days to flowering with seed yield in early rain 2005, early rain and late rain 2006 indicated that early flowering lines were favoured by these environments. This may be due partly to the considerable decline in rainfall relatively in these environments, a situation that placed the early flowering lines at a relative advantage in terms of productivity.

Significant genotypic and phenotypic correlations of seed yield per plant with plant height at flowering, length of fresh pod, number of pods per plant, width of matured pod, weight of matured pods per plant and 100-seed weight in all the seasons imply that these characters possessed greater practical values for selection. Negative correlations of seed weight per plant with length of fresh pod suggests that selection for okra genotypes with long pod will give low seed yield probably because of physiological ability of the plant to successfully feed higher numbers in short pods. In early rain and late rain 2006, significant genotypic and phenotypic correlations of number of pods per plant, number of branches per plant and number of ridges per pod with seed yield suggested that selection based on phenotypic correlations would be effective. The significant genotypic and phenotypic correlations between number of ridges per pod and number of seeds per pod with seed weight suggested that there would be more seed yield since the greater the number of ridges and seeds, the more the number of seeds per pod and hence the more the seed yield. Thus, selection for these traits will lead to improvement in okra seed. Similar reports were observed by Murtadha *et al*. (2004).

Characters which are phenotypically correlated but not genotypically correlated will not produce repeatable estimates of inter-character associations and any selection based on the relationship is likely to be unreliable. This is true of the relationship between width of matured pod and 100-seed weight in the late rain 2006.

Very few of the environmental correlation coefficients were significant in the four seasons and this showed that the effect of environmental factors on the expression of the relationship between the characters was not so strong as to alter it markedly. Significant environmental correlations were observed for seed yield with weight of matured pods per plant, width of matured pod, length of matured pod and number of pod per plant but these were also genotypically and phenotypically correlated in all the seasons of the study.

Correlation measures mutual association with no regard to causation, whereas path analysis specifies causes and measures their relative importance (Dewey & Lu, 1959). Plant height at flowering had the largest positive direct effect on seed yield with its largest indirect effect via weight of matured pods per plant, though its correlation with seed yield was significant. Despite the strong positive association between the number of pods per plant and seed yield, its direct effect was negative indicating the inefficiency of selection based on correlation alone. The final plant height, width of matured pod and weight of matured pod per plant can be used for direct selection to improve seed yield in okra. Final plant height had a negative contribution with seed yield despite its significant correlation. This demonstrates the defects of selecting on the basis of inter-correlation as such a selection may not produce the desired results.

Weight of 100 seeds manifested high negative direct effect on seed yield. Its high positive indirect effects via days to flowering, branch length, final plant height and weight of matured pods per plant appeared to be the cause of their strong correlation with seed yield.

The residual effect of 0.16 in early rain 2005, 0.74 in off season 2006, 0.55 in early rain 2006 and 0.38 in late rain 2006 implied that 84%, 26%, 45% and 62% respectively of the total variation in seed yield had been determined. It further portrayed the influence of environment in the determination of genetic parameters.

In conclusion, the above findings illustrated that final plant's height, branch length and number of pod per plant were the most important component for higher seed yield. It was observed that the performance of the genotypes varied from season to season. Genotypes generally performed best in early rain followed by late rain which was as a result of favourable environmental conditions (lower rainfall, low relative humidity and higher temperature). It shows the early rainy season is the best growing period for okra.

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