Relationship between growth, yield, and yield components of some cultivars of okra (*Abelmoschus esculentus* (L) Moench)

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ABSTRACT

Studies on the growth, yield, and yield components of okra were conducted at Moor Plantation, Ibadan, Nigeria, in 1995 and 1996. Increase in plant height, leaf stalk, internode length, pod length, and pod diameter were largely determined by cultivar characteristics. Fruiting peduncle, leaf nodes, and edible fruit yield were significantly different ($P \leq 0.05$) among cultivars. Early flowering and long pods were indicators of low yield due to high negative correlation. However, late flowering, number of pods per plant, and length of fruiting peduncle were most highly positively correlated with yield, but highly negatively correlated with pod length. Of all the okra traits studied, number of capsules per plant was the most important determinant of yield. Days to first flowering was the most important character governing number of pods per plant which accounted for 52.7 per cent of yield variations. Edible fruit yield increased linearly until 14 weeks after planting and then declined. At 8 weeks after planting, internode length, leaf stalk length, and fruiting peduncle length increased as edible fruit yield increased. The period of most active growth of okra plant was 8 to 9 weeks after planting.

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RÉSUMÉ

RAJI, J. A.: *Relation entre la croissance, le rendement et les composants de rendement de quelques variétés de gombo (*Abelmoschus esculentus *(L) Moench).* Etudes sur la croissance, le rendement et les composants de rendement de gombo. Se déroulaient à la Plantation de Moor, Ibadan, en 1995 et 1996. L'augmentation en taille de plante, tige de feuilles, longueur d'entre-nœud, longueur de cosse, et diamètre de cosse étaient déterminé en grande mesure par les caractéristiques de variété. Pèdoncule fructifère, nœud de feuilles et rendement de fruit comestible étaient considérablement différents ($P \leq 0.05$) parmi les variétés. La floraison tôt et les cosses longues étaient les indicateurs de rendement bas à cause d'une corrélation négative élevée. Toutefois, la floraison tardive, nombre de cosses par plante et longueur de pédoncle fructifère étaient pour la plupart hantement corrélé positivement avec le rendement mais hantement corrélé négativement avec la longueur de cosse. De tous les traits de gombo étudiés, nombre de capsule par plante était le déterminant du rendement le plus important. Les jours avant la première floraison était le plus important caractère dominant le nombre de cosses par plante qui représentent 52.7 pour cent des variations de rendement. Le rendement de fruit comestible augmentait linéairement jusqu' à 14 semaines après la plantation et puis diminuait. A 8 semaines après la plantation, la longueur d'entre-nœud, longueur de tige de feuilles et longueur de pédoncule de fruit augmentaient comme le rendement de fruit comestible augmentait. La période de croissance la plus active de la plante de gombo était 8 à 9 semaines après la plantation.

Introduction

Okra (*Abelmoschus esculentus*) is an annual crop which belongs to the family Malvaceae. It is an important vegetable crop grown mainly for its edible fruit. The young leaves have high protein content and are eaten as vegetable soup. Girenko & Pugather (1986) identified 13 basic groups of okra by morphological differences in Africa.

Hence, the genetic diversity in Africa is high.

The stem may act as source of fuel. Okra, when planted in the early season, is more vigorous, flowers earlier, and has longer harvest duration than in the late season (Tremiren & Okly, 1986). Continuous harvesting of immature pods enhances vegetative growth, and hence yield. The pods may be green or pink, while the claws of the calyx are crimson (Cobley, 1976). It is very rich in vitamins A, B, and C, and rich in calcium, iron and sodium. Potassium is the most abundant mineral element. The trace elements in immature pods are copper, sodium, and iodine. The young pods contain about 86.1 per cent moisture, 9.7 per cent carbohydrate, 12.2 per cent protein, 0.1 per cent fibre, 0.2 per cent fats, and 0.9 per cent ash (Ariyo & Aken'ova, 1986). Okra is a dicotyledonous, deep-rooted herbaceous plant which grows to a height of 0.9-2.4 m, depending on variety, environmental conditions, and management practices (Cobley, 1976). All varieties of okra have the same flower shape, i.e., five large white, yellow or pink-coloured petals, with the claws of the calyx being crimson.

Limited documented information exist on the association between and among growth and yield attributes of okra in the tropics. This study, therefore, examined the relationship between yield and growth parameters in 15 lines of okra.

Materials and methods

The experiment was conducted in 1995 and 1996 at the Moor Plantation, Ibadan, Nigeria. Seeds of 15 lines of okra were used for the study. The okra cultivars planted were UI 79-5 (T1), TAe 38 (T2), NHAe 474 (T3), UI 92 (T4), UI 9 (T5), UI 86 (T6), UI 211 (T7), NHAe 15 (T8), UI 212 (T9), UI 10 (T10), UI 104 (T11), UI 22-77 (T12), V2 (T13), UI 53-139 (T14), and V35 (T15). Field size was 3.0 m × 3.6 m, designed in a randomized complete block with four replications. Three seeds were sowed per hill at a spacing of 90.0 cm and later thinned to two plants per hill at 2 weeks after sowing (WAS). Each plot comprised six rows of plants. Compound fertilizer (NPK 15-15-15) was applied at the rate of 100 kg/ha at 3 WAS. Weed was initially controlled by spraying gramoxone at a rate of 10 ml/l of water at 4 days before sowing. Three subsequent hand weedings were carried out at 3, 6, and 9 WAS. Insects were controlled by spraying Azodrin 60 and Decis each at 1.25 ml in 1.0 l of water (1.25 ml/l) at 5 WAS.

Seven growth parameters were taken on weekly basis on five tagged plants from two mid-rows of each plot. Plant height was measured at 7, 8, 9, 10, 12, 14, and 16 WAS (measured from the plant base to the apex). Internode length (distance between two leaf nodes), leaf stalk length (measure of distance between the leaf base and point of attachment to the stem), fruiting peduncle (length of the stalk attaching the pod to the stem), pod length (base of pod to the apex), and pod diameter (measured with Venier callipers) were also measured at the same time interval. The measurements were taken until senescence. Other agronomic parameters determined were number of days to first, 50 and 100 per cent flowering, and number of leaf nodes per plant. Simple linear correlation coefficients and simple multiple regression (Roy, 1965; Kaltzikes, 1973; Lee & Kaltzikes, 1973) were calculated to determine the relationship between edible fruit yield and the components of yield.

Results and discussion

Plant growth measured as plant height was significantly different among cultivars (Table 1), and was rapid from 7 WAS when flower opening and pod formation commenced. Between 9 and 12 WAS during which 49.2 per cent of edible pods were already harvested, growth rate was two to three times what was observed when pod formation started. It is, therefore, suggested that this growth period (9-12 WAS) is ideal for the use of okra stem as support for tomato plant where intercropping agriculture is practised. At 8 WAS, unharvested pods were not succulent and became fibrous. Thus, since flower opening started at 7 WAS and unharvested pods were not succulent at 8 WAS, pods for consumption must, therefore,

TABLE 1

Estimate of Yield and Growth Components of Okra

Cultivar	*Plant height (cm)*							*Total edible fruit yield (× 10^2 kg/ha)*						*Internode length (cm)*					
	7	*8*	*9*	*10*	*12*	*14*	*16*	*8*	*9*	*10*	*12*	*14*	*16*	*7*	*8*	*9*	*10*	*12*	*14*
UI 79-5	55.8	74.5	93.8	109.3	139.0	144.7	152.3	357.4	468.1	763.3	329.7	94.7	166.3	4.8	9.6	12.5	12.9	10.6	13.3
TAe 38	62.8	85.5	109.5	125.3	145.6	148.1	150.4	229.8	514.8	876.3	662.5	197.0	243.5	3.0	8.0	12.7	14.9	15.6	15.9
NHAe 474	32.8	42.5	57.3	71.4	102.0	118.5	126.5	79.1	97.4	383.2	1230.0	1250.0	829.5	2.5	5.5	6.8	6.9	7.9	7.9
UI 92	48.5	64.7	85.8	104.7	138.4	168.0	184.5	37.1	141.8	447.7	557.5	1055.0	924.5	3.7	6.9	10.3	10.7	11.4	11.4
UI 9	35.9	48.9	66.5	85.7	121.7	140.6	148.7	37.6	34.3	181.4	897.5	844.0	673.0	3.3	5.7	10.3	10.9	11.1	11.4
UI 86	56.5	76.0	107.5	143.3	203.5	249.9	276.4	234.8	84.5	126.1	842.5	1225.7	858.7	3.4	8.4	12.7	13.3	13.4	13.8
UI 211	34.5	44.3	56.8	64.3	80.7	83.1	84.7	83.4	378.6	583.4	350.0	212.0	151.3	2.8	5.1	6.6	7.1	7.7	7.9
NAe 15	45.8	63.1	88.5	106.5	144.7	168.0	179.0	56.5	156.3	457.0	667.5	568.0	666.0	2.7	6.7	10.5	11.1	11.5	11.5
UI 212	46.4	60.8	85.4	101.0	132.0	143.7	147.0	145.1	198.7	426.3	618.7	743.0	539.0	3.8	7.5	9.9	10.1	10.7	11.1
UI 10	55.3	73.3	98.0	106.7	140.5	143.9	152.6	118.8	134.7	477.5	688.7	548.7	744.0	2.9	6.7	12.4	13.4	13.6	13.7
UI 104	34.3	46.3	62.0	81.3	119.5	139.1	144.9	56.3	103.7	312.7	922.7	1030.0	800.7	2.5	4.5	6.5	6.9	7.4	7.7
UI 22-77	45.3	59.6	75.0	85.3	100.0	106.1	110.0	202.8	346.2	868.7	507.5	270.3	362.5	3.6	7.2	10.1	10.5	10.6	11.2
V2	34.5	43.8	58.8	72.5	109.3	123.5	125.6	94.8	113.4	362.2	951.3	888.7	555.7	2.0	3.9	5.5	5.7	5.9	6.1
UI 53-139	36.8	40.3	64.0	79.7	110.0	117.9	121.5	83.4	211.1	455.7	846.3	923.7	560.5	2.4	4.6	6.8	7.3	7.5	7.5
V 35	39.3	53.6	75.8	96.0	145.3	166.7	170.1	103.5	119.0	271.5	622.5	1100.0	537.7	3.3	6.3	8.7	9.2	10.3	10.3
LSD 0.05	17.7	22.7	34.2	41.7	66.0	77.5	83.0	25.6	40.4	44.8	66.3	73.9	51.3	1.6	2.8	4.7	3.9	5.8	4.7
LSD 0.01	29.6	37.9	57.1	69.7	110.3	129.5	138.7	42.3	70.4	73.9	109.4	122.2	84.7	2.7	4.9	7.8	6.5	8.5	7.9

not last up to 1 week on the stem before they are harvested. Only 11.9 per cent of the edible pods harvested were from 8 to 9 WAS, a period of most active plant growth in preparation for carrying okra pods. The maximum edible fruit yield (26.0 per cent of the total) was attained at 14 WAS (Table 1).

The peak of stem elongation was at 16 WAS during which edible pod yield started to decline. At 8 - 16 WAS, internode and leaf stalk lengths were two to three times the observed at 7 WAS (Table 1). The differences in plant height were attributed to differences in internode length. The leaf stalk length increased until 10 WAS after which senescence started (Table 2). The maximum leaf stalk length among cultivars studied was 35.1 cm. The cultivar with the maximum leaf stalk produced the maximum edible pod yield at 14 WAS and second highest at 16 WAS when harvesting was stopped due to declining yields. Observed high yields in this cultivar might be due to the potential of its leaf stalk to subtend the leaf to maximum inlet radiation. The fruiting peduncle length was not significantly different among cultivars, and ranged between 1.4 and 4.8 cm. Pod length was significantly different ($P \leq 0.05$) among cultivars, and ranged between 2.3 and 18.4 cm at 8 WAS to 7.5 and 19.9 cm at 11 WAS. However, the cultivar UI 79-5, which had the maximum pod length, was one of the low-yielding cultivars, suggesting that pod length may not be an index of optimum yield. Both cultivars, UI 79-5 and TAe 38, which had long pods, also had relatively broader diameter than the others.

Correlation studies indicate that pod yield was highly positively and significantly ($P \leq 0.05$) related with first flowering, 50.0 per cent flowering, number of pods per plant, and length of fruiting peduncle length, but highly negatively correlated with pod length (Table 3). Therefore, it is recommended that plant breeders and agronomists must look for these traits for yield improvements in okra. There were no significant ($P \leq 0.05$) relationships between yield, leaf nodes per plant, internode length, and plant height. Thus, these traits may not be considered in breeding for okra plant improvement. The 100 per cent flowering was most highly positively correlated with first flower opening and 50.0 per cent flowering, implying that okra cultivars which flower early will also reach full flowering potential early.

Fruiting peduncle per plant and length of leaf stalk were highly positively correlated with leaf nodes per plant, suggesting that they are all highly important traits for yield improvement. Of all the characters studied, number of pods per plant was the most important determinant of yield (R=0.981) (Table 4). This agrees with the report of Olasantan & Aina (1987). Also, flowering was the most important determinant of number of pods per plant, and it accounted for 52.7 per cent ($DR^2 = 0.527$) of yield variations (Table 4). One hundred per cent flowering which explained 19.0 per cent of the variation was the second most important parameter. The multiple regression analysis indicated greater contribution of flowering (90.8 per cent) to okra yield, and that the contribution of other yield parameters were not significant ($P \leq 0.05$) (Table 5). The results of this study showed that late flowering, i.e. 100 per cent flowering, resulted in greater pod yield. Thus, the positive and significant correlation between pod yield and late flowering suggest that okra cultivars with late flowering character give higher yields and should be selected for commercial agriculture.

In general, number of pods per plant was the most important character determining okra yield. Pods per plant was in turn enhanced by long period of flowering (100.0 per cent flowering). Both attributes are again influenced by short pod diameter, short pod length, short internode length, and long fruiting peduncle length. Therefore, plant breeding efforts must be directed towards optimizing these traits for enhanced yields.

TABLE 2

Estimate of Some Agronomic Parameters of Okra

Cultivars	*Leaf stalk length (cm)*				*Fruiting peduncle length (cm)*				*Pod length (cm)*				*Pod diameter (cm)*			
	7	*8*	*9*	*10 (WAP)*	*8*	*9*	*10*	*11 (WAP)*	*8*	*9*	*10*	*11 (WAP)*	*8*	*9*	*10*	*11 (WAP)*
UI 79-5	4.9	13.5	24.5	28.7	3.1	3.5	3.5	3.5	18.4	19.9	16.4	19.9	8.5	10.3	11.0	11.0
TAe 38	6.3	14.6	21.9	23.1	3.3	3.5	3.6	3.6	16.8	18.8	14.2	18.9	9.5	10.6	10.8	10.8
NHAe 47-4	6.9	16.5	27.0	28.0	1.4	3.7	3.9	3.9	3.8	7.2	10.0	11.9	2.3	8.3	11.3	11.4
UI 92	8.3	16.6	24.1	27.0	2.9	4.1	4.2	4.2	7.0	7.9	9.3	9.3	4.8	11.2	13.2	13.2
UI 9	5.5	16.1	25.6	26.5	2.1	3.8	3.9	3.9	2.3	6.6	8.6	8.6	2.3	8.9	11.5	11.9
UI 86	6.9	18.0	30.7	35.1	2.1	3.9	4.3	4.3	2.7	9.1	12.6	12.8	2.4	8.1	11.1	11.3
UI 211	5.9	15.4	26.3	28.0	2.6	2.9	3.0	3.0	8.7	10.6	12.1	12.2	8.4	10.5	12.5	12.5
NHAe 15	3.9	11.7	22.6	25.3	2.3	3.3	3.3	3.3	3.3	10.9	12.5	12.5	4.5	9.1	9.8	9.8
UI 212	6.5	17.0	27.1	29.3	2.8	3.2	3.5	3.5	4.5	8.4	10.0	11.3	4.3	9.5	11.9	12.2
UI 10	6.7	16.3	25.4	27.3	3.2	3.5	3.5	3.5	5.1	10.8	11.9	12.1	5.5	9.3	10.8	10.8
UI 104	7.2	15.5	24.4	26.5	2.9	3.1	3.8	3.9	2.3	6.6	7.8	8.6	3.4	6.6	9.8	12.2
UI 22-77	8.2	17.6	24.0	24.4	2.5	2.7	2.8	2.8	9.2	10.9	11.3	11.3	9.8	10.8	10.9	10.9
V2	7.1	18.5	27.5	31.3	0.9	3.3	4.3	4.3	4.8	6.4	12.9	13.1	1.1	4.9	9.9	10.4
UI 53-139	6.7	16.0	27.4	30.6	3.4	3.6	3.8	3.8	2.4	7.9	10.0	10.3	4.6	9.9	12.8	12.9
V 35	6.7	13.9	28.1	31.5	2.1	3.4	3.4	3.4	3.9	6.3	7.1	7.5	4.1	10.3	12.7	12.7
LSD 0.05	3.3	5.7	6.7	7.8	0.8	1.2	1.2	1.2	2.5	5.6	4.3	6.7	2.4	3.9	3.2	0.8
LSD 0.01	4.5	9.5	11.2	13.1	1.5	1.9	2.1	2.1	5.7	9.4	7.3	9.6	3.9	6.6	5.3	1.4

TABLE 3

Correlation Between Yield and 13 Yield Parameters in Okra

	Y	*FF*	*50% F*	*100% F*	*LNPP*	*LLS*	*FPPL*	*PPP*	*HSW*	*PD*	*PL*	*IL*	*H*	*FPL*
Y	1.000	0.697***	0.640***	0.686***	0.350^{ns}	0.276^{ns}	-0.081^{ns}	0.726***	0-3.86*	-0.488**	-0.647***	-0.358^{ns}	0.222^{ns}	0.645***
FF		1.000	0.930***	0.953***	0.314^{ns}	0.489*	-0.777^{ns}	0.759***	-0.105^{ns}	-0.717***	-0.802***	-0.566***	0.263^{ns}	0.604***
50% F			1.000	0.924***	0.283^{ns}	0.445*	-0.128^{ns}	0.686***	-0.092^{ns}	-0.783***	-0.737***	-0.467*	0.219^{ns}	0.611***
100% F				1.000	0.355^{ns}	0.431*	-0.107^{ns}	0.842***	-0.025^{ns}	-0.640***	-0.914***	-0.565**	0.186^{ns}	0.531**
LNPP					1.000	0.607***	0.679	0.583**	-0.160^{ns}	-0.305^{ns}	-0.348^{ns}	-0.135^{ns}	0.178^{ns}	0.353^{ns}
LLS						1.000	0.449*	0.377*	-0.319^{ns}	-0.343^{ns}	-0.321^{ns}	-0.249^{ns}	0.467*	0.451
FPPL							1.000	0.149^{ns}	-0.263^{ns}	-0.015^{ns}	-0.106^{ns}	-0.296^{ns}	0.286^{ns}	0.044^{ns}
PPP								1.000	0.169^{ns}	-0.519**	-0.847***	-0.399^{ns}	0.197^{ns}	0.408*
HSW									1.000	0.327^{ns}	-0.226^{ns}	-0.031^{ns}	0.266^{ns}	-0.259*
PD										1.000	0.398^{ns}	-0.305^{ns}	-0.278**	-0.604***
PL											1.000	-0.590**	-0.58**	-0.307^{ns}
IL												-1.000	0.506	-0.117^{ns}
H													1.000	0.504**
FPL														1.000

Y = yield
FF = first flowering
50% F = 50% flowering
100% F = 100% flowering
LNPP = leaf nodes per plant
LLS = length of leaf stalk
FPPL = fruiting peduncle per plant
FPL = fruiting peduncle length
PPP = pods per plant
HSW = hundred seed weight
PD = pod diameter
PL = pod length
IL = internode length
H = Height (of plant)

TABLE 4

Co-efficient of Determination (R^2) and R^2 Change (ΔR^2) from Stepwise Multiple Regression of First Flowering and Other Agronomic Traits on Okra Yield

Trait	R^2	ΔR^2
FF	0.527	0.527
FF, 50% F	0.673	0.146
FF, 50% F, 100% F	0.863	0.190
FF, 50% F, 100% F, LNPP	0.883	0.020
FF, 50% F, 100% F, LNPP, LLS	0.891	0.008
FF, 50% F, 100% F, LNPP, LLS, FPPP	0.903	0.012
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP	0.905	0.003
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP, HSW	0.916	0.010
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP, HSW, PD	0.928	0.013
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP, HSW, PD, PL	0.947	0.018
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP, HSW, PD, PL, IL	0.959	0.012
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP, HSW, PD, PL, IL, H	0.962	0.003
FF, 50% F, 100% F, LNPP, LLS, FPPP, PPP, HSW, PD, PL, IL, H, FPL	0.981	0.018

FF = first flowering, LLS = length of leaf stalk, PD = pod diameter, 50% F = 50% flowering, 100% F = 100% flowering, FPL = fruiting peduncle length, PL = pod length, HSW = hundred seed weight, LNPP = leaf nodes per plant, PPP = pods per plant, IL = internode length, H = height (of plant)

TABLE 5

Multiple Regression and Percentage Contribution of Different Attributes to Edible Okra Yield

$Y = 14.258 + 0.580x_1$	0.908	0.908
$Y = 5.680 + 0.398x_2$	0.937	0.028
$Y = 4.065 - 0.130x_1 + 0.437x_2 + 0.804x_3$	0.943	0.005
$Y = 5.869 + 0.020x_1 + 0.403x_2 + 0.870x_3 + 0.765x_4$	0.962	0.019
$Y = -7.835 + 1.300x_1 + 0.29x_2 + 0.485x_3 + 0.516x_4 + 0.742x_5$	0.968	0.006
$Y = -11.843 + 0.055x_1 + 1.599x_2 + 0.023x_3 - 0.492x_4 + 0.560x_5 + 0.767x_6$	0.971	0.003
$Y = -5.552 - 0.275x_1 - 0.158x_2 + 1.870x_3 + 0.039x_4 - 0.792x_5 + 0.8647x_6 + 0.789x_7$	0.983	0.012
$Y = -15.714 - 0.147x_1 - 0.335x_2 + 1.236x_3 + 2.513x_4 + 0.043x_5 - 0.842x_6 + 0.633x_7 + 0.858x_8$	0.989	0.006
$Y = -18.769 - 0.642x_1 - 0.148x_2 - 0.349x_3 + 0.245x_4 + 2.670x_5 + 0.047x_6 - 0.891x_7 + 0.012x_8 + 0.9449x_9$	0.991	0.002
$Y = -16.599 - 0.110x_1 - 0.458x_2 - 0.118x_3 - 0.313x_4 + 0.305x_5 + 2.522x_6 + 0.046x_7 - 0.824x_8 + 0.653x_9 + 0.922x_{10}$	0.991	0.000
$Y = -9.238 + 0.0688x_1 - 0.128x_2 - 0.466x_3 - 0.090x_4 - 0.322x_5 + 0.311x_6 + 2.228x_7 + 0.046x_8 - 0.837x_9 + 0.563x_{10} + 0.787x_{11}$	0.992	0.001
$Y = -6.8500 + 0.763x_1 + 0.172x_2 - 0.084x_3 - 0.551x_4 - 0.054x_5 - 0.392x_6 + 0.294x_2 + 1.872x_8 + 0.052x_9 - 0.952x_{10} + 0.556x_{11} + 0.662x_{12}$	0.992	0.000

FF = first flowering, LLS = length of leaf stalk, PD = pod diameter, 50% F = 50% flowering, 100% F = 100% flowering, FPL = fruiting peduncle length PL = pod length, HSW = hundred seed weight, LNPP = leaf nodes per plant, PPP = pods per plant, IL = internode length, H = height (of plant)

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