Interpreting Morphology and Yield Response of Okra (*Abelmoschus esculentus*) to Weed Variables Using Regression Analysis

Olatunde Philip Ayodele, Department of Agronomy, Adekunle Ajasin University Akungba Akoko, Ondo State, Nigeria (*Nigeria*)
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ABSTRACT

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The cohabitation of weeds with crops may not always pose problems. Weeds are plant pests that negatively impact crop yield. However, it is essential to determine when pest status is reached in crops for weed management decisions in crop production. Field experiments were conducted during the rainy seasons of 2017 and 2018 at the research farm of the Institute of Agricultural Research and Training Ibadan (7°38' N 3° 84' E), located in the rainforest-savanna transition agroecology of southwestern Nigeria. The experiments consisted of nine weed management practices and a weedy check arranged in Randomised Complete Block Design with three replications. Weed density and weight, along with okra's morphological attributes such as the number of leaves, leaf area, plant height and stem girth, were recorded 9 weeks after sowing (WAS). At commercial maturity, unlignified okra pods were harvested from 9-12 WAS. Simple linear correlation and regression analysis between weed parameters and okra traits was performed. The result showed a negative relationship between weed growth and okra yield in both trials. The negative impact of weeds on some morphological traits of okra probably led to the reduction in okra yield. However, plant height and number of nodes did not significantly ($P < 0.05$) influence okra yield. Weeds attained pest status for okra at a weed density of about 14.17 plants/m^2 with weed dry and fresh weights of 10.05 g/m^2 and 54.86 g/m^2, respectively. Hence, weed management is necessary for okra production to reduce yield loss.

Keywords: Okra, pest status, weed, yield

Okra (*Abelmoschus esculentus* L. Moench) is a commercial vegetable crop in the family *Malvaceae*. It originated from tropical Africa and is widely cultivated in many parts of the world, especially in tropical and sub-tropical countries (Hayati 2020). Okra is an annual crop mainly valued for its immature fruits, consumed boiled or fried (Odey 2022). The mucilage produced from its pod is used to prepare stew or soup, which combines well with starchy foods cooked to a dense paste popularly called 'swallow' in Nigeria. Okra fruit has a proximate composition of 2.01% protein, 88.29% moisture content, 1.96% fat, 1.66% ash, 3.67% crude fibre, and 4.72% carbohydrate (Aladesanwa 2005). It is also rich in carotene, vitamin A, vitamin C and

Corresponding author: Olatunde Philip Ayodele
Email: olatunde.ayodele@aaua.edu.ng

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trace elements such as Fe and Zn (Liu et al. 2021). The production of okra has increased recently due to its nutritional value (Odey 2022). However, weeds negatively impact okra yield (Opadokun and Olorunmaiye 2019).

Farmers are targeting sustainable high okra yield. Therefore, it is essential to identify the roles of the agroecosystem components in achieving this objective. Studies have shown that biotic factors such as weeds may impact crop yield (Ayodele 2021; Ayodele et al. 2021). Weeds are wild plants which may hamper cultivated crops from growing properly. In rare cases, leguminous weeds promote crop growth due to their nitrogen-fixing ability (Bhandari and Sen 1979). Though the detrimental effect of weeds on crops may eventually result in yield loss, the benefits accruing from weeds, such as erosion control (Moreau et al. 2020) and pollinator attractants (Kleiman et al. 2021), make weed eradication indefensible.

The cohabitation of weeds with crops may not always pose yield problems. An earlier study revealed that a milkweed plant (*Euphorbia heterophylla*) cohabiting with okra at a distance of 20 cm or 30 cm had a comparable pod yield with weed-free (Opadokun and Olorunmaiye 2019). At 5% crop yield loss due to weeds, pest status is consequently attained (Khan et al. 2014). Weed management aims only to permit the minimal harmful effect of weeds. Hence, crop and weed growth monitoring is essential to avoid low yields. Morphological features of crops are reliable yield indicators (Shu et al. 2021). Parts of plant serving as yield differ in different crops. Hence, it is essential to study the relationship between yield and other morphological attributes of crops. The same morphological attribute may reflect different yield levels in different crops. For instance, fiber yield in cotton (*Gossypium hirsutum*) correlates positively with plant height (Rehman et al. 2020). Contrarily, roselle (*Hibiscus sabdariffa*), in the same *Malvaceae* family, has calyx yield which negatively correlates with plant height (Sanoussi et al. 2011).

Generally, plant morphological attributes such as plant height, plant girth, number of leaves and leaf area have been associated with the yield in many agricultural crops (Aladesanwa and Ayodele 2011; Ayodele 2021). A study by Norman et al. (2020) showed that okra pod yield positively correlates with plant height and leaf area. Also, these morphological traits positively correlate with the number of leaves and plant girth. However, weeds impact morphological characteristics in different ways. For instance, weed pressure reduces the plant height of maize (Begna et al. 2001) and increases soybean height (Braz 2021). Hence, this study seeks to investigate the empirical relationship between weeds and the morphological characteristics of okra as well as its pod yield.

MATERIALS AND METHODS

Experimental site.

Field experiments were conducted at the research farm of the Institute of Agricultural Research and Training (IAR&T) Ibadan, Nigeria (7º38' N 3º 84' E) during the 2017 and 2018 rainy seasons. The experimental site had clay loam soil with soluble organic carbon of 18.0 g kg^{-1}, N 1.5 g kg^{-1}, P 11.39 mg kg^{-1}, K 0.46 cmol kg^{-1}, Ca 1.85 cmol kg^{-1}, Mg 1.31 cmol kg^{-1} and pH of 4.9 at 5 cm soil depth. The experimental site was partitioned into 2 m × 2 m plots with an alley of 0.5 m and 1 m between plots and blocks, respectively. Okra seeds (v 35) were sown at 40 cm × 50 cm on the flat with three seeds per 1 cm depth hole. At 2 weeks after sowing (WAS), seedlings were later thinned to one plant per stand.

Experimental treatment and design.

The study consisted of ten experimental treatments, viz., cassava effluent (CE) of 24 g cyanide (CN)/ha applied at 3 WAS, pendimethalin of 1.2 kg a.i/ha applied at sowing (P), hoe-weeding (1 hoe-weeding) at 3 WAS, CE of 24 g CN/ha applied at 3 WAS and hoe-weeding at 5 WAS (CE + 1 hoe-weeding), hoe-weeding at 3 and 5 WAS (2 hoe-weeding), CE of 24 g CN/ha applied at 3 and 5 WAS (CE + CE), pendimethalin of 1.2 kg a.i/ha applied at sowing and CE of 24 g CN/ha applied at 5 WAS (P + CE), pendimethalin of 1.2 kg a.i/ha applied at sowing and hoe-weeding at 5 WAS (P + 1 hoe weeding), weedy check and weed-free. The trials were laid out in a randomized complete block design with three replications.

Data collection and analysis.

Weed density and weights were assessed at 9 WAS using 0.25 m^2 quadrats randomly fixed at two spots along the diagonals of the plots. Weeds collected from each plot were piled, weighed, oven-dried at 80°C for 48 h, and reweighed. The weed control efficiency (WCE) was mathematically derived as follows:

$$\mathrm{WCE} = \frac{(\mathrm{x}-\mathrm{y})}{\mathrm{x}} \times 100,$$

where x = weed dry weight in weedy check, y = weed dry weight in the treatment.

The morphological characteristics of okra, such as plant height, stem girth, number of leaves, and leaf area, were assessed at 9 WAS from six okra plants tagged within each plot. The plant heights and stem diameters were measured using the meter rule and vernier calliper. Unlignified okra pods, ranging from 3-5 cm in length, were harvested from the tagged plants at three-day intervals starting from 9-12 WAS. Simple linear correlation and regression analysis between weed and okra variables was performed using Microsoft Excel®.

RESULTS

Effect of weeds on the growth of okra.

The prominent weeds in the experimental field were *Brachiaria deflexa*, *Euphorbia heterophylla*, *Senna obtusifolia*, *Tridax procumbens*, *Mitracapus villosus*, *Cyperus rotundus*, and *Oldenlandia corymbosa* The descriptive statistics of okra and weed components that resulted from the 2017 and 2018 trials at 9 WAS are presented in Table 1.

The regressions of weed weight and okra growth parameters such as plant height, number of nodes and stem girth were not significant (P < 0.05) in both trials (Tables 2, 3). However, the regressions of weed weight and number of okra leaves were significant (P < 0.05). The correlation coefficient was 0.79 in 2017 and 0.7 in 2018. The weed dry and fresh weight showed similar relationships with okra growth. There were negative relationships between weed weight (X) and okra growth parameters (Y) such as the number of leaves, plant stem girth, leaf area, plant fresh weight, and plant dry weight in the 2017 and 2018 trials (Tables 2, 3). Contrarily, a positive correlation existed between weed weight and plant height of okra in both trials. The relationship between weed weight and number of nodes on okra plant differed in both trials. The number of nodes on okra plants correlated positively with weed weight in 2017 trial, whereas the same variables were negatively correlated in 2018 trial.

The regressions of weed density and okra growth parameters such as plant height and number of nodes were not significant (P < 0.05) in the trials, whereas leaf area and plant weight of okra had significant (P < 0.05) regressions with weed density. The regressions of weed density with stem girth and number of leaves of okra were significant (P < 0.05) in 2017 and 2018 trials, respectively. Weed density negatively correlated with the number of leaves, stem girth, leaf area, number of nodes, plant fresh weight and plant dry weight of okra in the trials (Table 4). However, the directions of correlation coefficients between weed density and plant height were inconsistent in both trials. It was negative in 2017 trial and positive in 2018 trial.

Table 1. Characteristics of okra and weeds grown under field conditions in 2017 and 2018 trials at 9 weeks after sowing

Statistics	Okra				Weeds			
	Plant height (cm)	No of leaves	Stem girth (mm)	Leaf area (cm^2)	Density (plant/m^2)	Fresh weight (g/m^2)	Dry weight (g/m^2)	WCE (%)
	2017 Trial							
Max	28.2	8.1	8.1	183.4	312	1027.2	180.9	100
Min	17.9	2.9	4.2	63	0	0	0	-48.4
Average	22.01	6.03	6.11	115.12	98.4	446.4	84.55	30.61
SV	3.67	1.73	1.22	34.36	89.94	326.33	61.67	50.61
	2018 Trial							
Max	40.2	13.73	17.7	240.2	245.3	1883.2	243.7	100
Min	24.6	4.8	5.7	75.2	0	0	0	0
Average	33.96	7.92	9.33	145.71	120.54	700.62	92.64	61.99
SV	4.99	2.74	3.65	52.88	91.39	629.67	83.11	34.1

WCE = Weed control efficiency; SV = Standard deviation.

Table 2. Linear correlation and regression at 9 weeks after sowing between growth parameters of okra (Y) and weed dry weight (X) (n = 10)

Growth Parameter	2017 Trail		2018 Trail	
	Correlation coefficient (R)	Regression equation	Correlation coefficient (R)	Regression equation
Plant height (cm)	0.15	Y=21.23+0.009x	0.31	Y=32.21+0.02x
No of leaves	-0.79	Y=7.89-0.02x*	-0.7	Y=10.05-0.02x*
Stem girth (mm)	-0.52	Y=6.94-0.01x	-0.33	Y=10.67-0.01x
Leaf area (cm^2)	-0.41	Y=134.39-0.23x	-0.71	Y=187.42-0.45x*
Number of nodes	0.1	Y=7.20+0.002x	-0.17	Y = 9.33-0.002x
Plant fresh weight (g)	-0.25	Y=31.95-0.04x	-0.7	Y=103.01-0.34x*
Plant dry weight (g)	-0.24	Y=6.21-0.007x	-0.58	Y= 22.02-0.06x

* = Significant at $P < 0.05$.

Table 3. Linear correlation and regression at 9 weeks after sowing between growth parameters of okra (Y) and weed fresh weight (X) (n = 10)

Growth Parameter	2017 Trial		2018 Trail	
	Correlation coefficient (R)	Regression equation	Correlation coefficient (R)	Regression equation
Plant height (cm)	0.16	Y=21.21+0.002x	0.32	Y=32.2+0.003x
No of leaves	-0.81	Y=7.95-0.004x*	-0.68	Y=9.99-0.003x*
Stem girth (mm)	-0.51	Y=6.96-0.002x	-0.31	Y=10.6-0.002x
Leaf area (cm^2)	-0.38	Y=133.01-0.04x	-0.7	Y=186.89-0.059x*
Number of nodes	0.07	Y=7.24+0.0002x	-0.39	Y=9.53-0.0005x
Plant fresh weight (g)	-0.24	Y=31.82-0.007x	-0.68	Y=102.16-0.043x*
Plant dry weight (g)	-0.23	Y=6.2-0.001x	-0.69	Y=23.12-0.01x*

* = Significant at $P < 0.05$.

Table 4. Linear correlation and regression at nine (9) weeks after sowing between growth parameters of okra (Y) and weed density (X) (n = 10)

Growth Parameter	2017 Trial		2018 Trial	
	Correlation coefficient (R)	Regression equation	Correlation coefficient (R)	Regression equation
Plant height (cm)	-0.4	Y=23.61-0.016x	0.19	Y=32.7+0.01x
No of leaves	-0.55	Y=7.06-0.01x	-0.69	Y=10.42-0.021x*
Stem girth (mm)	-0.81	Y=7.19-0.011x*	-0.32	Y=10.85-0.013x
Leaf area (cm^2)	-0.8	Y=145.14-0.305x*	-0.71	Y=195.38-0.412x*
Number of nodes	-0.44	Y=7.83-0.005x	-0.48	Y=9.69-0.004x
Plant fresh weight (g)	-0.66	Y=35.53-0.07x*	-0.71	Y=109.34-0.312x*
Plant dry weight (g)	-0.67	Y=6.97-0.014x*	-0.7	Y=24.56-0.069x*

* = Significant at $P < 0.05$; Weed density = Number of weeds/m^2.

Effect of weeds and okra growth parameters on yield.

The weed control efficiency (WCE) of the treatments had a positive relationship with okra pod yield in both years (0.78, 0.54 at $P < 0.05$, respectively), and the prediction equation was significant in 2017 (Table 5). The trials showed negative relationships between okra pod yield and weed growth. Regressing okra pod weight per unit area (*Y*) against weed parameters (*X*) indicated negative relationships for weed dry weight, weed fresh weight, and density in the trials with significant ($P < 0.05$) prediction equations in 2017. It was deduced from the study that to prevent weeds from reaching pest status on the okra field, weed dry weight and fresh weight should be less than 10.05 g/m^2 and 54.86 g/m^2, respectively. Also, weed density should be less than 14.17 plants/m^2.

The correlation between okra yield and okra morphological characteristics such as plant height, number of leaves, leaf area, stem girth, number of nodes and plant weight indicated positive relationships in the trials. However, the regression equations were not significant ($P < 0.05$) for plant height and number of nodes.

Table 5. Linear correlation and regression between okra yield per unit area (Y) and growth parameters of weeds and okra (X) at 9 weeks after sowing (n=10)

Growth Parameters	2017		2018	
	Correlation Coefficient (R)	Regression Equation	Correlation Coefficient (R)	Regression Equation
	Weed Parameters			
Weed dry weight (g/m^2)	-0.78	Y=369.71-1.84x*	-0.54	Y=289.80-1.04x
Weed fresh weight (g/m^2)	-0.74	Y=362.09-0.33x*	-0.54	Y=288.98-0.14x
Weed density (plant/ m^2)	-0.72	Y=328.78-1.16x*	-0.55	Y=309.68-0.96x
WCE (%)	0.78	Y=145.63-2.24x*	0.54	Y=37.37+2.52x
	Okra Parameters			
Plant Height (cm)	0.39	Y= -129.06+15.60x	0.51	Y= -359.07 + 16.29x
No of Leaves	0.75	Y= -168.24+63.41x*	0.9	Y= -221.63 + 52.46x*
Stem girth (mm)	0.88	Y= -425.54+104.84x*	0.7	Y= -90.20 + 30.46x*
Leaf Area (cm^2)	0.83	Y= -191.56 +3.53x*	0.92	Y= -209.07 +2.77x*
Number of Nodes	0.38	Y= -177.42+53.37x	0.56	Y= -844.06 +133.15x
Plant fresh weight (g)	0.75	Y= -108.48 +11.29x*	0.87	Y= -53.66 + 3.45x*
Plant dry weight (g)	0.74	Y= -110.83+58.06x*	0.86	Y= -56.37 +15.36x*

* = Significant at $P < 0.05$; WCE = Weed control efficiency; for WCE $n = 9$; Y is expressed in g/m^2.

DISCUSSION

This study agrees with Law-Ogbomo et al. (2013) that okra morphology, such as number of leaves, leaf area and stem girth, reduces as weed weight increases. However, it differs based on the evidence that okra plant height increased with increasing weed weight in the trials. Similarly, Moody (2009) and Agahiu (2020) reported an increase in the height of crops in the presence of weeds. The increase in plant height of okra with decreasing stem girth could be attributed to etiolation (de Oliveira et al. 2017). This phenomenon reflects intense competition between okra and weeds for sunlight.

The consistent significant correlation between weed weight and number of leaves suggests that the weed weight could be used in predicting the number of leaves on okra plants growing in a weedy environment. Similarly, on the same premise, it is opined that weed density could be reliably used in predicting okra leaf area and plant weight. The significant negative correlation between weed density and okra leaf area may be attributed to the shading effect of weeds (Shadbolt and Holm 1956), resulting in reduced photo-assimilates and manifesting in reduced weight of okra plant.

The negative correlation between weed density and growth components of okra corroborates previous reports that increasing weed density reduces crop growth (Ayodele 2021; Bajwa et al. 2020). Also, Okayi et al. (2017) reported a reduction in plant height, number of leaves and plant weight of okra with increasing density of tick weed (*Cleome viscosa*). Similarly, Opadokun and Olorunmaiye (2019) reported that increasing density of milkweed (*Euphorbia heterophylla*) reduced the plant height, number of leaves, stem diameter, and pod yield of okra.

The positive correlation between okra pod yield and okra morphological characteristics, such as plant height, number of leaves, leaf area, stem girth, number of nodes and plant weight, agrees with the findings of Mahmoud et al. (2020) that good vegetative growth is necessary to attain high okra yield. However, the positive and negligible effect of plant height on okra pod yield in this study corroborates Mohammed et al. (2020) who reported the same.

The negative relationship between weed growth parameters and okra pod yield in both trials corroborates the reports of previous studies that weeds may reduce crop yield (Ibrahim and Hamma 2012; Rajasree et al. 2017; Santos et al. 2017). Also, the positive correlation between weed control efficiency and okra pod yield implies that superior weed control may result in higher yield. This could be due to reduced competition for nutrients, light and water. Hence, the prediction equations of weed growth and okra yield provide an empirical basis for determining when weed management actions are required in okra production.

The negative impact of weeds on some morphological characteristics of okra probably led to the reduction in okra yield since these were positively correlated. However, the effect of weeds on the height and the number of nodes of the okra plant is inconsequential as it did not substantially impact okra yield in the trials. The negligible positive relationship between okra yield and growth parameters such as plant height and number of nodes suggests a different viewpoint to the reports of Echezona et al. (2010) that taller plants and more nodes give a better chance for more okra pods. Generally, morphological attributes such as leaf area and the number of leaves directly correlate with the plant photosynthetic capacity, which determines the yield (Li et al. 2022; Yang et al. 2019). Also, stem girth could be a reliable growth indicator since the plant stem is a major sink organ for carbon assimilates from the source leaf (Kanai et al. 2011).

RESUME

Ayodele, Olatunde Philip. 2022. Interprétation de la réponse de la morphologie et du rendement du gombo (*Abelmoschus esculentus*) aux variables des adventices à l'aide d'une analyse de régression. Tunisian Journal of Plant Protection 17 (2): 67-76.

La cohabitation des adventices avec les cultures ne pose pas toujours des problèmes. Les adventices sont des plantes pestes qui ont un impact négatif sur le rendement des cultures. Cependant, il est essentiel de déterminer quand le statut de peste est atteint dans les cultures pour les décisions de gestion des adventices dans la production agricole. Des expériences au champ ont été menées pendant les saisons des pluies de 2017 et 2018 à la ferme de recherche de l'*Institute of Agricultural Research and Training Ibadan* (7º38' N 3º84' E), situé dans la forêt tropicale-savane agroécologique de transition du sud-ouest du Nigeria. Les expériences consistaient en 9 pratiques de gestion des adventices et un test de contrôle des adventices, réalisé avec le dispositif expérimental des blocs aléatoires complets, avec trois répétitions. La densité et le poids des adventices, ainsi que les traits morphologiques du gombo tels que le nombre de feuilles, la surface foliaire, la hauteur de la plante et la circonférence de la tige, ont été enregistrés 9 semaines après le semis (SAS). A maturité commerciale, les gousses du gombo non lignifiées ont été récoltées après 9-12 SAS. Une simple corrélation linéaire et une analyse de régression entre les paramètres des adventices et les caractéristiques du gombo ont été réalisées. Le résultat a montré une relation négative entre la croissance des adventices et le rendement du gombo dans les deux essais. L'impact négatif des adventices sur certains traits morphologiques du gombo a probablement conduit à la réduction de son rendement. Mais la hauteur de la plante et le nombre de nœuds n'ont pas influencé significativement ($P < 0,05$) le rendement du gombo. Les adventices ont atteint le statut de peste pour le gombo à une densité d'environ 14,17 plants/m^2 avec des poids secs et frais de 10,05 g/m^2 et 54,86 g/m^2, respectivement. Par conséquent, la gestion des adventices est nécessaire pour la production du gombo afin de réduire les pertes de rendement.

Mots clés: Adventices, rendement, okra, statut de peste

ملخص

أيوديلي، أولاتاندي فيليب. 2022. تفسير تجاوب مرفولوجيا وإنتاجية البامية (*Abelmoschus esculentus*) مع متغيرات الأعشاب الضارة باستخدام تحليل الانحدار. Tunisian Journal of Plant Protection 17 (2): 67-76.

قد لا يسبب تعايش الأعشاب الضارة مع المحاصيل الزراعية مشاكل دائمًا. الأعشاب الضارة هي آفات نباتية تؤثر سلبًا على غلة المحاصيل. ومع ذلك، من الضروري تحديد متى يتم الوصول إلى مستوى الآفة في المحاصيل لاتخاذ قرارات إدارة الأعشاب الضارة في إنتاج المحاصيل. أجريت تجارب ميدانية خلال مواسم الأمطار لسنتيْ 2017 و 2018 في مزرعة الأبحاث التابعة لمعهد البحوث الزراعية والتدريب بإبادان (7º38' N 3º84' E)، الواقعة في البيئة الزراعية الانتقالية للغابات المطيرة والسافانا في جنوب غرب نيجيريا. شملت التجارب 9 ممارسات للتعامل مع الأعشاب الضارة وفحصها مرتبة في تصميم القطاعات العشوائية الكاملة بثلاثة مكررات. تم تسجيل كثافة الأعشاب الضارة ووزنها مع الصفات المورفولوجية للبامية مثل عدد الأوراق ومساحة الورقة وارتفاع النبات ومحيط الساق بعد 9 أسابيع من تاريخ البذر. عند النضج التجاري، تم جني قرون البامية غير المتخشبة بعد 9-12 أسبوع من تاريخ البذر. تم حساب ارتباط خطي بسيط وتحليل انحداري بين معاملات الأعشاب الضارة وصفات البامية. أظهرت النتائج وجود علاقة سلبية بين نمو الأعشاب الضارة ومحصول البامية في كلا التجربتيْن. يمكن أن يكون التأثير السلبي للأعشاب الضارة على بعض الصفات المرفولوجية للبامية قد أدى إلى انخفاض محصولها. لكن ارتفاع البامية وعدد عقدها لم يؤثر معنويا ($P < 0.05$) على محصولها. بلغت الأعشاب الضارة مستوى آفة للبامية عند وصولها إلى كثافة تبلغ حوالي 14.17 نبتة/م^2 بأوزان جافة وطازجة بلغت 10.05 غم/م^2 و 54.86 غم/م^2، على التوالي. لهذا، فإن إدارة الأعشاب الضارة ضرورية لإنتاج البامية والتقليل خسارة غلتها.

كلمات مفتاحية: آفة، أعشاب ضارة، بامية، محصول

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