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Response of Okra (*Abelmoschus esculentus* (L.) Moench) and Weeds to Plant Spacing and Weeding Regime in a Humid Forest Agro-Ecology of South-Eastern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Authors OS and UEU designed the study. Author OS established the field experiment performed the statistical analysis. Both authors wrote the protocol and wrote the first draft of the manuscript. Both authors managed the analyses of the study. Author OS managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Field experiment was carried out in late 2015 and repeated in early 2016 cropping season at the Teaching and Research Farm of the University of Port Harcourt, Choba, Rivers State, Nigeria to determine the appropriate spacing and weeding regimes for okra production. Three spacing (60 cm x 15 cm, 60 cm x 20 cm and 60 cm x 30 cm) and three weeding regimes [no weeding, weekly weeding, and twice at 3 and 7 weeks after planting (WAP)] were used. The experimental design was a 3 x 3 factorial scheme laid out in a Randomised Complete Block Design (RCBD) with three replications. The results showed that plant spaced at a closer spacing of 60 cm x 15 cm suppressed weeds better than other spacing in both years of study. Okra performance was better at closer spacing of 60 cm x 15 cm than in other spacing regimes. Similarly, weedy check had higher weed growth and least performance than other weeding regimes. There was significant interaction between spacing and weeding regimes. Plant spaced at closer spacing of 60 cm x 15 cm combined

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with weekly weeding plots had the lowest weed density and dry weight of 0.00 plants /m^2 and 0.00 g/m^2 in both years of study. While 60 cm x 30 cm combined with no weeding gave the highest weed density and dry weight (395.00 plants/m^2 and 306.33 plants/m^2) and (88.33 plants/m^2 and 95.33 g/m^2) in the late and early 2015 and 2016 cropping seasons respectively. The interaction effect further showed that the highest fresh pod yield was obtained from plant spaced at 60 cm x 15cm with weekly weeding (3.02 t/ha and 2.26 t/ha) followed by 60 cm x 15 cm with twice weeding at 3 and 7 WAP (2.96 and 2.22 t/ha). While, plant spaced at 60 cm x 30 cm with no weeding had the lowest fresh pod yield (0.08 t/ha and 0.03 t/ha). Since, the yield obtained from 60 cm x 15 cm with twice weeding (3 and 7 WAP) was not statistically different from 60 cm x 15 cm weekly weeding, for economic considering the former could be recommended.

Keywords: Pod yield; plant spacing; weeding regimes; weeds suppression; Southeastern Nigeria.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is a vegetable crop belonging to the family of Malvaceae. It is extensively grown in the tropic and sub- tropics but had its origin in Central Africa [1]. FAOSTAT [2] noted that okra production in Nigeria ranged between 630,000 t/ha to 730,000 t/ha from 1993 to 2006. In Nigeria, it is cultivated in almost all the states because of its mucilaginous drawing fruit. It is a multi-purpose fruit vegetable for human consumption; feeds for livestock, fibres raw material for textile and paper industries [1]. Despite its importance, the yield obtained from the farmers' plots in Nigeria is less than 2.5 t/ha, [3] when compared to 6.39 t/ha obtained from world average [4]. This low yield could be as result of in appropriate spacing and weed regime practiced by farmer.

One of the cultural practices that farmers used in controlling weeds in okra farm is spacing. It is a distance between one cultivated crop and another. The spacing between rows and along rows varies one type of crop to another. When adequate plant spacing is used for planting crops, it enables crops to have a high yield as water and nutrients would be made available for the crop. [5] noted that desirable planting spacing could lead to optimum pod yield while undesirable planting spacing could result in almost low yield and poor quality pods. Crop grow at a closer spacing with high plant population density benefit in competition against weeds because closer spacing quickens the promptness of canopy closure and improves canopy radiation interception, increasing crop performance [6]. It also reduced weed infestation and competitive capability [7].

Knowledge of the critical period of weed competition in okra helps growers implement effective and timely weed management practices. A critical period of weed control can be defined in two ways namely: the weed competition period and the weed free time requirement. The weed competition period defines the maximum period in which weeds can be allowed to compete with the crop without resulting in an unacceptable yield loss that is; it defines the beginning of the critical period of weed control [8]. The weed-free time requirement referred to as the minimum amount of time a crop must be maintained free of weeds to prevent crop yield loss (the end of the critical period of weed control). Havoc caused by weeds differed from one geographical location to another, types of crop species, planting date, cropping pattern and crop density.

The frequency of hoe weeding is high in okra as a result of the plant inability to developed adequate canopy cover that would effectively shade the ground to prevent weed growth at its early stages of establishment. High weed frequency has also been reported in other vegetable crop like carrot, pepper and tomato [9]. Uncontrolled weed growth caused yield reduction of 88-90% [10,11] in okra farm when compared to weed free. Okra and weed compete for growth resources light, moisture and nutrients. The accurate time to weed might help to reduce the competition and lessen weed competition [12]. In the life cycle of crop, not all the growth stages of a crop are susceptible to weed competition. However, there is a misunderstanding that weeding at any period during plant growth will subdue the issues of competition with weeds [13]. Hence, the knowledge of the critical period of weed control will assist farmers to known the appropriate time to weed a farm so as to attained optimum yield . [1] noted that the critical period of weed competition in okra occurred between 3 and 7 weeks after planting. Keeping the crop weed free until 3 weeks after planting (WAP) reduced okra performance because of the harmful consequence of succeeding weed growth while weed growth up to 3 WAP and subsequently keeping the plots weed-free had no harmful consequence on okra [14].

Okra growers' cultivate okra without having the good knowledge of proper spacing and the right time to weed their farm .The consequence of these unsound practices can led to poor okra performance. Hence, the objective of this current study was to evaluate the effect of appropriate spacing and weeding regimes for okra production in humid forest agro ecology of southeastern Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted at the Teaching and Research Farm of the University of Port Harcourt during late (21th August – 21th November, 2015) and early (13th May – 13th August,2016) cropping seasons to evaluate the appropriate spacing and weeding regimes for okra production. University of Port Harcourt is located in a humid forest agro-ecology with latitude 04° 54' 538'N and longitude 006° 55' 329'E with an elevation of 17metres above sea level. The area has an average temperature of 27°C, relative humidity of 78% and average rainfall that ranges from 2500-4000 mm [15]. The area had distinct wet and dry seasons. The wet season has double rainfall peaks. There are two cropping seasons, early from March to July and late from August to December. The experimental site was left fallow for seven years before the commencement of the study. Weeds such as *Chromolaena odorata, Aspilia africana, Commelina benghalensis, Panicum maximum* and *Cyperus* spp. dominated the vegetation.

2.2 Soil Analysis

Prior to the experimentation, representative soil samples were taken randomly from the experimental plot at a uniform depth of 0-15 cm with an auger for physico-chemical properties. These soil properties were determined by standard laboratory procedures [16].

2.3 Source of Planting Material

An Emerald cultivar of okra was used as a planting material. It was obtained from Rivers State Agricultural Development Program (R.A.D.P). The cultivar has been used by farmers in the region and it takes 56-60 days to mature with an average height of 120 cm. It has a dark green pod which is angular without spines.

2.4 Treatments, Experimental Design and Cultural Details

The experimental design was a 3 x 3 factorial scheme arranged in a randomised complete block design (RCBD) with 3 replications in both seasons. Spacing and weeding regimes constituted the factors. The Three spacing were: 60 cm x 15 cm, 60 x 20 cm and 60 cm x 30 cm equivalent to three population densities: 111, 111, 83, 333 and 55, 555 plants /ha) plants /ha while the three weeding regimes were: no weeding, weeding twice at 3 and 7 weeks after planting (WAP), and weekly weeding . The experiment occupied land dimension of 35 m x 11 m (385m^2) which is approximately 0.04 ha. The experimental area was manually clear with cutlasses and hoes, and the debris was packed. Each block was divided into nine plots with each treatment allocated to a plot. The plot size was 3m x 3m (9m^2) with alleyway of 1m. Okra seed was sown on August 21 and May 13 in 2015 and 2016 respectively using different spacing of 60 cm x 15 cm, 60 cm x 20 cm, and 60 cm x 30 cm with three seeds per hill. The three seedlings were thinned to one seedling at two weeks after planting (2WAP). Some plots were hoe weeded at 3 and 7 WAP and weekly.

2.5 Data Collection and Analysis

Data collected were weed and okra. Weed data collected were: weed density and weed biomass, weed control efficiency and weed index. They were assessed with 50 cm x 50 cm quadrat at 3, 6 and 9WAP. Weed control efficiency was calculated as:

$$WCE = \frac{\text{DWT of weeds in no weeded contol} - \text{DWT of weeds in treated plots}}{\text{DWT of weeds in no weeded plots}} \; x\ 100 \qquad (1)$$

Where, WCE = Weed control efficiency, DWT = Dry weight.

Weed index (WI) was calculated as:

$$WI = \frac{\text{Yield from the weed free check} - \text{ yield from treated plot}}{\text{Yield from the weed free check}} \; x100 \qquad (2)$$

Okra data such as: plant height, and leaf area index were randomly taken in-situ of five plants from the middle row at 3, 6 and 9WAP while the yield and components (number of pods, and yield per plant and yield per hectares) were taken at harvest.

Data generated were subjected to statistical analysis of variance (ANOVA) and significant treatment means were compared using least significant difference (LSD) at 5% probability level.

3. RESULTS

3.1 Soil Characteristics and Rainfall Data of the Experimental Sites

The physiochemical properties of the soil in the experimental site are presented in Table 1. The soil in the experimental site was sandy loam and slightly acidic. Total organic carbon was moderate. The nitrogen contents of the soils were quite adequate. Available phosphorous (P) were quite adequate in both years of experimentation. The levels of Calcium (Ca), Magnesium (Mg) and Potassium (K) Sodium (Na) content of the soil at both sites were quiet adequate. Base saturation was adequate. Generally, there were no marked differences in soil characteristics between the two sites of both years of experimentation. The soils in both sites had moderate soil fertility, which seemed suitable for crop growth and development. Table 2 shows the amount of rainfall data during the experimental period in late 2015 and early 2016. The total amount of rainfall in early 2016 (1079.60 mm) outclassed that of the 2013 cropping season (675 mm) by 59.82%.

Table 1. Physicochemical properties of the experimental site in late 2015 and early 2016 cropping seasons

Soil parameters	**Value**	
	2015	**2016**
Physical properties (%)		
Sand	82.20	81.10
Silt	6.00	6.90
Clay	11.80	12. 00
Textural class	Sandy loam	Sandy loam
Chemical properties		
pH in H_2O	6.10	6.00
Organic carbon (%)	1.82	1.75
Total Nitrogen (%)	0.17	0.16
Available P mg/kg	20.17	18.95
Exchangeable bases		
Ca cmol/kg	2.20	1.94
Mg cmol/kg	0.26	0.25
K cmol/kg	0.25	0.23
Na cmol/kg	0.22	0.21
Exchangeable acidity (cmol/kg)	0.02	0.01
ECEC (cmol/kg)	2.95	2.64
Base saturation (%)	99.32	99.62

Table 2. Rainfall data at the experimental sites during late 2015 and early 2016 cropping seasons

Months/year	**Rainfall mm**
Late 2015	
August	120.00
September	55.50
October	300
November	200
Total	**675.50**
Early 2016	
May	341.50
June	217.50
July	353.60
August	167.00
Total	**1079.60**

Source: Department of Geography, University of Port Harcourt

3.2 Weed Growth Characteristics

3.2.1 Weed density and weed dry weight

The effect of treatments and their interactions on weed density and weed dry weight in okra are presented in Tables 3 and 4. There were significant main and interaction effects of weeding regine and spacing on both weed density and weed dry weight, and both weed density and dry weight consistently decreased from 3 to 9 WAP irrespective of spacing, weeding regime or their interaction. Thus, the highest weed density and dry weight among the sampling periods was at 3 WAP followed by 6WAP and 9WAP. Plant spaced at a wider spacing of 60 cm x 30 cm had the highest weed density and dry weight at each sampling time in both seasons while plant at closer spacing of 60 cm x 15 cm had the lowest weed density and dry weight. Similarly, among the weeding regimes, no weeding and weeded twice plots recorded the highest weed density and dry weight while plot that was weekly weeded had the lowest weed density and dry weight. Furthermore, there was significant interaction effect of spacing and weeding regimes on weed density and dry weight ($P < 0.05$). Plant spaced at closer spacing of 60 cm x 15 cm combined with weekly weeding plots had the highest weed density and dry weight throughout the sampling periods than other treatments combination.

3.2.2 Weed control efficiency

The effect of treatments and their interactions on weed control efficiency in okra are presented in Table 8. Plant spaced at 60 cm x 15 cm differed significantly from other spacing regimes by producing the highest weed control efficiency throughout the sampling intervals except at 3WAP where it was at *par* with other spacing regimes. Similarly, among the weeding regimes, the highest weed control efficiency was obtained in weekly weeded plots while the least was obtained from no weeding plots in both years of study except at 3wap, where it was at par with weeding twice in 2015. The interaction effect of spacing and weeding regimes on weed control efficiency was significantly higher at plant spaced at 60 cm x 15 cm combined with weekly weeding than in other treatment combination at the different interval of sampling.

Table 3. Effect of plant spacing and weeding regime on weed density (no./m^2) in okra during 2015 and 2016 cropping seasons

Weeks after planting	Spacing (S) (cm)	Weeding regimes (WR)-2015				Weeding regimes (WR)- 2016			
		No weeding	Weeding twice	Weekly weeding	Spacing mean	No weeding	Weeding twice	Weekly weeding	Spacing mean
	60 x15	450.67	451.67	0.00	300.78	701.00	699.67	0.00	466.89
3 WAP	60 x 20	551.00	551.33	0.00	367.44	910.00	920.00	0.00	610.00
	60 x 30	600.00	599.67	0.00	399.48	1233.33	1216.67	0.00	816.67
	WR mean	533.89	534.22	0.00		948.11	945.45	0.00	
	LSD(=0.05)								
	Spacing			1.317				20.455	
	WR mean			1.317				20.455	
	S X WR			2.281				35.428	
	60 x15	222.00	63.33	0.00	95.11	456.67	116.67	0.00	191.11
6 WAP	60 x 20	351.00	145.67	0.00	165.56	533.33	255.00	0.00	262.78
	60 x 30	501.33	170.00	0.00	223.78	816.67	416.67	0.00	411.11
	WR mean	358.11	126.33	0.00		602.22	262.78	0.00	
	LSD(=0.05)								
	Spacing			3.583				57.15	
	WR mean			3.583				57.15	
	S X WR			6.206				100.312	
	60 x15	191.67	30.00	0.00	73.89	376.67	60.33	0.00	145.67
	60 x 20	241.67	68.00	0.00	103.22	460.00	192.00	0.00	217.33
9 WAP	60 x 30	395.00	91 .67	0.00	162.22	644.67	306.33	0.00	317.00
	WR mean	276.11	63.22	0.00		493.78	186.22	0.00	
	LSD(=0.05)								
	Spacing			2.207				16.823	
	WR			2.207				16.823	
	S X WR			3.822				29.138	

Table 4. Effect of plant spacing and weeding regime on weed dry weight (g/m^2) of okra during 2015 and 2016 cropping seasons

Weeks after planting	Spacing (S) (cm)	Weeding Regimes (WR)-2015 No weeding	Weed twice	Weekly weeding	S mean	Weeding Regimes (WR)-2016 No weeding	Weed twice	Weekly weeding	S mean
	60 x15	55.00	55.67	0.00	36.89	171.67	155.33	0.00	109.
3WAP	60 x 20	93.33	93.67	0.00	62.33	233.33	234.33	0.00	155.89
	60 x 30	140.00	139.33	0.00	93.11	366.67	348.67	0.00	238.45
	WR mean	96.11	96.22	0.00		257.22	246.11	0.00	
	LSD(0.05)								
	Spacing			5.988				28.765	
	WR			5.988NS				28.765NS	
	S X WR			10.372				49.822	
	60 x15	45.00	16.00	0.00	20.33	116.67	61.00	0.00	59.22
6WAP	60 x 20	80.33	25.00	0.00	35.11	182.67	83.33	0.00	88.67
	60 x 30	122.33	39.67	0.00	54.00	213.67	188.33	0.00	134.00
	WR mean	82.55	26.89	0.00		171.00	110.89	0.00	
	LSD(0.05)								
	Spacing			0.910				23.587	
	WR			0.910				23.587	
	S X WR			1.576				40.854	
	60 x15	31.67	5.33	0.00	12.33	56.67	21.00	0.00	
	60 x 20	65.00	10.67	0.00	25.22	74.67	31.33	0.00	
9 WAP	60 x 30	88.33	21.00	0.00	36.44	95.33	40.00	0.00	
	WR mean	61.67	12.33	0.00		75.56	30.78	0.00	
	LSD(0.05)								
	Spacing			1.148				1.285	
	WR			1.148				1.285	
	S X WR			1.988				2.225	

3.2.3 Weed index

The effect of treatments and their interactions on weed index in okra are presented in Table 6. There were no significant differences among the various spacing regime on weed index in 2015 but in 2016 the weed index differed with various spacing regimes. Thus, in 2016 cropping season, the highest weed index was obtained at plant spacing of 60 cm x 30 cm while the lowest was from plant spaced at 60 cm x 15 cm. Similarly, among the weeding regime, the highest weed index was recorded at weedy check while the lowest was from weekly weeding (weed free check) in both seasons. Furthermore, the interaction effect on weed index differed in both years of study. The highest interaction was obtained from all the three spacing with no weeding while the lowest was from all the plant spacing with weekly weeding application.

3.3 Okra Performance

3.3.1 Plant height

Treatment effect on okra plant height is presented in Table 5. There was significant increase in plant height in both seasons of the study. As plant spacing increased, plant height deceased at various levels of spacing in each of the sampling interval. The tallest plants were obtained from okra grown at closer spacing of 60 cm x 15 cm in all sampling intervals in both seasons of the experiment, while plant spaced at 60 cm x 30 cm had the shortest plant. Similarly, among the weeding regime, plots that were weeded weekly produced significantly taller plants than other spacing. In addition, the interaction effect between spacing and weeding regime was significant throughout the sampling period. Plant spaced at 60 cm x 15 cm with weekly weeding application produced the tallest plants while the shortest plants were produced from plant spaced at 60 cm x 30 cm with no weeding but at *par* with 60 cm x 30 cm with twice weeding at 3 and 7WAP in both seasons.

3.3.2 Leaf area index (LAI)

LAI response to treatment followed similar trend as in plant height (Table 6). The highest value LAI was obtained from okra spaced at 60 cm x 15 cm while the lowest was from plant spaced at 60 cm x 30 cm at the various periods of observation in both seasons. In the same vein, plots that were weeded weekly gave the highest

LAI value when compared to others. The interaction between spacing and weeding regimes on LAI was significant (P< 0.05). Plant spaced at closer spacing of 60 cm x 15 cm combined with weekly weeding plots had the highest LAI throughout the sampling periods when compared to other treatments combination.

3.4 Number of Fruits/Plant

Number of pods/plant was significantly ($p < 0.05$) affected by spacing, weeding regimes and their interaction. Plant spaced at 60 x15cm produced the highest number of fruits while the lowest number of fruits was produced from plant spaced at 60 cm x 30 cm in both seasons (Table 7). Similarly, among the weeding regimes, weekly weeding gave highest numbers of fruits but it was stastically similar to weeding twice plots, while the least number of fruits were produced from plots that were unweeded. In addition, the interaction effect indicated significant differences on number of fruits. Plant spaced at 60 cm x 15 cm with weekly weeding application produced the highest number of pods (16.67 in late 2015 and 14.67 in early 2016) but had comparable values with plant spaced at 60 cm x15 cm with weeding twice (16.63 in late 2015 and 16.67 in early 2016). The lowest number of pods (4.33 in 2015 and 2.33 in 2016) was produced from plant spaced at 60 cm x 30 cm with no weeding.

3.5 Fruit Yield/Plant

The effect of plant spacing and weeding regimes on number of pod yield/plant of okra during the late and early planting seasons of 2015 and 2016 are presented in Table 7. Plant grown at a spacing of 60 cm x 15 cm produced higher pod yield /plant than other spacing. Similarly, within the weeding regime, plots hoe weeded weekly had the highest yield but comparable with hoe weeded twice. The lowest yield was from no weeding plots. The interactions effect between spacing and weeding regimes was significant with plant spaced at 60 cm x 15 cm and weekly weeding producing the highest yield but statistically identical to plant spaced at 60 cm x 30 cm with no weeding. Plant spaced at 60 cm x 15 cm and no weeding application produced the lowest yield.

Table 5. Effect of plant spacing and weeding regime on plant height (cm) of okra during 2015 and 2016 cropping seasons

Weeks after planting	Spacing (S) (cm)	Weeding regimes (WR)-2015				Weeding regimes (WR)-2016			
		No weeding	Weed twice	Weekly weeding	Spacing mean	No weeding	Weed twice	Weekly weeding	Spacing mean
	60 x15	8.33	9.00	11.67	9.67	6.33	7.00	9.67	7.67
3WAP	60 x 20	9.00	7.03	10.67	8.23	5.00	5.00	8.67	6.22
	60 x 30	6.60	6.53	9.33	7.49	4.53	4.43	7.33	5.43
	WR mean	7.31	7.52	10.56		5.29	5.48	8.56	
	LSD(0.05)								
	Spacing			0.512				0.501NS	
	WR			0.51				0.501	
	S X WR			0.886				0.867	
	60 x15	11.67	25.00	45.33	27.33	11.67	22.00	33.00	22.22
6WAP	60 x 20	9.33	21.33	39.33	23.33	8.33	19.00	29.00	18.78
	60 x 30	7.00	15.33	35.00	19.11	6.00	15.00	22.00	14.33
	WR mean	9.33	20.55	39.89		8.67	18.67	28.00	
	LSD(0.05)								
	Spacing			0.495				0.697	
	WR mean			0.495				0.697	
	S X WR			0.857				1.207	
	60 x15	29.00	36.00	67.00	44.00	22.33	42.00	57.33	40.55
	60 x 20	22.67	31.00	55.67	36.45	18.67	38.00	49.33	35.33
9 WAP	60 x 30	19.00	21.00	48.33	29.44	15.67	29.33	45.33	30.11
	WR mean	23.56	29.33	57.00		18.89	36.44	50.66	
	LSD(=0.05)								
	Spacing			0.608				2.790	
	WR			0.608				2.790	
	S X WR			1.053				1.368	

Table 6. Effect of plant spacing and weeding regime on leaf area index of okra during 2015 and 2016 cropping seasons

Weeks after planting	Spacing (S) (cm)	Weeding regimes (WR)-2015				Weeding regimes (WR)-2016			
		No weeding	Weed twice	Weekly weeding	Spacing mean	No weeding	Weeding twice	Weekly weeding	Spacing mean
	60 x15	0.09	0.13	0.17	0.13	0.05	0.06	0.12	0.08
3WAP	60 x 20	0.07	0.09	0.11	0.09	0.04	0.03	0.08	0.05
	60 x 30	0.05	0.06	0.09	0.07	0.02	0.02	0.05	0.03
	WR mean	0.07	0.09	0.12		0.04	0.04	0.08	
	LSD(P=0.05)								
	Spacing			0.032				0.007	
	WR mean			0.032NS				0.007NS	
	S X WR			0.055				0.012	
	60 x15	0.36	1.17	2.63	1.39	0.26	1.13	2.37	1.25
6WAP	60 x 20	0.18	0.60	1.20	0.67	0.08	0.52	1.12	0.57
	60 x 30	0.15	0.46	0.91	0.51	0.05	0.36	0.81	0.41
	WR mean	0.23	0.74	1.59		0.13	0.67	1.43	
	LSD(P=0.05)			0.11				0.032	
	Spacing								
	Weeding			0.11				0.032	
	(S X WR)			0.19				0.055	
	60 x15	0.73	2.64	5.29	2.89	0.63	2.56	4.36	2.52
	60 x 20	0.48	1.32	2.47	1.42	0.38	1.20	1.63	1.07
9 WAP	60 x 30	0.31	0.93	1.90	1.05	0.22	0.80	0.93	0.65
	WR mean	0.51	1.63	3.22	0.41	1.52	2.31		
	LSD(=0.05)								
	Spacing			0.207				0.197	
	Weeding			0.207				0.197	
	S X WR			0.359				0.342	

Table 7. Effect of plant spacing and weeding regime on number of fruits and fruit yield during 2015 and 2016 cropping seasons

Yield components	Spacing (S) (cm)	Weeding regimes (WR)-2015				Weeding regimes (WR)-2016			
		No weeding	Weeding twice	Weekly weeding	S mean	No weeding	Weeding twice	Weekly weeding	S mean
	60 x15	8.33	16.33	16.67	13.78	6.33	14.33	14.67	11.78
	60 x 20	7.33	12.33	12.67	10.78	5.33	10.33	10.67	8.78
	60 x 30	4.33	9.33	9.33	7.66	2.33	7.67	7.67	5.89
No. fruits/plant	WR mean	6.66	12.66	12.89		4.66	10.78	11.00	
	LSD(0.05)								
	Spacing			0.255				0.366	
	WR			0.255				0.366	
	S X WR			0.441				0.634	
	60 x15	2.71	26.67	27.00	18.46	2.33	20.00	20.33	14.22
	60 x 20	1.83	14.67	15.00	10.18	1.17	11.67	12.00	8.28
	60 x 30	1.47	9.67	10.00	6.69	0.61	6.00	6.33	4.31
Fruit yield (g/plant)	WR mean	2.01	17.00	17.33		1.37	12.56	12.89	
	LSD(0.05)								
	Spacing			0.523				0.638	
	WR			0.523				0.638	
	(S X WR)			0.906				1.106	
	60 x15	0.30	2.96	3.00	2.09	0.26	2.22	2.26	1.58
	60 x 20	0.15	1.22	1.25	0.87	0.10	0.97	1.00	0.69
	60 x 30	0.08	0.54	0.56	0.39	0.03	0.33	0.35	0.24
Fruit yield (t/ha)	WR mean	0.18	1.57	1.61		0.13	1.17	1.20	
	LSD(0.05)								
	Spacing			0.045			0.055		
	WR			0.045			0.055		
	S X WR			0.077			0.095		

Table 8. Effect of plant spacing and weeding regime on weed control efficiency (%) of okra during 2015 and 2016 cropping seasons

Weeks after planting	Spacing (S) (cm)	Weeding regimes (WR)-2015				Weeding regimes (WR)-2016			
		No Weeding	Weeding twice	Weekly weeding	S mean	No weeding	Weeding twice	Weekly weeding	S mean
	60 x 15	0.00	- 1.19	100	32.94	0.00	0.22	100	33.44
3WAP	60 x 20	0.00	- 0.35	100	33.22	0.00	- 0.88	100	33.04
	60 x 30	0.00	0.36	100	33.45	0.00	0.50	100	33.50
	WR mean	**0.00**	**- 0.39**	**100**		**0.00**	**- 0.52**	**100**	
	LSD(P=0.05)								
	Spacing			0.657NS				0.781NS	
	Weeding			0.657				0.781	
	S x WR			1.138				1.352	
	60 x 15	0.00	71.34	100	57.11	0.00	74.41	100	58.14
6WAP	60 x 20	0.00	58.54	100	52.85	0.00	52.08	100	50.76
	60 x 30	0.00	66.03	100	55.34	0.00	49.00	100	49.67
	WR mean	**0.00**	**65.30**	**100**		**0.00**	**58.50**	**100**	
	LSD(P=0.05)								
	Spacing			0.118			0.063		
	Weeding			0.118			0.063		
	S x WR			0.205			0.109		
	60 x 15	0.00	83.16	100	61.05	0.00	62.91	100	54.30
9WAP	60 x 20	0.00	83.36	100	61.12	0.00	58.04	100	52.68
	60 x 30	0.00	76.37	100	58.80	0.00	57.69	100	52.56
	WR mean	**0.00**	**80.96**	**100**		**0.00**	**59.55**	**100**	
	LSD(P=0.05)								
	Spacing			0.109			0.836		
	Weeding			0.109			0.836		
	S x WR			0.190			1.448		

Table 9. Effect of plant spacing and weeding regime on weed index (%) of okra during 2015 and 2016 cropping seasons

Spacing (S)	Weeding regimes (WR)-2015				Weeding regimes (WR)-2016			
	No weeding	Weeding twice	Weekly weeding	Spacing mean	No weeding	Weeding twice	Weekly weeding	Spacing mean
60 cm x 15 cm	89.35	1.42	0.00	30.26	88.37	2.06	0.00	30.14
60 cm x 20cm	88.30	2.41	0.00	30.23	91.03	2.99	0.00	31.34
60 cm x 30 cm	86.22	4.78	0.00	30.33	90.56	5.66	0.00	32.67
WR mean	**87.96**	**2.87**	**0.00**		**89.98**	**3.57**	**0.00**	
LSD(P=0.05)								
Spacing			1.343NS			0.694		
WR			1.343			0.694		
S x WR			2.327			1.202		

3.6 Fresh Pod Yield (kg/ha)

The effect of plant spacing and weeding regimes on number of pod yield/plant of okra during the late and early planting seasons of 2015 and 2016 are presented in Table 7. Pod yield was significantly influenced by spacing. Plant grown at a spacing of 60 cm x 15 cm produced higher Pod yield /plant than other spacing. Similarly, within the weeding regime, plots hoe weeded weekly had the highest yield but had a comparable value with hoe weeded twice. The lowest yield was obtained from no weeding plots. The interactions effect between spacing and weeding regimes was significant in both seasons. highest fresh pod yield was obtained from plant spaced at 60 cm x 15 cm with weekly weeding 3.02 t/ha and 2.26 t/ha followed by 60 cm x 15 cm with twice weeding at 3and 7 WAP (2.96 and 2.22 t/ha) in late and early 2015 and 2016 cropping seasons respectively. Plant spaced at 60 cm x 30 cm with no weeding had the lowest pod yield (0.08 t/ha and 0.03 t/ha) in late and early 2015 and 2016 cropping seasons respectively.

4. DISCUSSION

The soil used for the experiment in both years was rich in nutrient that could promote the growth and yield of okra. Organic carbon, Total nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) and Sodium (Na) were adequate [17]. The high fertility status of the soil could be attributed to long periods of fallow that the site was under.

Okra plant spaced at 60 x 15 cm reduced weed density and dry weight than other spacing as result of its high plant population density. Plant spaced at a closer spacing of 60 x 15 cm had a plant population of 100 plants/plot (111,111 plants/ha), 60 cm x 20 cm had 75 plants/plot (83,333plants/ha and 60 cm x 30 cm had 50 plants/plot (55,555 plants/ha). For instance at 9 WAP, Plant spaced at a closer spacing of 60 cm x 15 cm reduced weed density by 54.45% and 54.05% while 60 cm x 20 cm reduced weed density by 28.42% and 31.44% when compared to 60 cm x 30 cm in the late and early cropping seasons of 2015 and 2016 respectively. On the other hand, weed dry weight were reduced by 66.16% and 42.61% at a spacing of 60 cm x 15 cm while it were reduced to and 30.79% and 21.68% at 60 cm x 20 cm when compared to 60 cm x 30 cm in late 2015 and early 2016 cropping seasons. The probable reason for reduction in both weed density and dry weight could be attributed to its high population density, which forms high canopy cover that suppressed weed growth by intercepting solar radiation reaching the soil surface that could have stimulated weed growth. This further showed that closer spacing increased the competitiveness of the okra with weeds. This observation was in agreement with that of [18] that okra planted at a closer spacing suppressed weeds better than those spaced at a wider spacing. In the same vein, [19] noted that closer spacing increased the competitiveness with weeds in some crops like soybeans and tomatoes. The higher weed control efficiency and lower weed index recorded at plant spacing of 60 cm x15cm might be attributed to drastic reduction in weed population and weed dry weight. Plots that were unweeded, had the highest weed density and dry weight in all the sampling periods except at 3WAP. The probable reason for while the weeding plot at 3 and 7WAP had similar weed density and weed dry weight could be attributed to no application of weeding treatment at that initial stage of growth and the plots were not disturbed. Weed density and dry weight were taken at 3 WAP before the plots were weeded at that period. Weed density was reduced to 100% in weekly weeded plots in both seasons when compared to no weeding while it was reduced to 77.10 % and 62.29 % on plots weeded twice at 3 and 7 WAP in late and early seasons of 2015 and 2016 respectively. Similarly, weed dry weight was reduced to 100% and 59.26% by weekly weeded and weeded twice plots. The possible reason for the 100% weed reduction in weekly weeded plots could be attributed to the weed free condition of the plots. The higher weed control efficiency and lower weed index recorded in weekly weeded plots might be due to no weed growth, which invariably translated to maximum fruit yield. Generally, weeds were less in the late season than in the early season in plots that were weeded twice probably as result of differences in rainfall. Rainfall was more in the early season than in the late season by 59.82%. This increase in rainfall could have prompted more weeds growth in the early season than in the late season.

Okra sown at a plant spacing of 60 cm x15 cm produced the tallest plant at each interval of sampling intervals probable as a result of intra specific competition among the plants for environmental resource especially sunlight. At relative to wider spacing of 60 cm x 30 cm, plant spaced at closer spacing 60 cm x 15 cm and at intermediate spacing (60 cm x 20 cm) increased okra height by 49.46% and 23..81% respectively in the late season of 2015; 34.67%, and 17.34% respectively in early 2016. The probable reason for this could be that plant spaced at 60 cm x 15 cm had more plant population density than that of 60 cm x 20 cm, that resulted to crowdedness. At high density, plants tend to compete vigorously for limiting growth resources especially light due to overcrowding; hence will grow taller to enhance its acquisition of the limiting light resources [20]. The crowded nature makes the okra plants to struggle among themselves for available growth resources space, sunlight, moisture, carbon dioxide and soil nutrients. This finding is in consonance with that of [18,21] who noted that okra spaced at closer spacing grew taller plants than those spaced at wider spacing. Plots that were weekly weeded followed by weeding twice produced taller plants than the unweeded plot due to uncontrolled weed growth. Compared to the no weeding treatment, weekly weeding and weeding twice plots increased okra height by 141.94% and 24.49% respectively in the late season of 2015, 168.18%, and 92.90% respectively in early 2016. When okra height was compared to weekly weeding and weeding twice treatments, uncontrolled weed growth reduced okra height by 58.67% and 19.67% in 2015, 62.71% and 48.16% in 2016 respectively. The reduction in plant height in no weeding plot could be because of interspecific competition between okra plant and weeds for growth resources. Invariably, the weeds out compete plant which resulted to stunted growth by producing shorter okra plant. This finding is in agreement with that other researcher [22,23] who reported that uncontrolled weed growth reduced okra plant height. The greater leaf area index recorded at 60 cm x 15 cm might be due to inadequate space for each plant as result of high population density. This showed that plants spaced at closer spacing of 60 cm x 15 cm were able to compete for space and light than others spacing which is a mechanism that improves the crops suppressive ability [24]. Similarly, [25] also noted that increased in ground area cover engaged by singly okra plant resulted in the high leaf area index as plant population increases under closer spacing.

Fewer stands could be responsible for the less Leaf area index of okra observed at wider spacing of 60 cm x 30 cm, that result in less ground coverage. Okra fresh pod yield was higher at closer spacing of 60 cm x 25 cm than other spacing. Compared to wider spacing of 60 cm x 30 cm, increased okra yield by 435.9% (60 cm x 15 cm) and 123.08% (60 cm x 20 cm) in the late season of 2015; 558.33% (60 x 15cm) and 187.50% (60 cm x 20 cm) respectively in early 2016. Increased in number of pods as result of higher plant population per plot might be responsible for higher yield obtained from a closer spacing than others spacing. The higher yield could also be ascribed to better weed control through canopy cover, efficient water utilisation due to less surface soil evaporation and better radiant energy usage. [18,26,21,27] noted that closer/ narrow spacing increased okra yield than medium and wider spacing. Compared to the no weeding treatment, weekly weeding and weeding twice plots increased okra pod yield by 794% and 772.22% respectively in the late season of 2015; 1066.67%, and 1000% respectively in early 2016. When okra fruit yield was compared to weekly weeding and weeding twice treatments, uncontrolled weed growth reduced okra pod yield by 88.82% and 88.54% in 2015, 89.17% and 88.89% in 2016 respectively. The results of the percentage *of* uncontrolled weeds growth obtained from this study fell between 63% and 91% as reported by [14]. Fresh pod yield was higher in the late season than in the early season. The probable reason for this are fewer weeds growth and insect pest (data not recorded) caused by low rainfall during okra growth period in late season of 2015.

The combined effect of the two factors (spacing and weeding regimes) resulted in adequate weed control and high okra performance than either of plant spacing or weeding regimes applied individually. For circumventing spending much money in controlling weeds, it may be appropriate to use spacing of 60 cm x15 cm combined with weeding twice at 3 and 7WAP as choice to weekly weeding.

5. CONCLUSION

It can be concluded that two weedings, at 3 and 7 WAP in okra spaced 60 cm x 15 cm was appropriate in reducing weed interference, and increasing okra yield in the humid forest agro-ecology of Southeastern Nigeria. This is recommended for the poor resource farmers in the humid forest agro-ecology of Southeastern Nigeria, given their poor economic resource conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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