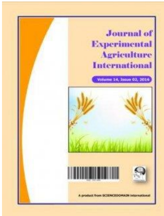

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Impact of Nitrogen Levels and Weed Control Methods on Growth and Yield of Okra (*Abelmoschus esculentus* (L.) Moench) in the Nigerian Forest-Savanna Transition Zone

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JAA, ORA and PMO designed and wrote the protocol. Authors JAA and OSD executed and wrote the first draft. Author AOO initiated statistical analysis. Author OAO managed the analyses and report of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate the effect of nitrogen levels and weed control methods on the growth and yield of okra.
Study Design: Treatments were laid out in a split-plot design.
Place and Duration of Study: Field trials were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Nigeria in the early and late wet seasons of 2015.
Methodology: The main plot treatments comprised of three nitrogen (N) levels (0, 60 and 90 kg N/ha), while the sub-plot treatments were made up of seven weed control methods (probaben®

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[metolachlor 20% w/v + prometryn 20% w/v] at 2 kg a.i/ha; probaben® at 2 kg a.i/ha followed by supplementary hoe weeding (SHW) at 6 weeks after sowing [WAS]; butachlor [50% w/v] at 2.0 kg a.i/ha; butachlor at 2.0 kg a.i/ha followed by SHW at 6 WAS; 2 hoe weedings at 3 and 6 WAS; 3 hoe weedings at 3, 6 and 9 WAS; and weedy check).

Results: Unchecked weed growth throughout the crop life cycle resulted in 51 and 59% reduction in potential okra fruit yield in the early and late wet seasons, respectively.

Application of N at 90 kg/ha compared to lower rates, increased weed density and weed dry matter production in both seasons. N application at 90 kg/ha resulted in significant increase in growth and fruit yield of okra. All weed control methods resulted in significant reduction in weed growth, and subsequently increased okra fruit yield. The most effective weed control methods were pre-emergence application of probaben® and butachlor at 2.0 kg a.i/ha each followed by SHW at 6 WAS.

Conclusion: Results suggest that farmers can reduce the burden of hoe weeding and cut down on labour input with the use of pre-emergence herbicides for weed control in okra production, and increase okra yield with application of N into the low fertile soils of the forest-savanna transition zones.

Keywords: Nitrogen level; weed control methods; okra; metolachlor; prometryn; butachlor.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the most important vegetable crops grown in tropical and sub-tropical parts of the world. It is a widely cultivated fruit vegetable found in almost every market in Nigeria and Africa [1]. In Nigeria, it ranks third in terms of consumption and production area following tomato and pepper [2]. It is usually grown on small farm holdings in mixtures with staple food crops such as cassava, yam, maize and pepper or with various vegetable crops [3]. Okra is one of the most nutritious vegetables which contain an average of 1.9 g of protein, 0.2 g fat 6.4 carbohydrate, 0.7 g minerals and 1.2 g fibre per 100 g edible portion and energy value of 4550 kcal/kg [4]. It is grown for its young leaves and green pods. In Nigeria the green pods are usually boiled in water to make slimy soup and sauces or as soup thickeners. The tender leaves are also used as vegetable and considered as good cattle feed, while the mature dried seed is a nutritious material that can be used to prepare vegetable soup, or roasted and grounded to be used as coffee additive [5].

World production of okra is estimated at 6 million tonnes per year. India ranks first in the world with 3.5 million tons (70% of world production) [6], followed by Nigeria and Sudan [7]. In Africa, total annual production was put at 1.9 million tons per year. The leading producers are Nigeria (1,039,000 tons per annum) followed by Sudan, Ivory Coast, Ghana, Benin and Egypt [8]. Although okra is widely cultivated throughout Nigeria, yields obtained from farmers' fields are often very low. Average yield per hectare in Nigeria is 2.10 t/ha, which is less than half of those in other countries like India (10.12 t/ha) and world average (7.65 t/ha). Production constraints such as low soil fertility, weed infestation and the use of low yielding varieties are major problems attributed to low yields of okra in Nigeria [9,10].

Of all these constraints, low soil fertility and weed infestation appears to be the most deleterious. Small holder farmers in the tropics face the problem of maintaining productivity because of the overriding constraints of soil infertility and weed infestation. Tropical soils are generally poor in organic matter and available nutrients. Hence, productivity and sustainability decline over time [11,12]. Furthermore, the high rainfall and high relative humidity favours rapid and excessive weed growth, which results in high okra yield losses of up to 90% [13]. Because of the slow growth rate of okra during the early stages, weeds take advantage of moisture, soil nutrients and environmental conditions to suppress the growth of the crop. Hence, strategies to increase productivity of okra in soils with sub-optimal fertility to meet the increasing demand of okra in Nigeria will have to focus on supply of adequate nutrient for vigorous crop growth and aggressive crop competition against weeds.

Interestingly, crops and weeds have the same basic nutrient requirements [14]. The same nutrients applied to crops are generally available to weeds [15]. The level and time of nutrient application therefore, determines the relative competitiveness between the crop and weeds. Of all nutrients required by crops, response to nitrogen (N) fertilizer is the most widely observed, and it is suggested that the availability of nutrients such as N can influence the timeliness and extent of early season competition from weeds [16].

Hoe weeding is the most common weed control practice in okra, but this method is usually cumbersome, time consuming and expensive. Apart from high cost of hoe weeding, scarcity of labour is a common problem usually experienced during the peak period of farming operation, and can sometimes result in abandonment of field crops [17,18]. Although few workers [19,20,21] have reported the use of herbicides for weed control in okra, season long weed control has proved difficult. Hence the need to evaluate some integrated methods involving the use of N and herbicides treatment for effective and season long weed control in the okra. The objective of this study was therefore, to determine the optimum N level in combination with appropriate weed control method for optimum crop growth and fruit yield in okra in Abeokuta, South Western Nigeria.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

Field experiments were conducted to evaluate the effects of N levels and weed control methods on growth and yield of okra at the Teaching and Research Farm of Federal University of Agriculture, Abeokuta, Nigeria (07 15’N 03 25’E) in the Forest-Savanna transition zone of South West Nigeria during the early (April-July) and late (August-October) cropping season of 2015. The location is characterized by a bimodal rainfall pattern with peaks usually in July and September and a short dry spell in August with annual mean of about 1300 mm and a mean temperature of about 27°C. Laboratory analysis showed that soils of the experimental sites were freely drained loamy sand with a pH of 6.7 and 6.9, organic carbon of 0.5 and 0.7, total N of 0.08 and 0.15 and available p of 10.75 and 11.23.

2.2 Treatment and Experimental Design

In both season, the experiment consisted of three main plots of N levels which included 0, 60 and 90 kg N/ha and seven sub-plots treatment of weed control methods which included probaben® at 2 kg ai/ha, probaben® at 2 kg ai/ha followed by supplementary hoe weeding (SHW) at 6 weeks after sowing (WAS), butachlor at 2 kg ai/ha, butachlor at 2 kg ai/ha followed by SHW at 6 WAS, two hoe weedings at 3 and 6 WAS, three hoe weedings at 3, 6 and 9 WAS and weedy check). All treatments in different combinations were laid out in split-plot design with three replications.

2.3 Land Preparation and Crop Management

The land was ploughed and disc-harrowed at two weeks interval. Gross and net plot sizes were (4.5×3.0) m^2 and (3 x 3) m^2, respectfully. Okra seeds were sown manually on flat at three seeds per hole and spacing of 75 cm × 30 cm and later thinned to two plants per stand at 2 WAS. N fertilizer was applied as urea following the treatment (0, 60 and 90 kg/ha) by drilling method in two splits at 3 and 6 WAS. Herbicide treatments were applied as pre-emergence with Knapsack (CP3) sprayer with a spray volume of 250 L/ha using a green deflector nozzle at a pressure of 2.1 kg/cm^2 one day after sowing okra seeds. Cypermethrin and forcelet were applied against insects and fungi twice at 3 and 6 WAS while weeding was carried out using West African local hoe.

2.4 Parameters Measured and Data Analysis

Weed cover score at 6 and 9 WAS, weed density at 9 WAS, weed dry matter production at harvest, crop vigour plant height, number of leaves and leaf area per plan, number of fruits per plant and fruit yield per hectares were some of the parameters used to evaluate the performance of the treatments. Crop vigour score was taken by visual observation based on scale 0-10, where 0 represented plots with crops completely killed and 10 represented plots with the most vigorous growing and healthy crop. At each time of weed removal, weed density were taken from quadrat of 1m^2 by physically counting the number of weeds which were then cleaned and oven dried to constant weight to get the weed dry matter production. All parameters collected were subjected to analysis of variance (ANOVA) using GENSTAT discovery package to determine the level of significance (F value) of the treatments. Treatment means were separated using the least significant difference (LSD at P ≤ 0.05) where F value was significant.

3. RESULTS AND DISCUSSION

The soils in the experimental sites were low in organic carbon and percentage N justifying the need for additional fertilizer input to boost crop yield. The total rainfall received during the period of crop growth in the early wet season (April-July) was 548 mm (Table 1) which was 97 mm higher than total rainfall received during the period of crop growth in the late wet season (451 mm) (August-November).

The experimental sites were infested with different categories of weed including broad leaf weeds, grasses and sedges. Weed challenge is often a serious problem in the forest-savanna transition zone of South West Nigeria. This is due to favourable climatic and conducive environmental conditions for their growth. The high rainfall, temperature and relative humidity in the study area is highly favourable for weed growth and competition. However, there was reduction in the relative abundance of weed species such as *Euphobia heterophylla* (Linn.), *Tridax procumbens* (Linn.), *Commelina bengalensis* (L.), *Panicum maximum* (Jacq.) *Cyperus rotundus* and *Kylinga squaminata* (Thonn) as well as total weed dry matter production in the late wet season than in the early wet season (Tables 2 and 3). Weed dry matter production of about 626 and 440 kg/ha was obtained from the weedy check plots in early and late wet seasons respectively. The relative more abundance of weeds and higher weed dry matter production in the early wet season when compared with late wet season may be attributed to the higher amount of rainfall received in the early than in the late wet season. Higher rainfall usually favours weed species abundance, prevalence, spread and competitiveness within weed and crop communities. For example, [22] reported that *Cyperus* occurrence was more prominent under irrigation condition while [23,24] also observed variation in abundance, biomass and distribution of weed species with season.

3.1 Effect of Nitrogen Levels and Weed Control Methods on Weed Growth in Okra in Early and Late Wet Seasons of 2015

N level had significant effect on weed cover score at 6 and 9 WAS, weed density and weed dry matter production in both early and late wet season (Table 3). During these periods, there was significant reduction in weed cover score as the level of N increased from 0-60 and 0-90 kg/ha. These results are in conformity with the findings of [25] who reported a decline in weed cover score with increased rate of N attributed to more competitive crop growth. Application of N in this study must have assisted the crop to grow faster and enhance smothering of weed thus reducing weed cover at earlier stage of crop growth. Increase in N level from 0 to 90 N kg/ha resulted in significant increase in weed density

Table 1. Meteorological data during the experiment in 2015 at Abeokuta

	Month	Total rainfall (mm)	Temperature °C	
			Minimum	Maximum
	April	87.2	23.6	31.4
	May	113.8	23.4	32.1
Early season	June	116.5	23.6	31.0
	July	230.5	14.7	30.5
Total		**548**		
	August	83.7	12.8	32.7
	September	174.0	9.8	30.4
Late season	October	175.8	11.4	31.8
	November	17.6	22.6	33.1
Total		**451**		

Source: Department of Agro Meteorology and Water Resources Management, Federal University of Agriculture Abeokuta, Ogun State

Table 2. Relative abundance of common weed species found on the experimental sites in early and late season of 2015

Weed species	Early	Late
Broad leaves		
Abutilion maritamim (Jacq.)	*	*
Chochorus olitorus (L.)	**	**
Euphobia heterophylla (Linn.)	* **	**
Gomphrena celozoides (mart.)	***	***
Talinum triangulare (Jacq.) Wild.	**	**
Tridax procumbens (Linn.)	* **	**
Hyptis sauveolens (Poit)	* **	***
Spigelia anthelmia (Linn.)	* *	**
Amaranthus spinosus (L)	***	***
Amaranthus viridis (L)	**	**
Boerhavia diffusa (L)	**	**
Grasses		
Andopogon gayanus (Kunth var.)	* **	-
Commelina bengalensis (L.)	* *	*
Cynodon dactylion (Linn.)	**	**
Imperata cylindrica (Linn.)	**	-
Panicum maximum (Jacq.)	* *	*
Sedges		
Cyperus rotundus (Linn)	**	*
Kylinga squaminata (Thonn)	* **	*
Mariscus alternifolius (Vahl)	*	*

**** High infestation (60 – 90%) * Low infestation (1 – 39%)*
*** Moderate infestation (40- 50%) - Not noticeable*

and weed dry matter production in the early and late wet seasons. N level had earlier been reported to affect weed abundance and alter crop weed interactions significantly [25]. Similar results were reported by [26] who observed increase in total weed biomass with increasing N application.

All the weed control methods caused significant reduction in weed growth compared to the weedy check as observed in weed cover score, weed density and weed dry matter production throughout the period of observation in early and late wet seasons. Similar result was reported by [27]. Pre-emergence application of probaben® and butachlor each at 2.0 kg a.i/ha followed by supplementary hoe weeding at 6 WAS caused significant reduction in weed growth similar to two and three hoe weedings all of which showed superiority in controlling weeds over any of the herbicides applied alone in both early and late wet seasons. Similar results were obtained by [28] and [21]. Results suggest that farmers can reduce the burden of hoe weeding and cut down on labour input with the use of pre-emergence herbicides for weed control in okra production.

3.2 Effect of Nitrogen Levels and Weed Control Methods on Growth and Yield of Okra in Early and Late Wet Season of 2015

Application of N fertilizer resulted in significant effect on the growth of okra as reflected in the plant height at 6 WAS in the early season and 9 WAS in the late season, crop vigour score at 6 and 9 WAS in early season and at 9 WAS in late season, number of leaves at 6 and 9 WAS in the early and late season and leaf area per plant at 9 WAS in early and late wet seasons (Tables 4 and 5). During these periods, crop vigour score, plant height, number of leaves and leaf area of okra increased significantly with increase in N level from 0 to 90 kg/ha. In addition, N application had significant effect on yield and yield attributes of okra during the early and late wet season. Application of N at 60 kg/ha produced highest number of fruit per plot during the early wet season. During the late wet season however, number of fruit increased with increasing N level up to 90 kg/ha. Similarly, during the early and late wet seasons, fruit yield of okra increased with increasing N level from 0 to 90 kg/ha while fruit length and diameter peaked with application of 60 N kg/ha.

In both seasons, fruit yield increased by 9-15 and 17-21% with increase in N level from 0-60 and 0-90 kg/ha respectively. These results suggest that higher N level enhanced better crop growth and yield of okra. The soil fertility elements, especially organic matter and total N contents, at the experimental sites in both early and late wet seasons were low therefore, the okra crop is expected to benefit from N fertilizer application as the adequate supply would correct N deficiency and result in rapid vegetative and higher fruit yield. N is a constituent of protein and is essential for chlorophyll which led to production of more photosynthates needed for vegetative growth. Thus, plants were taller and indicated improvement in other growth parameters. The increase in yield from higher N application can also be attributed to better and earlier canopy formation which checked the growth and reduced competition for nutrients from weeds. Similar observations were made by [29,30] and [31] that the growth and yield of okra fruits depends on available soil N and amount of N fertilizer applied. The earlier response of okra growth to applied N fertilizer at 6 WAS during early wet season relative to that of late wet season as observed in this study, however, may be attributed to higher total amount of rainfall in the former than in the later (Table 2). Several studies [32,33,34] have revealed that plant growth and yield response to N fertilizer depends on the amount of rainfall and available soil moisture.

All the weed control methods produced significantly higher crop growth and yield compared to the weedy check during the early and late wet seasons. These results are in consonance with the finding of [21]. Similarly, all the herbicide treatments applied alone or supplemented with hoe weeding at 6 WAS produced significantly taller plants than 2 and 3 hoe weedings during the early and late wet seasons. This might be attributed to effective early weed suppression provided by pre-emergence herbicides, thereby minimizing crop-weed competition and maximum height of the plants. Similar results was earlier reported by [35]. In addition, the use of probaben® and butachlor at 2.0 kg a.i/ha applied alone or supplemented with hoe weeding at 6 WAS produced crop vigour, number of leaves and leaf area per plant similar to 2 and 3 hoe weedings but significantly higher than the respective weedy check in both early and late wet season. Similarly, number of fruits and fruit yield obtained with application of probaben® or butachlor alone at 2.0 kg a.i/ha was comparable to those obtained with 2 hoe weedings in both early and late wet season. Furthermore, pre-emergence application of probaben® and butachlor applied at 2.0 kg a.i/ha followed by supplementary hoe weeding at 6 WAS produced number of okra fruits and fruit yield similar to 3 hoe weedings but significantly higher than 2 hoe weedings or either herbicides applied alone in both early and late wet season. Removal of weed at the early stage in the season and subsequent timely later weed removal, reduced crop-weed competition to the lowest possible limit and provided almost weed free environment. This was probably the reason for higher fruit yield in 3 hoe weeded plots and those plots that received pre-emergence application of probaben® or butachlor followed by supplementary hoe weeding at 6 WAS. The effectiveness of pre-emergence application of probaben® and butachlor for weed control similar to three hoe weeding in both years is an indication that the herbicides when complemented with a single hoe weeding, can be used as alternative weed control option to two or three hoe weedings particularly where labour is limiting and land under cultivation is large. Similar result was also reported by [20].

The need to keep okra weed free throughout the period of crop growth for maximum fruit yield has been reported by [36]. The use of pre-emergence herbicide for weed control therefore can save the farmer a lot of time and money in achieving this [37,38]. Most of the pre-emergence herbicides used for weed control could be effective up to 6 WAS and could take care of the early stage of the crop growth while supplementary hoe weeding will be required to take care of the late emerging weeds and keep weed free condition throughout the crop life cycle. In this study, maximum fruit yields of 3491 and 4100 kg/ha was obtained with three hoe weedings in early and late wet season respectively. Higher fruit yield obtained in the late wet season than in the early wet season may be attributed to higher weed infestation occasioned by higher rainfall in the later than in the former. Weed dry matter production was about 186 kg higher in early season than the late wet season hence the lower yield obtained in the early season. Unchecked weed growth throughout the crop life cycle resulted into 51 and 59% reduction in potential okra fruit yield in early and late wet seasons, respectively.

Table 3. Effect of nitrogen levels and weed control on weed cover score, weed density and weed dry matter of okra in 2015 early and late season

Treatments	Weed cover score						Weed density (plants/m^2)		Weed dry matter production at harvest (kg/ha)	
	Weeks after sowing (WAS)									
	3		6		9		9			
Nitrogen level (kg/ha)	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**
0	5.1	4.6	6.6	5.6	6.5	6.4	27.5	15.7	195.6	137
60	5.4	4.4	5.2	5.0	4.9	6.1	29.4	23.3	203.6	143
90	4.3	3.5	3.9	3.4	4.5	4.7	31.5	26.1	218.6	158
LSD (5%)	ns	ns	0.2	0.1	0.3	0.1	0.6	0.3	5.8	1.8
Weed management										
Probaben® at 2.0 kg a.i/ha	4.8	3.3	5.6	4.5	6.0	5.1	31.3	26.7	163	130
Probaben® at 2.0 kg a.i/ha fb HW at 6 WAS	4.9	3.7	5.2	3.8	4.3	4.9	22.3	19.1	127	85
Butachlor at 2.0 kg a.i /ha	4.7	3.8	5.2	4.7	5.6	5.9	30.1	21.2	173	124
Butachlor at 2.0 kg a.i /ha fb HW at 6 WAS	3.9	5.6	4.8	3.7	4.1	4.8	20.7	17.3	117	88
2 hoe weedings at 3 and 6 WAS	4.9	4.3	4.7	4.0	5.4	5.4	25.6	18.5	122	93
3 hoe weedings at 3, 6 and 9 WAS	4.3	4.1	4.4	3.9	5.6	5.0	19.0	17.6	119	67
Weedy check	6.8	4.6	6.9	8.3	6.7	9.2	56.9	31.6	626	440
LSD (5%)	0.6	ns	0.4	0.2	0.4	0.4	5.5	3.5	8.8	2.8
Nitrogen × Weed management	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

a. a.i. = active ingredient; LSD = least significant difference; fb = followed by; WAS = weeks after sowing; SHW = supplementary hoe weeding.
b. weed cover score was by visual observation based on scale 1-10 where 1 represented completely weedy plot and 10 represented the most clean plot

Table 4. Effect of nitrogen levels and weed control on growth parameters of okra in 2015 early and late season

Treatments	Plant height (cm)				Crop vigour score				No of leaves per plant				Leaf area (cm^2)	
	Weeks after sowing													
	6		9		6		9		6		9		9	
Nitrogen level (kg/ha)	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**
0	26.9	28.8	45.7	52.5	4.1	5.1	5.6	7.0	6.2	6.4	9.0	6.4	187.2	206.6
60	29.7	29.1	45.8	54.6	4.6	5.2	6.0	5.8	7.1	7.3	10.8	8.1	206.1	254.3
90	31.3	28.0	46.7	55.2	4.1	6.1	5.6	6.7	7.4	8.6	11.0	10.0	265.4	295.7
LSD (5%)	1.5	ns	ns	1.2	0.3	0.4	ns	0.2	0.3	0.6	0.5	0.7	51.8	56.7
Weed management														
Probaben® at 2 kg a.i/ha	30.0	32.6	48.2	53.9	5.6	4.7	6.4	6.5	7.6	7.0	10.4	8.6	168.5	277.8
Probaben® at 2 kg a.i/ha fb SHW at 6 WAS	30.0	27.4	45.7	59..3	5.2	5.4	6.3	6.5	6.3	6.0	10.1	7.0	234.3	234.7
Butachlor at 2 kg a.i /ha	31.9	29.8	49.2	55.9	4.2	5.6	5.6	6.1	7.8	8.0	10.3	9.0	216..9	279.1
Butachlor at 2 kg a.i /ha fb SHW at 6 WAS	33.3	27.2	54.2	59.7	2.7	6.8	5.1	6.1	7.2	9.0	10.3	10.0	232.4	238.9
2 hoe weedings at 3 and 6 WAS	27.4	25.8	42.9	59.6	3.7	6.3	5.2	5.7	7.0	8.0	10.4	9.0	214.3	280.7
3 hoe weedings at 3, 6 and 9 WAS	27.4	29.8	44.4	48.3.	2.4	6.6	4.7	6.8	6.0	10.0	10.2	8.6	276.7	285.0
Weedy check	25.1	27.7	38.0	43.1	5.9	3.1	6.7	3.4	6.3	5.0	10.0	5.1	193.3	169.6
LSD (5%)	2.3	ns	4.0	ns	0.4	0.6	0.4	0.3	0.5	0.8	ns	0.9	ns	27.4
Nitrogen × Weed management	ns	ns	6.9	ns	0.8	ns	0.7	0.6	ns	1.4	ns	1.8	ns	47.5

a. a.i. = active ingredient; LSD = least significant difference; fb = followed by; WAS = weeks after sowing; SHW = supplementary hoe weeding.
b. crop vigour score was by visual observation based on scale 1-10 where 1 represented completely dead okra and 10 represented the very healthy okra

Table 5. Effect of nitrogen levels and weed control methods on yield parameters of okra in early and late wet season of 2015

Treatments	No of fruits/plot		Fruit yield (kg/ha)		Fruit length (cm)		Fruit diameter (cm)	
Nitrogen level (kg/ha)	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**	**Early**	**Late**
0	34.3	35.0	2516	2970	4.30	4.35	1.70	4.13
60	36.8	42.0	2738	3359	4.30	4.50	2.20	4.31
90	37.9	48.6	3116	3570	3.90	4.43	2.10	4.10
LSD (5%)	1.4	2.3	130.0	293.3	ns	ns	0.03	0.04
Weed management								
Propaben® at 2 kg ai/ha.	34.3	41.3	2557	3044	4.80	2.17	2.12	3.33
Propaben® at 2 kg ai/ha fb SHW at 6 WAS	39.7	47.0	3270	3966	3.73	1.80	1.77	3.67
Butachlor at 2 kg ai/ha,	33.3	39.6	2840	2900	4.42	2.00	1.95	3.67
Butachlor at 1 kg ai/ha fb SHW at 6 WAS	40.4	48.0	3320	3833	4.78	2.02	2.46	5.56
2 Hoe weeding at 6 and 9 WAS	35.2	40.3	2377	3244	4.31	1.88	1.84	4.33
3 Hoe weeding at 3, 6 and 9 WAS	39.4	51.3	3491	4100	3.53	1.93	1.98	4.11
Weedy check	23.4	25.3	1678	2011	3.68	1.36	1.96	4.56
LSD (5%)	3.0	3.1	311.1	376.0	0.3	0.1	ns	ns
Nitrogen level × Weed management	ns	ns	ns	ns	ns	ns	ns	ns

a.i. = Active ingredient; LSD = Least significant difference; fb = Followed by; WAS = Weeks after sowing; SHW = Supplementary hoe weeding

4. CONCLUSION

The results of this study showed that N application at the rate of 60 and 90 kg/ha promoted crop growth and okra fruit yield compared to without N application. However, application of 90 kg N produced significantly higher okra fruit yield than 60 kg N/ha. In addition, pre-emergence application of probaben® and butachlor at 2.0 kg a.i/ha each followed by supplementary hoe weeding at 6 WAS consistently reduce weed growth with subsequent higher crop growth and okra fruit yield similar to three hoe weedings in both early and late wet seasons. It is therefore recommended that farmers can use these herbicides followed by supplementary hoe weeding at 6 WAS in integration with 90 kg N/ha to increase okra fruit yield and to cut down on labour inputs for manual weeding which is a major constraint in crop production in Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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