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Assessment of Butachlor, Diuron and Atrazine + Alachlor for Weed Management in Okra

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Abstract- Weed interference decreases okra (*Albelmoschus esculentus* (L.)Moench) yields. Weeding is mostly manual with drudgery and cost, unlike the use of herbicides. Herbicides identified for okra productivity are few and scarce. Objectives of this experiment are to evaluate the tolerance and development of okra to three frequently used herbicides. But achlor, diuron and atrazine+alachlor, at 2.0, 3.6 and 3.3 kga.i./ha, respectively, were screened for weed control in okra. Hoe-Weeded (HWC) and un-weeded plots (WDC) served as controls. Data collected were subjected to statistical analysis. Okra establishment was in the order of 91.8% (HWC)> 89.0% (butachlor)> 86.8% (WDC)> 70.8% (atrazine+alachlor)> 51.9% (diuron). But achlor at 2.0kg a.i./ha was safe on okra. Diuron at 3.6kg a.i./ha was severely (7.8) phytotoxic, while atrazine+alachlor at 3.3kg a.i./ha was moderately (4.4) phytotoxic on okra, on 0-10 scale. Shoot biomass of 7.35g/plant in okra grown in butachlor treated plots were similar to 7.90g/plant in HWC, and greater than 1.4g/plant in diuron treated plots, 3.5 and 3.45g/plant in atrazine+alachlor and WDC, respectively. The herbicides had better weed control than WDC. Butachlor had no phytotoxic effect on okra and had okra establishment and shoot biomass comparable with HWC and should be listed for weed control in okra production.

Keywords: herbicide screening, okra establishment, weed control.

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I. Introduction

Okra (*Albelmoschus esculentus* (L.)Moench) is a highly nutritive fruit vegetable which is rich in vitamins, iron and iodine, yet its growth and development is greatly limited by weed interference, particularly at the early growth stage. Adeyemi *et al.* (2014) reported that uncontrolled weed interference in okra resulted in 50.1% okra fresh pod yield loss. Manual weeding is the popular weed management strategy in okra production in most places. The use of herbicides is a convenient weed control method under large–scale operation. Dittmar & Stall (2019) reported that herbicides tagged for use in okra production are severely limited. Pendimethalin as a suitable herbicide for okra production in the rainforest ecological zone of Asaba, Nigeria has been reported by Obiazi *et al.* (2020). However there is still need to identify many more herbicides for weed management in okra. Among some herbicides that are frequently used for weed control in the rainforest zone of Nigeria are butachlor, diuron and a combination of atrazine+alachlor. Butachlor is a pre-emergence herbicide generally recommended for weed control in upland or paddy rice production. Butastar used in this study has butachlor as active ingredient and it is the first listed herbicide for upland or paddy rice. Butachlor is also recommended in combination with some herbicides as post emergence spray and is reported to control most annual weeds (NACWC, 1994). (Konlan*et al.* (2016) noted that diuron suppresses weeds for a prolonged period in pineapple, plantain, banana, sugarcane, yam and cassava. Diuron, is an effective broad-spectrum herbicide for both annual grassy and broadleaf weeds in pre and post-emergence control. NACWC (1994) reported that atrazine + alachlor are recommended for weed control in maize, a commonly cultivated crop, at the rate of 2.5 - 3.0 kga.i./ha in Nigeria. This study was therefore set up to identify more herbicides for okra production by evaluating the selectivity on okra and weed control efficacy of butachlor, diuron and atrazine+alachlor, that have been found to effectively control weeds in widely cultivated crops in the rainforest ecology.

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II. Materials and Methods

a) *Experimental Site*

The field experiment was conducted in the Teaching and Research farm of Department Agronomy, Forestry and Wildlife, Delta State University, Asaba Campus, Asaba, Nigeria in the rainy seasons of 2013 and 2014. Asaba lies within latitude 6^0 14^1N and longitude 6^0 49^1E in the rainforest zone of Southern Nigeria.

b) *Procurement of Seeds*

A commonly grown early maturing local okra cultivar, *Ozigolo*, which was used for the study, was purchased from Oki market in Agbor, Delta State, Nigeria.

c) *Land Preparation Experimental Layout and Design*

The land preparation was done manually with a total of fifteen plots marked out. Each plot measured 2 m by 2 m with 1 m between plots and 1.5 m separating replicates. The experimental treatments consisted of pre-emergence application of butachlor at 2.0 kg a.i./ha, diuron at 3.6 kg a.i./ha and atrazine + alachlor (1:1)) at 3.3 kg a.i./ha. Plots hoe-weeded at 3 and 6 Weeks After Sowing (WAS) and weedy check which involved non-removal of weeds throughout the experiment served as controls to compare the pre-emergence herbicide

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treatments and estimate the loss in growth due to uncontrolled associated weeds. Hoe was used to remove weeds in plots designated for hoe-weeded control at three and six WAS. Five treatments of the study were laid out in a Randomized Complete Block Design (RCBD) and replicated thrice.

d) Seed Protection and Plant Protection Treatments

The seeds were soaked overnight in water and air dried under shade to enhance germination. The air dried seeds were dressed with Apron star at the rate of 10 g Apron star per 4 kg of seeds. Apron star which contained both insecticide and fungicide was for protection of okra from pests and diseases, its active ingredients are 200/Kg Metalaxyl–M, 20g/Kg Difenoconazole and 200g/Kg Thiamethoxam (Syngenta, 2017).

Cypermethrin was used at the rate of one ml per litre of water to spray the okra plants against pests at 3, 5 and 7 WAS.

e) Seeding and Thinning of Seedlings

Three okra seeds were sown per hole at an average depth of two cm on the flat at a spacing of 50 x 50 cm, resulting in 16 stands per plot and 40,000 stands/ha. At 3 WAS the okra seedlings were thinned to one seedling per stand after taking the phytotoxicity readings.

f) Application of Fertilizer

The sandy loam soil had pH value of 5.9 and 6.0 and total N of 1.1 and 1.0 g/ kg in 2013 and 2014, respectively. Fifty kg of N/ha was applied using urea as the source of nitrogen, 50% of the fertilizer was applied at three weeks growth stage while the second dosage was applied three weeks later.

g) Herbicide Application

A CP knapsack sprayer, delivering 265 l/ha fitted with polijet nozzle, was used to apply the herbicides.

h) Experiment Duration

The experiment was established on the 10th of May in 2013, while in 2014, the planting of okra and pre-emergence application of the herbicides was carried out on the 6th of May, 2014. The experiment studied the growth of okra as affected by pre-emergence application of butachlor, diuron and atrazine+alachlor for eight weeks.

i) Data Gathered

i. *Phytotoxicity Rating*

Phytotoxicity rating on okra seedlings was taken at three weeks after sowing using the scale of 0-10 where 0 means no damage and 10 denotes total kill.

ii. *Okra Establishment*

Okra establishment was taken at eight weeks after sowing by counting all the established stands per plot.

iii. *Okra Growth Parameters*

The okra growth parameters taken at eight weeks after sowing were number of leaves per plant, number of branches per plant, stem diameter at 10 cm height, stem height and shoot biomass. Data on the effects of treatments on okra growth were taken from four tagged stands located in central rows of each plot; the mean for the four measurements represent the okra growth response in each plot.

iv. *Weed Control Efficacy*

Effects of treatments on weed control efficacy of the tested herbicides were assessed by taking data on weed biomass at 4, 6 and 8 WAS using a quadrat of 50 cm by 50 cm dimension. The quadrat was randomly placed within the plots in two locations per plot. All the weeds within the quadrats were collected, dried in the oven at 70 ^{0}C to constant weight. Dry weeds were weighed using Citizen Electronic Balance with maximum capacity of 2 000 g.

The weed control efficacy for each of the treatments was calculated based on the method used by Prachandet *al.* (2015) as shown below:

$$WCE\ \% = \frac{WD\,c - WDt}{WD\,c} \times \frac{100}{1}$$

Where,
WCE = Weed Control Efficacy (%)
WDc = Weed biomass (g/m^2) in weedy control plot
WDt = Weed biomass (g/m^2) in treated plot.

j) Statistical Analysis

Data concerning okra establishment and weed control efficacy were transformed to square root scale of √ x+0.5 and analyzed as suggest by (Little & Hills, 1978). Data obtained with respect to the treatments were subjected to analysis of variance and treatment means separated using Least Significant Difference (LSD) tests at 5 % level of probability.

III. Results

a) Phytotoxicity

The pre-emergence herbicide applications had significant phytotoxic effect on okra plants at 3 WAS (Table 1.0). Okra grown in plots that received pre-emergence application of butachlor at 2.0 kg a.i./ha did not display any phytotoxic effect; the outlook of the okra plants compared with the ones grown in un-treated plots in 2013 and 2014. Okra grown in plots treated with diuron at 3.6 kg a.i./ha had the highest average phytotoxicity values of 7.8, this value was significantly greater than 4.4 observed in okra grown in in plots treated to atrazine + alachlor (1:1) applied at 3.3 kg a.i./ha. Atrazine + Alachlor used at 3.3 kg a.i/ha was less injurious to okra plant than diuron used at 3.6 kg a.i./ha in this study. Okra showed high sensitivity to pre-emergence application of diuron used at 3.6 kg a.i. /ha.

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Table 1: Effects of pre-emergence herbicide applications on the phytotoxicity, number of leaves per plant, stem height and stem diameter of okra plants

Treatment	Phytotoxicity Rating at 3 WAS	No. of leaves / plant at 8 WAS	Stem height (cm) at 8 WAS	Stem dia. (cm) at 8 WAS
2013				
Butachlor at 2.0 kg a.i./ha	0.0c	7.3b	78.1a	2.4ab
Diuron at 3.6 kg a.i./ha	7.8a	4.0 c	20.0d	0.7c
Atr +Ala at 3.3 kg a.i./ha	4.8b	5.7bc	55.5b	1.8b
Hoe-weeded at 3 and 6 WAS	0.0c	11.0a	52.1b	3.1a
Weedy	0.0c	7.0b	36.9c	0.8c
SE ±	0.54	1.21	3.48	0.41
2014				
Butachlor at 2.0 kg a.i./ha	0.0C	9.7a	67.8a	2.3a
Diuron at 3.6 kg a.i./ha	7.7a	7.3a	28.2c	1.0b
Atr +Ala at 3.3 kg a.i./ha	4.0b	7.0 a	21.0c	2.1a
Hoe-weeded	0.0c	9.3 a	57.0a	2.9a
Weedy	0.0c	9.3 a	41.7b	0.9b
SE ±	0.59	1.48	5.25	0.44
Average				
Butachlor at 2.0 kg a.i./ha	0.0 c	8.5 b	73.0 a	2.4 a
Diuron at 3.6 kg a.i./ha	7.8 a	5.7 c	24.1 d	0.9 c
Atr +Ala at 3.3 kg a.i./ha	4.4 b	6.4 c	38.9 c	2.0 b
Hoe-weeded	0.0 c	10.2 a	54.6 b	3.0 a
Weedy	0.0 c	8.2 b	39.3 c	0.9 c
SE ±	0.55	0.75	2.21	0.21

Means within a column followed by the same letter(s) in the same year do not differ significantly at 5% level of probability using LSD.

WAS = Weeks After Sowing

Dia = Diameter, Atr +Ala =Atrazine +Alachlor, Hoe-weeded = Hoe-weeded at 3 and 6 WAS

b) *Number of leaves per plant*

Number of leaves per plant ranged from 4.0 to 11.0 (Table 1.0). In 2013, okra grown in plots that were hoe-weeded at 3 and 6 weeks after sowing had significantly greater number of leaves per plant (11.0) than what was obtained in any other treated plots (4.0 - 7.3) in 2013, but in the 2014, all the treatments had similar number of leaves which ranged from 7.3 to 9.7. On the average, number of leaves per plant in hoe-weeded (10.2) was similar to 8.5 in butachlor treated plots but greater than what was obtained in diuron and alachlor + atrazine treated plots, 4.0 – 5.7 and 7.0 – 7.3, in 2013 and 2014, respectively (Table 1).

c) *Stem height*

Plants of okra in butachlor treated plots were the tallest in 2013 and 2014 with heights of 78.1 cm and 67.8 cm in 2013 and 2014, respectively (Table 1.0). In 2013, okra grown in diuron treated plots were significantly the shortest in height of 20.0 cm and these were even significantly shorter than what was obtained in weedy plots (36.9 cm). In 2014, shortest okra plants were in plots that received pre-emergence application of atrazine + alachlor at 3.3 kg a.i./ha (21.0 cm). On the average, stem height as shown in Table 1, were in the order of butachlor (73.0 cm) > hoe-weeded (54.6 cm) > weedy (39.3 cm) = atrazine + alachlor (38.3 cm) >diuron (24.1 cm).

d) *Stem diameter*

The stem diameter differed significantly due to different weed control methods applied in both years (Table 1). The thickest stem among the pre-emergence herbicide treatments of 2.4 cm in 2013 and 2.3 cm in 2014 were found in plots treated with butachlor at 2.0 kg a.i./ha. The thinnest stems of 0.70 cm in 2013 and 1.0 cm in 2014 were found in plots treated with diuron at 3.60 kg a.i./ha. The average stem thickness ranged from 0.9 cm (weedy control and diuron) to 3.0 cm (hoe-weeded plots). That of butachlor of 2.4 cm was similar to that of hoe-weeded plots.

e) *Okra establishment*

Method of weed control had significant effect on average percentage okra establishment (Figure 1). Mean okra establishment ranged from 43.8 % (diuron at 3.6 kg a.i./ha) to 97.9 % (un-weeded in plots). Okra grown in hoe-weeded plots had the highest mean establishment (92.6%) which was similar to what was

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obtained in un-weeded plots (91.7%) and plots treated with butachlor at 2.0 kg a/i./ha (90.6%), these were significantly better than the establishment level of okra plants grown in plots treated to atrazine + alachlor (1:1) used at 3.3 kg a.i./ha (75.0%). Okra grown in plots treated with diuron at 3.6 kg a.i./ha had the least average establishment level of 53.2% at eight WAS. Among the pre-emergence herbicides, the highest average okra establishment was in butachlor of 90.6 % which was significantly greater than 70.8 % observed in plots treated to atrazine + alachlor (1:1) which was also significantly greater than 53.2 % establishment level in plots that received pre-emergence application of diuron at 3.6 kg a.i./ha.

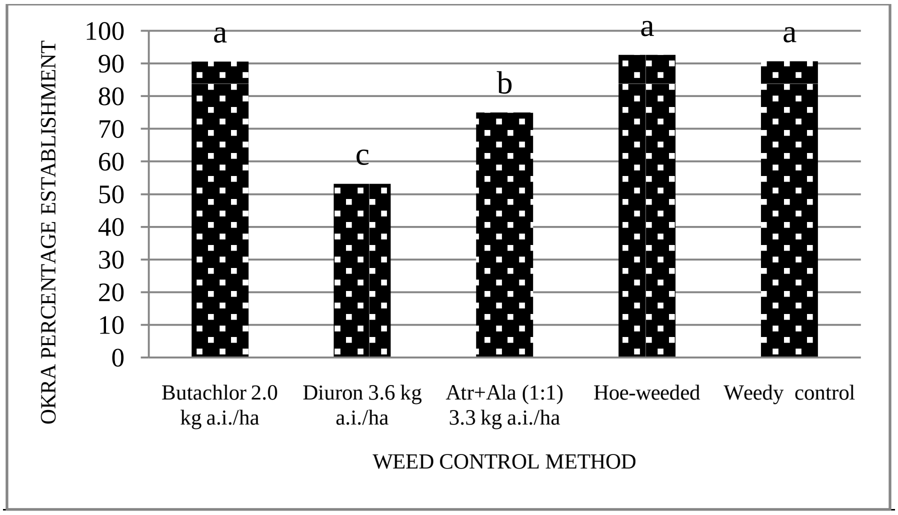

Figure 1: Effects of pre-emergence herbicide applications on okra percentage establishment per plot (Values are averages for 2013 and 2014)

Values with similar letter do not differ significantly at 5% level of probability using LSD.
Atr+ala = Atrazine + Alachlor, Hoe-weeded = Hoe-weeded at 3 and 6 weeks after sowing, Weedy = Un-weeded throughout the experiment.

f) Shoot biomass

Pre-emergence herbicide applications had significant effect on okra mean shoot biomass. Maximum average okra shoot biomass (7.9 g/plant) was produced on plots hoe-weeded at 3 and 6 WAS. The least okra shoot biomass (1.4 g/plant) was produced on plots sprayed diuron at 3.6 kg a.i. /ha. Mean shoot biomass were in the order 7.9 g/plant (Hoe-weeded) = 7.4 g/plant (butachlor) > 4.7 g/plant (atrazine + alachlor) 3.5 g/plant (weedy) >1.4 g/plant (diuron).

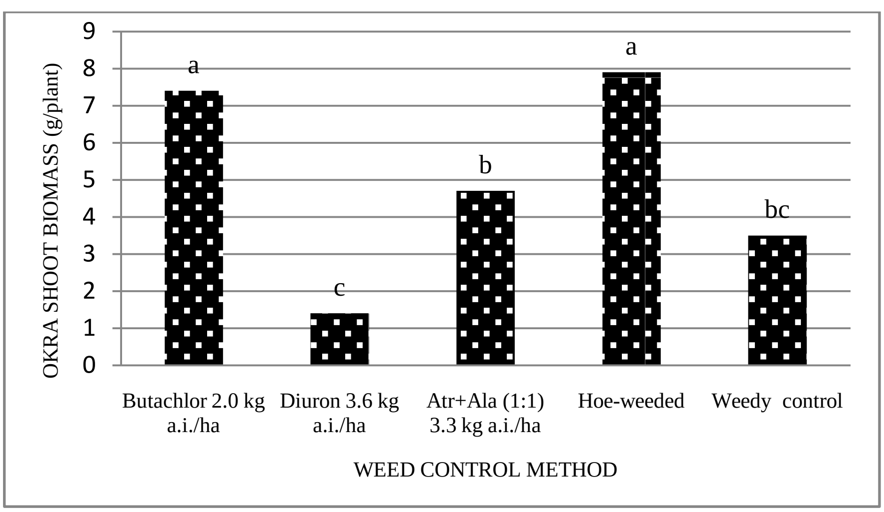

Figure 2: Effects of pre-emergence herbicide applications on okra shoot biomass. (Values are averages for 2013 and 2014)

Values with similar letter(s) do not differ significantly at 5% level of probability using LSD.
Atr+ala = Atrazine + Alachlor, Hoe-weeded = Hoe-weeded at 3 and 6 weeks after sowing, Weedy = Un-weeded throughout the experiment.

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g) *Weed biomass*

All the weed control treatments had less weed biomass than un-weeded control plots at four, six and eight WAS in 2013 and 2014 (Table 2.0).

The three herbicides had similar weed biomass at 4 WAS which ranged from 1.6 to 2.4 g/m^2 and these were similar to 1.2 to 2.3 g/m^2 obtained in hoe-weed plots and were significantly less than 21.2 - 21.4 g/m^2 observed in un-weeded plots. At 6 WAS the herbicide treatments had 11.2 -17.6 g/m^2 weed biomass which were significantly less than 70.3 – 73.5 g/m^2 recorded in un-weeded plots. At 8 WAS each of the herbicide treated plots had greater weed biomass each year than what was observed in the respective hoe-weeded plots.

Table 2: Effects of pre-emergence herbicide applications on weed biomass and weed control efficacy in okra plots between four and eight weeks after planting

Treatment	Weed biomass (g/m^2) Weeks After Sowing			Weed control efficacy (%) Weeks After Sowing		
	4	6	8	4	6	8
2013						
Butachlor at 2.0 kg a.i./ha	1.8b	17.5b	61.6b	91.5 a	75.1 bc	40.1 b
Diuron at 3.6 kg a.i./ha	1.6b	11.2b	54.3b	92.5 a	84.2 a	48.6 b
Atr + Ala at 3.3 kg a.i./ha	1.9b	15.3b	59.1b	91.0 a	78.2a b	44.1 b
Hoe-weeded	1.2b	18.3b	12.2c	94.3 a	71.0 c	90.3 a
Weedy	21.2a	70.3a	102.8a	0.0 b	0.0 d	0.0 c
SE ±	1.63	4.02	4.79	4.43	2.91	5.36
2014						
Butachlor at 2.0 kg a.i./ha	2.4a	17.6b	65.4b	88.8 a	76.0 a	41.0 b
Diuron at 3.6 kg a.i./ha	1.8b	15.5b	63.9b	91.6 a	78.9 a	42.4 b
Atra + Ala at 3.3 kg a.i./ha	2.1b	16.8b	67.0b	90.2 a	77.1 a	39.5 b
Hoe-weeded	2.3b	21.4b	14.4c	89.3 a	70.8 a	87.0 a
Weedy	21.4a	73.5a	110.8a	0.0 b	0.0 b	0.0 c
SE ±	1.27	4.25	5.53	5.91	5.38	2.29

Means within a column followed by the same letter(s) in the same year do not differ significantly at 5% level of probability using LSD.

WAS = Weeks After Sowing

Dia = Diameter, Atr +Ala =Atrazine +Alachlor, Hoe-weeded = Hoe-weeded at 3 and 6 WAS

h) *Weed control efficacy*

All the chemical weed control treatments had similar outcome at 4 WAS. Weed control efficacy of the pre-emergence herbicides was better than what was recorded in the weedy check at 4, 6 and 8 WAS (Table 2.0).

The response of okra to the pre-emergence application of the herbicides followed the same trend in WCE in the two years.

IV. Discussion

The phytotoxic effects on okra, okra stands survival, number of leaves per plant, stem diameter and shoot biomass in butachlor treated plots were not significantly different from hoe-weeded plots. In assessing the performance of okra in butachlor, diuron and atrazine + alachlor, used at 2.0, 3.6 and 3.3 kg a.i. /ha respectively, diuron significantly ($p< 0.05$) reduced (survival) number of okra seedlings per plot, number of leaves per plant, stem diameter and shoot biomass. Diuron was injurious to the okra plant; the plant showed sensitivity to the pre-emergence application of diuron at the rate of 3.6 kg a.i./ha. Butachlor had no phytotoxic effect on okra plant at the rate of 2.0 kg a.i./ ha. It must have only suppressed weed and not cause any detrimental effect on the crop hence it produced shoot biomass that was similar to that produced by hoe-weeded check. Adigun, *et al.* (2018) reported a successful use of butachlor at 2.0 kg a.i./ha in okra production.

Okra had greater number of leaves per plant, stem height and stem diameter at eight weeks after sowing in butachlor treated plots than in plots treated with diuron and atrazine + alachlor, this is probably beyond the case of competition between surviving weeds and okra for plant growth resources in the environment. At the time of terminating the experiment (eight weeks after sowing) the three herbicides applied pre-emergence had similar average weed control efficacy of 40.1 – 48.6 % in 2013 and 39.5 – 42.7 % in 2014, as well as similar average weed biomass of 54.3 – 61.6 and 63.9 – 67.0 g/m^2 in 2013 and 2014, respectively, yet the average stem height and stem

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diameter of okra plants in diuron were significantly less than what was observed in okra grown in butachlor and atrazine + alachlor treated plots. This observation points to an instance of diuron being more phytotoxic to okra than butachlor and atrazine+alaclhor. It is not a case of the quantum of weeds competition with the okra to cause depression in the performance of okra. The injurious effect of pre-emergence herbicides were more expressed in okra plants grown in diuron treated plots than those grown in atrazine + alachlor treated plots. The more injured a plant is, the less it is able to grow vigorously. Okra plants in butachlor treated plots grew vigorously while those grown in the other two grew with lesser vigor, hence the okra biomass was highest in butachlor treated plots followed by the ones grown in atrazine + alachlor and the least are the ones grown in diuron treated plots.

V. Conclusion

The fact that diuron and atrazine + alachlor showed phytotoxicity at 3.6 and 3.3 kg a.i./ha, respectively, does not close the possibility of the use of the two herbicides in okra production. The herbicides at certain lower rates may be less or non-phytotoxic on okra and still sufficiently suppress weed interference for an appreciable growth and yield of okra; such trials are therefore suggested. Butachlor had no phytotoxic effect on okra and had suitable growth performance in the pre-emergence application of the herbicide since it tolerated pre-emergence application of butachlor at 2.0 kg a.i./ha and provided okra establishment, shoot biomass and stem diameter comparable with plots hoe-weeded at three and six weeks after sowing, it also provided a significantly better weed control than weedy check. It is therefore recommended that butachlor should be one of the pre-emergence herbicides considered for weed management in okra production in Asaba in the rain forest ecology of Nigeria.

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