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Influence of supplementary hoe weeding on the efficacy of ButaForce® for lowland rice (*Oryza sativa* L.) weed management

Omovbude S.*, Kayii S. A., Ukoji S. O., Udensi U. E. and Nengi –Benwari A. O.

Department of Crop and Soil Science, University of Port Harcourt, P.M.B.5323, Choba, Port Harcourt, Rivers State, Nigeria.

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Field experiments to determine the influence of supplementary hoe weeding on the efficacy of ButaForce® (N-(butoxymethyl)-2-chloro-N-2,6-dimethyl acetanilide) for low land rice (*Oryza sativa* L.) weed management was conducted at the Faculty of Agriculture Teaching and Research Farm of the University of Port Harcourt during the early cropping seasons of 2018 and 2019. Seven treatments were used for the experiment namely: ButaForce® at 1.5 L/ha + SHW (21 DAS), ButaForce® at 2.0 L/ha + SHW (21 DAS), ButaForce® at 2.5 L/ha + SHW (21DAS), ButaForce® at 3.0 L/ha (recommended rate), weed-free (weekly weeding), hoe weeded twice at 21 and 42 DAS and weedy check. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replicates. Results from the study showed that weed-free check (weekly weeding) was more effective in weed control in lowland rice. It also gave the highest growth and yield attributes over all other treatments. Weed suppression and rice performance was better in plots treated with ButaForce® at 2.5 L/ha + SHW (21 DAS) than in other supplementary hoe weeding. The economic analysis showed that although hoe weeded plots had higher yields, the profit obtained from them were lower when compared with the supplementary hoe weeding and ButaForce® at 3.0 L/ha. Among all the weed control treatment, plots treated with ButaForce® at 2.5 L/ha with supplementary hoe weeding gave the highest profit. Since the highest profit was recorded in plots treated with ButaForce® at 2.5 L/ha with supplementary hoe weeding, it is therefore recommended to rice farmers in the study area.

Key words: Hoe weeding, lowland rice, supplementary, weed management, economic analysis.

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family of Poaceae and is a staple cereal crop in Nigeria. In Nigeria, it is grown in almost all agro-ecological zones as it forms one important cereal crop cultivated by farmers. Although rice is cultivated in almost all the agro-ecological zones in Nigeria, the cultivated area seemed to be small and the average rice farm holding is between 1 and 2 hectares (Akpokodje et al., 2001). Globally rice production records

*Corresponding author. E-mail: sundayomovbude@yahoo.com.

Table 1. Herbicide used in the study.

Common Name	Trade name	Formulation	Manufacturer	Main marketing agent in Nigeria
Butachlor	ButaForce ®	50%	Syngenta	Syngenta Nigeria limited

Table 2. Chemical name of the herbicide used in the study.

Herbicide name	Chemical name
ButaForce ®	N-(butoxymethyl)-2-chloro-N-2,6-dimethyl acetanilide

showed that of the 14.6 million metric tonnes of paddy rice produced annually on 7.3 million ha of land in Africa, Nigeria's production moved from 3.7 million metric tonnes in 2017 to 4.0 million metric tonnes in 2018 and with this slight increase it became the largest producer of rice in Africa (Oduntan, 2019) despite the increase, its yield remain moderate. Multifarious factors constrain rice production in Nigeria among which is ineffective weed control methods. Yield loss between 75 and 100% in rice as a result of uncontrolled weed growth has been reported by Akobundu (2011) and Imeokparia (2011). The elimination of weed competition at different stages of crop growth is critical and can be achieved manually or with the use of herbicides. However, both methods have their shortcomings. Hoe weeding is associated with drudgery and some weed species can develop resistance with the continuous use of herbicide (Udensi et al., 2017). As a result, herbicide application must be supplemented with hoe weeding in an integrated manner, to effectively control weeds in rice (Akobundu, 1987). The few reports on effectiveness of ButaForce® on weed control and performance of crops such as wheat and rice had been reported by Singh et al. (2016) and Hassan et al. (2017). No one weed control method has proved to be effective hence; this study tends to identify the efficacy of ButaForce supplemented with hoe weeding compared with the commonly adopted hoe weeding (weekly weeding and hoe weeded at 21 and 42DAS) and ButaForce® at 3.0 L/ha.

MATERIALS AND METHODS

Experimental site

The field trials were conducted during the 2018 and 2019 rainy seasons at the Teaching and research farm of the University, Port Harcourt, Rivers State, (latitude 04° 54 538'N, and longitude 006° 55 329'E; 17 m above sea level), Nigeria. The site had an average rainfall between 2500 – 4000 mm and a mean temperature of 27°C, relative humidity of 78% and Nwankwo and Ehirim, 2010). The area has two seasons (wet and dry). The wet season has double rainfall peaks with two cropping seasons in the area: early from March to July and late from August to December. The experimental site had been planted to mixed crops of maize, pepper and watermelon before commencement of the experiment. The dominant weed species found in the experimental site was identified with a weed handbook (Akobundu et al., 2016). These weeds were: *Ageratum conyzoides* Linn *Aspilia africana* (Pers.) C.D. Adams. *Chromoleana odorata* (L.) R.M. King & Robinson, *Cleome rutidosperma* DC. *Cyperus esculentus* Linn.. *Mariscus alternifolius* Vahl., *Mitracapus villosus* (Sw.) DC., *Oldenlandia corymbosa* Linn. and *Panicum maximum* Jacq.

Soil analysis

Soil samples were collected before planting operations at a depth of 0-15 cm deep using an auger of 10 cm in diameter at ten different points from the experimental site. The samples collected was air-dried at ambient temperature for two weeks and pulverized to facilitates laboratory analysis and for the removal of plant debris. The dry pulverized samples was assessed through a 2 mm mesh sieve and analyzed for physicochemical properties using standard methods (IITA, 1982).

Rice variety used

The rice variety used was (UPIA 2) and UPIA is an acronym for University of Port Harcourt, International Rice Research Institute and AGRA. It has an outstanding characteristic of high yield and tolerance to iron toxicity and African rice gall midge, matures between 110 - 120 days with a potential yield of 8.0 t/ha. The seeds were obtained from rice seed banks at the Teaching and Research Farm of University of Port Harcourt, Rivers State.

Herbicide used

ButaForce herbicide was used for the study. The herbicide was obtained at an Agrochemical store in Port Harcourt, Rivers State. The common name of the herbicide, its formulation, manufacturer and main marketing agent in Nigeria is shown in Table 1 and the chemical name Table 2.

Treatment and experimental design

Seven treatments were used for the experiment, which are itemized below:

(i) ButaForce ® at 1.5 L/ha + SHW (21 DAS)
(ii) ButaForce ® at 2.0 L/ha + SHW (21 DAS)
(iii) ButaForce ® at 2.5 L/ha + SHW (21 DAS)
(iv) ButaForce ® at 3.0 L/ha
(v) Weed free (weekly weeding)
(vi) Weeding twice at 21 DAS and 42 DAS

(vii) No weeding

These treatments were replicated three times to give a total twenty - one experimental plots, arranged in a Randomized Complete Block Design (RCBD).

Cultural details

The experimental land area of 29 m × 12 m (348 m^2) of approximately 0.03 ha was cleared manually, stumps and excess vegetation packed away from the plots. The experimental area was divided into three blocks while each block was further divided into seven plots making it a total of twenty one plots. Each plot size was 3 m × 3 m. The plots were separated by 1 m while the blocks were separated with a pathway of 1 m. Planting was done on the 14th and 15th May 2018 and 2019 respectively. The seeds were sown at a spacing of 30 cm × 30 cm with three seeds per hole and later thinned to one seedling at fourteen days after sowing (14 DAS) to give a plant population of 100 plants /plot which is equivalent to (111,111plants/ha). One day after sowing (1DAS) , twelve plots were sprayed with ButaForce ® at 1.5, 2.0 and 3.0 L/ha using a hand-operated CP3 knapsack sprayer calibrated to deliver approximately 240 L/ha spray volume at a pressure of 210 kpa with red polijet nozzle (swath width½m). Supplementary hoe weeding was carried at 21 DAS in plots that were treated with ButaForce ® at 1.5, 2.0 and 3.0 L/ha. Three plots were manually weeded with a hoe twice at 21 DAS and 42 DAS while another 3 plots were hoe weeded weekly. Basal application of urea fertilizer at 97.8 kg/ha was carried out at 21 DAS. This was done because the soil sample from the experimental site was found to be deficient of nitrogen (0.10 and 0.11% in 2018 and 2019 respectively) when compared to the critical level of nitrogen (0.15%) of southeastern soil established by Ibedu et al. (1988). Harvesting was carried out on 17th and 18th of September in 2018 and 2019 respectively with the use of sickle.

Data collection

Weed growth characteristics

Weed density and weed dry weight: Weed samples were collected at 21, 42, 63 and 84 DAS by placing 50 cm × 50 cm quadrats diagonally per plot twice. The weeds within each quadrat were removed by hand, counted and expressed in no/m^2. The weed dry weight was carried by using the same quadrat technique as weed density. The weeds were removed within the quadrat, sun dried to constant weight, weighed with an electronic scale, and expressed in g/m^2.

Weed control efficiency

Weed control efficiency was determined by using the method of Subramanian et al. (1991) as:

$$\text{WCE (\%)} = \frac{DWT\ of\ no\ weeding\ \ plot - DWT\ of\ treated\ \ plot}{DWT\ of\ no\ weeding\ \ plot} \times 100$$

Where:
WCE (%) = Weed control efficiency
DWT = Dry weight

$$\text{WI} = \frac{yield\ \ from\ weed\ \ free\ \ check - yield\ \ from\ treated\ \ plot}{yield\ \ from\ the\ weed\ \ free\ \ check} \times 100$$

Subramanian et al. (1991)

Where: WI = weed index

Rice performance

Five plants from the middle row of each plot were randomly selected and tagged and used to determined plant height, number of tillers, number of leaves, and leaf area index.

Plant height

The height of each tagged plant was taken at 4 intervals (21, 42, 63 and 84 DAS) using a meter ruler. Plant height was determined by placing a meter ruler at the soil surface to the tip of the flag leaf of each tagged plant and the mean calculated and recorded in cm.

Number of productive tillers

The number of tillers was obtained by counting starting from 21 to 84 DAS.

Number of leaves

This was done by counting the number of leaves per plant.

Leaf area index (LAI)

Leaf area index was determined by the following equation below:

LAI = T A x N /GA,

Where, TA = Total leaf area /plant N = number of plants/ gross plot, GA= Gross plot Area (Remison, 1997).

Panicle length

This was done by randomly from five panicles selected from harvested produce in each plot. It was measured from the neck-node to the tip of the apical grain and their average was taken as per panicle length.

Panicle weight (g)

The panicles selected for measuring length were weighed on an electrical weighing balance and then mean was worked out.

Paddy yield

The grains obtained after threshing and winnowing of the produce from each gross plot were sun dried, weighed per gross plot with a scale and the weight was expressed in kilogram per hectare (kg/ha).

Economic assessment

The economic assessment was done by using partial budgeting (Okoruwa et al., 2005).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) at 5% level of probability using GENSTAT 12th Edition while treatments mean

Table 3. Physiochemical properties of the experimental site before planting.

Soil properties	2018	2019
Physical properties		
Sand (%)	84	82
Silt (%)	4	3
Clay (%)	12	15
Textural class	Loamy sand	Loamy sand
Chemical properties		
pH (H_2O)	5.8	5.9
Total organic carbon (%)	1.17	1.19
Total nitrogen (%)	0.10	0.11
Available P (mg/kg)	14	15
Cation exchangeable capacity (cmol/kg)		
Ca	3.15	3.16
Mg	3.03	3.05
Na	1.35	1.12
K	3.05	3.03

Table 4. Rainfall (mm) data at the experimental sites during 2018 and 2019 cropping seasons.

Month	2018	2019
May	255	288.80
June	358	401.83
July	410	218.69
August	339	202.69
Total	1362	1112.01

Source: Department of Geography and Environmental Management, University of Port Harcourt.

were separated by using the least significant difference (LSD).

RESULTS

Soil analysis

The physiochemical characteristics of the soil before planting in both years are presented in Table 3. The soil of both years of study was loamy sand, slightly acidic with a moderate organic carbon content, available Phosphorus (P), exchangeable Potassium (K), Magnesium (Mg), Calcium (Ca) and low in total Nitrogen.

Rainfall

Table 4 shows the amount of rainfall data in 2018 and 2019 cropping seasons. The total amount of rainfall in 2018 cropping season (1362 mm) was higher than that of 2019 (1112.01 mm) by 22.48%.

Weed growth characteristics

Weed density

The effect of supplementary hoe weeding on the efficacy of Butaforce on weed density of low land rice is shown in Table 5. The treatments differed significantly ($P < 0.05$) throughout the sampling intervals (21, 42, 63 and 84 DAS). The highest weed density was recorded in no weeding plots throughout the observation periods except at 21DAS in 2018. The lowest weed density was recorded in plots that were weekly weeded throughout the periods of observation. All the ButaForce® rates with a supplementary hoe weeding had similar weed density at all the sampling intervals. Though at 21 DAS there were no significant differences between the supplementary hoe weeding and the recommended rates of ButaForce® at 3.0 L/ha at that period of sampling in both years, but all the herbicide plots that were supplemented with hoe weeding had lower weed density than the recommended rates of ButaForce® at 3.0 L/ha.

Table 5. Effect of supplementary hoe weeding on the efficacy of ButaForce® on weed density (no/m^2) of lowland rice.

Treatment	21 DAS	42 DAS	63 DAS	84 DAS
2018				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	86	97	143	207
ButaForce® at 2.0 L/ha + SHW (21 DAS)	81	80	115	183
ButaForce® at 2.5 L/ha + SHW (21 DAS)	69	80	111	160
ButaForce at 3.0 L/ha	47	205	253	303
Weed free (weekly weeding)	0	0	0	0
Hoe weeded at 21 and 42 DAS	103	89	54	76
No weeding	90	325	400	459
LSD (P=0.05)	55.36	85.4	93.5	93.2
2019				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	31.3	79.3	179	229
ButaForce® at 2.0 L/ha + SHW (21 DAS)	27.7	61.3	133	130
ButaForce® at 2.5 L/ha + SHW (21 DAS)	14.0	50.7	116	120
ButaForce at 3.0 L/ha	7.3	97.3	207	233
Weed free (weekly weeding)	0	0	0	0
Hoe weeded at 21 and 42 DAS	36.7	108	83	120
No weeding	159.3	216.7	353	390
LSD (P=0.05)	48.52	56.97	119.2	88.7

SHW = Supplementary hoe weeding, DAS = Days after sowing.

Table 6. Effect of supplementary hoe weeding on the efficacy of ButaForce® on weed dry weight (g/m^2) of lowland rice.

Treatment	21DAS	42DAS	63DAS	84DAS
2018				
ButaForce® 1.5 L/ha + SHW (21 DAS)	10.0	2.3	17.3	19.3
ButaForce® 2.0 L/ha + SHW (21 DAS)	7.3	1.0	13.7	16.7
ButaForce® at 2.5 L/ha + SHW (21 DAS)	5.3	0.8	10.9	16.0
ButaForce® at 3.0 L/ha	2.8	20.7	24.0	38.0
Weed free (weekly weeding)	0.0	0.0	0.0	0.0
Hoe weeded at 21 and 42 DAS	8.7	1.5	1.0	1.2
No weeding	7.3	37.3	36.7	42.7
LSD (P=0.05)	11.3	11.12	23.06	21.64
2019				
ButaForce® 1.5L/ha + SHW (21 DAS)	1.30	8.00	12.87	114.3
ButaForce® 2.0 L/ha + SHW (21 DAS)	1.10	5.53	9.00	104.1
ButaForce® at 2.5 L/ha + SHW (21 DAS)	1.07	3.77	7.33	68.3
ButaForce® at 3.0 L/ha	1.00	11.87	16.33	121.7
Weed free (weekly weeding)	0.00	0.00	0.00	0.00
Hoe weeded at 21 and 42DAS	2.37	1.53	2.50	70.3
No weeding	2.23	126.13	265.00	360.3
LSD (P=0.05)	0.179	0.679	2.331	38.59

SHW = Supplementary hoe weeding, DAS = Days after sowing.

Weed dry weight

The effect of supplementary hoe weeding on the efficacy of ButaForce® on weed dry weight of low land rice is shown in Table 6. The treatments differed significantly ($P < 0.05$) throughout the sampling intervals (21, 42, 63 and 84 DAS) on weed dry weight. Plots that were weeded weekly had the lowest weed dry weight when compared

Table 7. Effect of supplementary hoe weeding on the efficacy of ButaForce® on weed control efficiency (%) of lowland rice.

Treatment	21 DAS	42 DAS	63 DAS	84 DAS
2018				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	-36.99	94.0	64.40	40.1
ButaForce® at 2.0 L/ha + SHW (21 DAS)	0.00	96.7	73.20	56.9
ButaForce® at 2.5 L/ha + SHW (21DAS)	27.40	98.2	75.3	68
ButaForce® at 3.0 L/ha	61.64	44.50	34.60	11.01
Weed free (weekly weeding)	100	100	100	100
Hoe weeded at 21 and 42 DAS	-19.17	94.4	95.8	93.8
No weeding	0	0	0	0
LSD (P=0.05)	1.206	26.08	52.13	37.45
2019				
ButaForce® at 1.5 L/ha + SHW(21DAS)	41.39	93.66	95.14	68.26
ButaForce® at 2.0 L/ha + SHW (21 DAS)	50.32	95.61	96.00	71.10
ButaForce® at 2.5 L/ha + SHW(21 DAS)	51.90	97.01	97.23	81.05
ButaForce® at 3.0 L/ha	55.16	90.59	93.83	66.23
Weed free (weekly weeding)	100	100	100	100
Hoe weeded at 21 and 42 DAS	-6.20	98.90	99.02	89.73
No weeding	0.00	0.00	0.00	0.00
LSD (P=0.05)	2.427	0.566	0.807	0.812

SHW = Supplementary hoe weeding, DAS = Days after sowing.

to other treatments in both years of study. The highest weed dry weight was produced in weedy plots at the four periods of observations except at 21 DAS in 2018 where the dry weight was statistically on par with plots that were hoe weeded twice. All the ButaForce® rates with a supplementary hoe weeding had similar weed dry weight at all the sampling intervals. Though at 21DAS there were no significant differences between the supplementary hoe weeding and the recommended rates of ButaForce® at 3.0 L/ha at that period of sampling in both years, but all the herbicide plots that were supplemented with hoe weeding had lower weed dry weight than the recommended rates of ButaForce® at 3.0 L/ha.

Weed control efficiency

The effect of supplementary hoe weeding on the efficacy of ButaForce®on weed control efficiency of low land rice is shown in Table 7. The treatments differed significantly on weed control efficiency in both years of experimentation. Weed control efficiency was higher in plots that were hoe weeded weekly in all the sampling periods when compared to other treatments in both years of study. Weed control efficiency was lower in weedy plots throughout the sampling periods in both years of study except at 21 DAS where it was higher in plots with ButaForce® at 1.5 L/ha + SHW (21 DAS) and Hoe weeded at 21 and 42 DAS in 2018 and Hoe weeded at 21 and 42 DAS in 2019.

Rice performance

Plant height

The effect of supplementary hoe weeding on the efficacy of ButaForce® on plant height of low land rice is shown in Table 8. All the weed control treatments significantly ($P < 0.05$) affected rice height at the various sampling periods. Plants grown on weekly weeded plots grew taller than that of other treatments at 21, 42, 63 and 84 DAS. All the plots that received one supplementary hoe weeding at 21 DAS had identical plant heights in both years of study. Plots treated with ButaForce® at 3.0 L/ha at 21 DAS grew taller when compared to those plots that received one supplementary hoe weeding in both years. Plants in the weedy plots grew shorter throughout the sampling periods but it was at *par* with that of hoe weeded plots in both years of study at 21 DAS.

Leaf area index

Table 9 shows the effect of supplementary hoe weeding on the efficacy of ButaForce® on leaf area index of low land rice. The leaf area index differed significantly in all

Table 8. Effect of supplementary hoe weeding on the efficacy of ButaForce on plant height (cm) of lowland rice.

Treatment	21DAS	42 DAS	63DAS	84DAS
2018				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	21.17	40.09	53.81	62.39
ButaForce® at 2.0 L/ha + SHW (21 DAS)	22.12	42.03	54.71	62.55
ButaForce® at 2.5 L/ha + SHW (21 DAS)	24.23	43.30	55.19	65.89
ButaForce® at 3.0 L/ha	25.97	40.00	52.81	51.00
Weed free (weekly weeding)	27.37	52.83	65.00	70.21
Hoe weeded at 21 and 42 DAS	11.99	43.00	58.89	64.11
No weeding	11.33	23.00	38.72	46.00
LSD (P=0.05)	1.417	4.107	4.938	15.12
2019				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	25.31	41.8	55.14	59.23
ButaForce® at 2.0 L/ha + SHW (21 DAS)	25.33	43.8	55.71	59.53
ButaForce® at 2.5 L/ha + SHW (21 DAS)	25.59	46.2	56.19	60.22
ButaForce® at 3.0 L/ha	25.92	41.6	53.81	58.34
Weed free (weekly weeding)	27.75	51.8	68.33	69.20
Hoe weeded at 21 and 42 DAS	11.41	48.3	61.22	64.20
No weeding	11.38	35.4	40.06	44.87
LSD (P=0.05)	7.689	12.99	5.034	6.416

SHW = Supplementary hoe weeding, DAS = Days after sowing.

Table 9. Effect of supplementary hoe weeding on the efficacy of ButaForce® on leaf area index of lowland rice.

Treatment	21 DAS	42 DAS	63 DAS	84 DAS
2018				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	0.03	0.34	1.74	2.17
ButaForce® at 2.0 L/ha + SHW (21 DAS)	0.03	0.42	1.57	2.38
ButaForce® at 2.5 L/ha + SHW (21 DAS)	0.03	0.67	1.58	3.01
ButaForce® at 3.0 L/ha	0.04	0.62	0.63	0.95
Weed free (weekly weeding)	0.06	0.73	2.16	3.25
Hoe weeded at 21 and 42DAS	0.03	0.54	1.62	2.67
No weeding	0.03	0.21	0.67	1.01
LSD (P=0.05)	0.02	0.035	1.06	1.83
2019				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	0.02	0.29	0.69	1.15
ButaForce® at 2.0 L/ha + SHW (21 DAS)	0.03	0.31	0.91	1.28
ButaForce® at 2.5 L/ha + SHW (21 DAS)	0.04	0.43	1.08	1.47
ButaForce® at 3.0 L/ha	0.06	0.40	0.60	0.92
Weed free (weekly weeding)	0.06	0.52	1.2	1.62
Hoe weeded at 21 and 42 DAS	0.02	0.30	0.60	1.13
No weeding	0.01	0.18	0.48	0.33
LSD (P=0.05)	0.033	0.468	0.466	1.016

SHW = Supplementary hoe weeding, DAS = Days After Sowing.

the sampling periods in both years of study. Plots hoe weeded weekly consistently produced the greatest leaf area index at 21, 42, 63 and 84 DAS in both years of study. The lowest leaf area index was observed in

Table 10. Effect of supplementary hoe weeding on the efficacy of ButaForce® on number of tiller (no/plant).

Treatment	21 DAS	42 DAS	63 DAS	84 DAS
2018				
ButaForce® at 1.5 L/ha + SHW (21 DAS	0.47	4.67	18.00	23.00
ButaForce® at 2.0 L/ha + SHW (21 DAS	0.59	6.00	19.33	25.67
ButaForce® at 2.5 L/ha + SHW (21 DAS	0.83	6.67	21.00	27.67
ButaForce® at 3.0 L/ha	1.07	3.67	13.33	17.67
Weed free (weekly weeding)	1.1	7.67	23.00	30.00
Hoe weeded at 21 and 42 DAS	0.00	6.00	19.00	27.33
No weeding	0.00	1.67	8.67	13.00
LSD (P=0.05)	0.07	0.571	1.520	1.758
2019				
ButaForce® at 1.5 L/ha + SHW (21 DAS)	0.53	3.00	14.00	20.33
ButaForce® at 2.0 L/ha + SHW (21 DAS)	0.67	3.76	17.33	22.33
ButaForce® at 2.5 L/ha + SHW (21 DAS)	0.93	4.56	18.33	25.00
ButaForce® at 3.0 L/ha	1.20	3.34	12.67	16.00
Weed free (weekly weeding)	1.26	5.78	19.00	29.00
Hoe weeded at 21 and 42DAS	0.00	4.00	17.00	27.00
No weeding	0.00	1.75	6.00	11.00
LSD (P=0.05)	0.093	0.776	1.363	1.722

SHW = Supplementary hoe weeding, DAS = Days after sowing.

weedy plots. Although plots treated with ButaForce® at 3.0 L/ha tended to have the greatest leaf area index at 21 DAS but the leaf area index did not differed significantly from that plots that received supplemented one hoe weeding in 2018. While in 2019 plots treated with ButaForce® at 3.0 L/ha differ significantly from that of plots treated with ButaForce® at 1.5 L/ha with a supplementary hoe weeding (21 DAS) but statistically similar with that of ButaForce® at 2.0 L/ha + SHW (21DAS). In the 2018 cropping season, all the plots with one supplementary hoe weeding did not differ significantly from one another at all sampling intervals except at 42 DAS. However, in 2019 there were no significant differences among the supplementary hoe weeding throughout the sampling periods.

Number of tillers

Table 10 shows the effect of supplementary hoe weeding on the efficacy of ButaForce® on number of tillers on low land rice. There were significant differences in the number of tillers among the weed control treatments at the various intervals of sampling in both years of experimentation. The highest number of tillers was recorded in weekly weeding plots throughout the sampling intervals. The weedy plots had the lowest number of tillers at the various sampling intervals but at 21 DAS it has the same values on the number of tillers with plots that were hoe weeded twice in both sampling periods. At 21 DAS, plots that were treated at the recommended rates of ButaForce® at 3.0 L/ha had higher numbers of tillers that differed from those with supplemented hoe weeding plots.

Panicle length and panicle weight

Table 11 shows the effect of supplementary hoe weeding on the efficacy of ButaForce® on panicle length and panicle weight. There were significant differences among the weed control treatment on panicle length in both years of study. The weekly weeded plots had the longest length of panicle while the weedy plots had the shortest length in both years of study. Panicle length was longer in Plots treated with ButaForce® at 2.5 L/ha than the others supplementary hoe weeding Panicle weight was heavier in weekly weeding and lighter in weedy check. Plots treated with ButaForce® at 2.5 L/ha had a heavier weight of panicle than other plots that received one supplementary weeding.

Yield and weed index

Table 12 shows the effect of supplementary hoe weeding on the efficacy of ButaForce® on yield and weed index of low land rice. There were significant differences

Table 11. Effect of supplementary hoe weeding on the efficacy of ButaForce® on panicle length and panicle weight.

Treatment	Panicle length (cm)	Panicle weight (g/plant)
2018		
ButaForce® at1.5 L/ha + SHW (21 DAS)	22.00	8.00
ButaForce® at2.0 L/ha + SHW (21 DAS)	22.67	9.00
ButaForce®at 2.5 L/ha + SHW (21 DAS)	24.33	11.33
ButaForce® at 3.0 L/ha	19.00	6.67
Weed free (weekly weeding)	25.00	14.33
Hoe weeded at 21 and 42DAS	24.33	13.67
No weeding	10.33	5.33
LSD (P=0.05)	1.714	1.326
2019		
ButaForce® at1.5L/ha + SHW (21 DAS)	19.00	6.00
ButaForce® at2.0L/ha + SHW (21 DAS)	19.33	7.67
ButaForce® at2.5L/ha + SHW (21 DAS)	21.67	10.33
ButaForce® at 3.0L/ha	18.67	5.67
Weed free (weekly weeding)	23.33	11.33
Hoe weeded at 21 and 42 DAS	20.00	10.33
No weeding	8.00	3.33
LSD (P=0.05)	1.608	1.751

SHW = Supplementary hoe weeding, DAS = Days after sowing.

Table 12. Effect of supplementary hoe weeding on the efficacy of ButaForce® on paddy yield and weed index of lowland rice.

Treatment	Paddy yield (kg/ha)	Weed index (%)
2018		
ButaForce® at 1.5 L/ha + SHW (21 DAS)	2720	27.71
ButaForce® at 2.0 L/ha + SHW (21 DAS)	2740	27.18
ButaForce® at 2.5 L/ha + SHW (21 DAS)	2783	26.96
ButaForce® at 3.0 L/ha	2600	38.02
Weed free (weekly weeding)	2883	0.00
Hoe weeded at 21 and 42 DAS	2863	19.37
No weeding	502	86.67
LSD (P=0.05)	129.8	2.359
2019		
ButaForce® at 1.5L/ha + SHW (21 DAS)	2396.30	9.77
ButaForce® at 2.0L/ha + SHW (21 DAS)	2400.3	8.46
ButaForce® at 2.5L/ha + SHW (21 DAS)	2468.0	6.68
ButaForce® at 3.0 L/ha	2233.30	15.62
Weed free (weekly weeding)	2646.70	0.0
Hoe weeded at 21 and 42 DAS	2470.3	6.66
No weeding	425.00	83.94
LSD (P=0.05)	20. 48	1.377

SHW = Supplementary hoe weeding, DAS = Days After Sowing.

among the weed control treatments on paddy yield in both years. In 2018, the weekly weeded plots recorded significantly higher yields, which was comparable to the weeding twice plots and three supplementary hoe

Table 13. Economic evaluation of the different weed control treatments for the production of lowland rice.

Treatment	Cost of production (₦/ha)	Sale Revenue (₦/ha)	Profit (₦/ha)
2018			
ButaForce® at 1.5 L/ha + SHW (21 DAS)	271,222	1,088000	816,778
ButaForce® at 2.0 L/ha + SHW (21 DAS)	272,800	1,096000	823,200
ButaForce® at 2.5 L/ha + SHW (21 DAS)	274,378	1,113200	838,822
ButaForce at 3.0 L/ha	238,467	1,040000	801,533
Weed free (weekly weeding)	581,000	1,153200	572,200
Hoe weeded at 21 and 42 DAS	346,000	1,145200	799,200
No weeding	221,000	200,800	-20,200.
2019			
ButaForce® at 1.5 L/ha + SHW (21 DAS)	270,725	1,078335	807,610
ButaForce® at 2.0 L/ha + SHW (21 DAS)	272,300	1,080135	807,835
ButaForce® at 2.5 L/ha + SHW (21 DAS)	273,875	1,110600	836,725
ButaForce at 3.0 L/ha	238,465	1,004985	766,520
Weed free (weekly weeding)	581,000	1,191015	610,015
Hoe weeded at 21 and 42 DAS	346,000	1,111365	765,635
No weeding	221,000	191,250	-29750

SHW = Supplementary hoe weeding, DAS = Days After Sowing, calculation of sale revenue is based on N400/ kg in 2018 and 450/kg in 2019 at Choba market, Port Harcourt.

weedings at 21DAS while in 2019 it was comparable to hoe weeded plots at 21 and 42 DAS treated with ButaForce® at 2.0L/ha and 2.5 L/ha with one supplementary hoe weeding each, respectively.

Weed index differed significantly among the weed control treatments in both years. The highest weed index was recorded in weedy plots while the lowest was recorded in the weekly weeded plots. Weed index in 2018 cropping season in all the supplementary hoe weeded plots were comparable.

Economic assessment

The economic evaluation of the different weed control treatments for the production of lowland rice is presented in Table 13. The highest cost of production was recorded in plots that were manually hoe weeded weekly at 21 and 42 DAS in both years of study while the weedy plots had the lowest cost of production. Sale revenue was higher in plots weeded weekly and weeded twice at 21 and 42 DAS of both years while the lower revenue was produced in plots in the weedy check. The highest profit in both years of study was obtained in plots treated with ButaForce® at 2.5 L/ha with supplementary hoe weeding (21 DAS) while the weedy check had the lowest profit with negative values which signified no gain or loss.

DISCUSSION

The physiochemical characteristics of the soil before planting showed that the soil was sandy loam, slightly acidic with moderate organic carbon content, available P, exchangeable K, Mg, Ca and Na but was low in nitrogen content when compared to their critical levels (Ibedu et al., 1988). The low value of N obtained from the soil could be attributed to excessive rainfall, and leaching of nutrients and high temperature.

All the weed control treatment significantly reduced weed infestation judging from their lower weed density and weed dry weight when compared to weedy check probably due to their effectiveness in controlling weeds. Weed density and dry weight were low in weekly weeded plots as a result of the constant weekly hoe weeding. Unweeded plots had the highest weed density and weed dry weight probably because no treatment was applied to them. However, at 21 DAS, plots labeled as hoe weeded at 21 and 42 DAS were not weeded before collecting weed data as at that period, hence it was weedy as the no weeding plots. Among the plots that received supplementary hoe weeding, ButaForce® at 2.5 L/ha had the lowest weed density and dry weight than the others probably because it was applied at a higher rate. ButaForce® at 3.0 L/ha applied without supplementary hoe weeding could only have effective control of weeds at 21 DAS. As the rice growth stages progress there was a gradual decline of the herbicide rate in controlling weeds probably due to decrease of the herbicide concentration by gradual dissipation of the herbicide from the soil due to leaching. Although weed density and dry weight were reduced in all the plots that received supplementary hoe weeding, the reduction was more pronounced with ButaForce® at higher rates of 2.5L/.ha.

Imoloame (2017) reported similar findings that integration of herbicide rate with one supplementary hoe weeding provided better weed control in maize. Peer et al. (2013) also noted similar finding in other crops that herbicide supplemented with hoe weeding gave adequate weed control.

Generally, weed control efficiency was higher in weekly weeded plots when compared to other treatments probably as a result of constant weeding which made it free from weeds. The significantly higher plant height obtained in the weekly weeded plots could be attributed to efficient and effective weed control of the treatment. This is in line with Akbar et al. (2011) who reported taller plants in weed- free plots than in weedy plots. Leaf area index was higher in weekly weeded plots. High leaf area index indicates that the crop had a good canopy cover which shade out weeds from sunlight from penetrating the soil surface which could have stimulated weed growth. The weed - suppressing ability for other crops due to crop canopies has been reported by Busaari (1996) and Binang et al. (2016). The weedy plot had the lowest leaf area index which implies poor canopy formation which allows sunlight to penetrate the soil surface to stimulate rapid weed germination and weed growth. The highest tiller number and tiller dry weight was recorded in the weed -free plot while the lowest tiller number and tiller dry weight was recorded in the weedy plot. The number of tillers observed in the weekly weeded plots might be attributed to high weed control efficiency of the treatment as a result of reduced weed pressure.

Panicle length and panicle weight were longer and heavier in weekly weeded plots when compared to other treatments probably as a result of the weed-free condition of the plots. The rice plant was able to out-compete the weeds for available growth resources. The paddy yield was higher in weekly weeded plots probably as a result of no weed competition and higher leaf area index which produced good canopy closer for capturing sunlight for photosynthesis which promotes more yield. The high tillers produced from the weekly weeded plots also smothered the weeds giving the rice crop a competitive advantage. The weedy plots had the lowest paddy yield probably as a result of severe weed competition for water, carbon dioxide, sunlight, and space. Uncontrolled weed growth resulted to a paddy yield loss of 86.67 and 83.94% in 2018 and 2019 cropping seasons respectively. This result is in collaboration with that of Rodenburg and Johnson (2009) who reported 28- 89% yield loss in direct – seeded lowland rice due to uncontrolled weed growth. The yield variation observed in both years might be attributed to differences in rainfall. Rainfall was higher in 2018 than in 2019 and this could be the probable reason for the higher yield recorded in 2018 than in 2019.

The differences observed in the sale revenue of the various weed control treatments could be attributed to differences in yield. Although plots hoe weeded weekly and weeding twice had the highest sale revenue, their cost of production was higher than others probably as a result of expensive labour involved due to scarcity during the time of the weed control. This finding is in line with that of Adigun and Lagoke (2003) who noted that the cost of hoe weeding is expensive. The highest profit was obtained in plots treated with 2.5 L/ha +SHW, followed by 2.0 L/ha + SHW and ButaForce® at 1.5 L/ha + SHW, and ButaForce® at 3.0 L/ha without supplementary hoe weeding in both years of study probably because their cost of production was lower than that of hoe weeded plots. Imoloame (2009) also observed a similar finding that herbicide use in most crops production is more profitable than manual hoe weeding.

Conclusion

Weekly weeding plots had the lowest weed index and highest weed control efficiency. The performance of lowland rice was better in weed-free plots than other treatments. Weed suppressive ability was better in plots treated with ButaForce® at 2.5 L/ha with supplementary hoe weeding than other supplementary hoe weeding in both years; judging from it high weed control efficiency and lower weed index. SHW enhanced the yield in plots treated with ButaForce® rate lower than the recommended rate of 3.0 L/ha with about a 6% yield advantage and a 3.0% profit margin in 2018 while in 2019 they had 8.43% yield advantage and a 6.63% profit margin. Since ButaForce® at 2.5 L/ha with supplementary hoe weeding had the highest profit, it is therefore recommended to rice farmers in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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