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Original Research Article

Weed control and productivity of maize (*Zea mays* L.) in Malete, Kwara State of Nigeria

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Abstract

The need to determine the minimum application rates of commonly used herbicides in Malete and the Guinea savanna of Nigeria for effective weed control and higher grain yield of maize, triggered this study. Therefore, field trials were conducted at the Teaching and Research Farm of Kwara State University, Malete, to determine the weed control method that will be more effective in controlling weeds and give higher grain yield and cash returns in the production of maize. The experiment consisted of 9 treatments viz: primextra (metolachlor plus atrazine) + 2,4-D at 1.5 + 1.5 kg active ingredient (a.i.).ha^{-1}, primextra + 2,4-D at 2.0 + 2.0 kg a.i. ha^{-1}, primextra + 2,4-D at 2.5 + 2.5 kg ha^{-1}, primextra + nicosulfuron at 1.5 + 0.03 kg a.i. ha^{-1}, primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1}, primextra + niconsulfuron at 2.5 + 0.07 kg a.i. ha^{-1}, primextra at 1.5 kg a.i. ha^{-1} + one Supplementary Hoe Weeding (SHW) at 6 Weeks After Sowing (WAS), two hand weeding at 3 and 6 Weeks After Sowing (WAS) and a weedy check. These treatments were laid out in randomised complete block design (RCBD) with three replicates. Data collected were subjected to analysis of variance using Statistical Analysis Software (SAS) package, after which means were separated using Duncan's Multiple Range Test (DMRT). Results showed that treatment combinations of primextra + one SHW at 6 WAS, two hoe weeding at 3 and 6 WAS, primextra + 2,4-D at 2.0 + 2.0 kg a.i. ha^{-1} and primextra + nicosulfuron at 2.0+0.05 kg a.i. ha^{-1} gave effective weed control, higher grain yield and cash returns. Therefore, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, primextra +2,4-D at 2.0 + 2.0 kg a.i. ha^{-1} and primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1} are recommended to farmers as alternative to two hoe weeding at 3 and 6 WAS.

Keywords: integrated weed management; southern Guinea savanna; maize; yield; cash returns

INTRODUCTION

Maize (*Zea mays* L.) was cultivated previously on a subsistence scale in Africa. However, it has gradually become an important commercial crop and serves as raw material for many agro-allied industries (Iken and Amusa, 2004). Ogunsami et al. (2005) reported that growing maize by small-scale farmers can overcome hunger in the households and the aggregate effect could double food production in Africa.

The demand for maize is high and this creates opportunity to increase production per unit area. Anonymous (2018) reported that 1,147,689,084 tonnes of maize were produced worldwide in 2018, while FAO (2018) reported that Nigeria produced 10,155,027 tonnes in 2018. According to Anonymous (2017), the average production of maize in Africa is very low and stagnates at around 2 t ha^{-1} / year and except something is done to change this situation, Africa will have the world's largest net deficit in cereals in the near future (Mwangi,1995).

Among the factors attributed to the difference between potential and actual yields of maize in Africa, is weed infestation. Maize is highly sensitive to weed competition especially at the early stages of development (Hall et al., 1992). Weeds do not only cause severe yield losses, but also require farmers and families to spend more of their time on weeding. Manual weed control remains the predominant method of weed control by small-holder framers in Africa (Chikoye et al., 2002). Past research works have revealed that two hoe weeding at 3 and 6 WAS resulted in effective weed control and higher maize yields (Imoloame and Omolaiye, 2016; Imoloame 2017). Despite the advantages of this method, it is time-consuming, laborious and expensive per hectare. It is reported that weeding one hectare of land planted with maize may require as much as 25–40 man days, representing approximately 50–80% of labour budget (Darkwa et al., 2001; Chikoye et al., 2002). This is buttressed by the findings of Ekeleme (2009) that

25–55% of the total cost of production is spent on labour and weeding operations.

Chemical weed control has been reported to be a better alternative to manual weeding despite criticism that it leaves toxic residues in the environment. This is because it is cheaper, faster, minimizes drudgery, gives better control of weeds and increases biological yield of crops (Chikoye et al., 2004; Ali et al., 2003; Haider et al., 2009). However, this weed control method is being used indiscriminately by Nigeria farmers as most of them are illiterates and there is lack of information on the correct doses of herbicides to apply. These problems have the potential of causing environmental pollution, herbicide resistant weeds, herbicide residue in crops and health hazards (Best-Ordinioha, 2017). The manufacturers' recommendations for the herbicides used in this study are: 2.0–2.5 kg active ingredient (a.i.) ha^{-1} for primextra, 0.04–0.6 kg a.i. ha^{-1} for nicosulfuron, 1.0 kg a.i. ha^{-1} for paraquat and 2.0–3.0 kg a.i. ha^{-1} for 2,4-D. It is therefore important to come up with the correct minimum herbicide rates of the common herbicides applied in maize in Malete.

An integration strategy that combines low doses of herbicide and hand hoeing will not only cut down the herbicide dose used, but it has been found to be environmentally friendly, more effective and efficient for weed control compared with the use of one single method (Kardil and Kordy, 2013; Imoloame, 2017; Imoloame and Ahmed 2018). There is dearth of information that compares the performance of herbicide at low dose integrated with one SHW at 6 WAS with the application of a combination of pre and post emergence herbicides for weed control in maize. This is very important as the outcome of the study may provide information on the minimum application rates of the commonly used herbicides and better weed management options that can serve as alternative to hoe weeding for more effective and profitable weed control in maize in Malete and southern Guinea savanna of Nigeria. The hypothesis of this study is that pre-emergence application of a combination of low dose of herbicides plus one SHW at 6 WAS will provide most effective and season-long weed control, higher grain yield and cash returns in the production of maize. Therefore the objectives of this study are to determine:

1. the weed management strategy that will be more effective for weed control and that will increase maize grain yield.
2. the weed management strategy that will be more profitable in the production of maize.

MATERIALS AND METHODS

Site Description

The experiment was conducted during the 2017 and 2018 cropping seasons at the Kwara State University Teaching and Research (T & R) Farm, Malete (Lat.08°71′N; Long.04°44′E), Kwara state, in a southern Guinea savanna ecological zone of Nigeria. The experimental site was characterised by two peaks of rainfall, June and August 2017, and May and September 2018, and the soil was sandy loam with low water retaining capacity.

Treatment and Experimental Design

The experiment consisted of 9 treatments viz: Primextra +2,4-D at 1.5 + 1.5 kg a.i. ha^{-1}, primextra + 2,4-D at 2.0 + 2.0 kg a.i. ha^{-1}, primextra+ 2,4-D at 2.5 + 2.5 kg ha^{-1}, primextra + nicosulfuron at 1.5 + 0.03 kg a.i. ha^{-1}, primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1}, primextra + niconsulfuron at 2.5 + 0.07 kg a.i. ha^{-1}, primextra at 1.5 kg a.i. ha^{-1} + one Supplementary Hoe Weeding (SHW) at 6 Weeks After Sowing (WAS), two hand weeding at 3 and 6 WAS and a weedy check. These treatments were laid out in randomised complete block design (RCBD) with three replicates. Data collected were analysed using Statistical Analysis Software (SAS) package. Means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

The site was ploughed, harrowed and later demarcated into plots measuring 4 m×4 m each. Three treated seeds of maize variety SUWAN-1-SR were sown per hole spaced at 75 cm×25 cm, on the 14th and 11th of July, 2017 and 2018, respectively. The seedlings that emerged were thinned to one plant/stand to give a plant population of 53,333 per hectare. The SUWAN-1-SR variety grows to medium height and attain maturity within 110–120 days. Its leaves are of medium size. The application of pre-emergence herbicide was done a day after sowing, while that of post-emergence herbicides were carried out at 6 WAS. The sprayer used for herbicide application was calibrated to deliver 208 l ha^{-1} of herbicide solution. Fertilizer was applied in two split doses, one at planting and the other 6 WAS at the rate of 120 kg N, 60 kg P and 60 kg K.

The insecticide 'Strong Force' containing Methomyl 90% as active ingredient was applied to control the armyworm (*Spodoptera exempta*) at the rate of 10 g/15 litres of water. Harvesting of maize was done on November, 13th and 12th of November 2017 and 2018, respectively.

The following parameters were measured:

Weed dry matter (g m^{-2})

Weed dry matter was determined by harvesting weeds from one square meter quadrat, randomly placed in three locations within each plot. The weeds were put in well labelled envelopes which were later oven-dried at a temperature of 80 °C for 2 days to a constant weight before the final weights were taken. The weed dry matter was taken at 6 and 12 WAS.

Weed cover score

Weed cover score was determined 6 and 12 WAS by visual observation using a scale of 0–9, where 0 means weed free plots and 9 complete weed cover of plots.

Weed Density (no m^{-2})

Weed density was determined at 6 and 12 WAS by counting the number of weed species within a 1 m^2, randomly placed in three locations within each plot and the total number of weed species per unit area was recorded.

Shannon Weiner Index of Species Diversity Index H' of Weed Species

This is a mathematical measure of species diversity in a given community and it is based on the species richness (the number of species present) and species abundance (the number of individuals per species. It is calculated using the formula below:

$$\text{Shannon Weiner Diversity Index } H' = \sum_{n}^{s} = 1 Pi \text{ In } Pi$$

Pi...... Proportion of (ni/N) and it is the number of individuals of one particular species (n) divided by the total number of all individuals in the sample (N).
S .... The total number of species found in the community
In ..... Naparian log (2.303 × $\log_{10}$)

Leaf Area (cm^{-2})

Leaf area of maize was determined at 6 and 12 WAS by using the expression. Leaf area (LA) = Length (L) × breadth (B) × 0.75. The leaf area was obtained by measuring the length and breadth of leaves from five randomly selected plants from each plot and the average of these measurements was multiplied by a factor 0.75 to give the leaf area per plant.

Grain Yield (kg ha^{-1})

Grain yield was determined by weighing the grains harvested from each net plot and was converted to kilogram per hectare using the equation below:

$$\text{Grain Yield} = \frac{\text{Grain yield per net plot} \times 10{,}000\ \text{m}^2}{\text{Net plot size (m}^2\text{)}}$$

Economic Analysis

Information on the cost of all the cultural practices from land preparation to harvesting and processing was collected from Kwara State Agricultural Development Programme (KWASADP), Ilorin, an agency responsible for extension services in Kwara State, Nigeria. The average price of 1 kg of maize in 2018 was obtained from the open market to calculate the income/revenue. The economic assessment was done for different treatments to determine the most cost-effective or profitable method of weed management for the production of maize.

The economic analysis was carried out using partial budgeting (Okoruwa et al., 2005) to calculate the gross margin (profit). Benefit: cost ratio was also determined as follows:

$$GM = TR - VC$$

$$TR = (Ys \times Ps)$$

$$VC = M + L$$

Where:
GM Gross margin/ ha for each Treatment
TR.... Total revenue (Naira / United States Dollars (USD) for each Treatment
VC.... Variable cost (Naira / USD) for each Treatment
Ys..... maize grain yield (kg/ ha) for each Treatment
Ps ..... Price of maize per kg
M ..... Value of material input (seeds, fertiliser, insecticide, herbicides etc.)
L....... Value of Labour (land preparation, planting, insecticide and herbicide, fertiliser application, harvesting, processing and packaging).

Also, the benefit-cost ratio was determined using the following equation:

$$\text{Cost benefit ratio} = \frac{I}{TCP}$$

where TCP is total cost of production and I is income.

RESULTS AND DISCUSSION

Rainfall Figures

Total rainfall figures of 1014.8 and 1451.1 mm were recorded in 2017 and 2018, respectively. The two peaks of rainfall occurred in June and August in 2017, while in 2018, the two peaks occurred in May and September (Fig 1).

Effect of Weed Control Treatments on weed Dry Matter and Weed Cover Score

Weed control treatments had a significant ($P < 0.05$) effect on weed dry matter in 2017 and 2018 in Malete (Table 1). In 2017, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6WAS and primextra + nicosulfuron at 1.5 + 0.03 kg a.i. ha^{-1} resulted in weed dry matter that was significantly ($P < 0.05$) lower than weedy check, but was comparable with other herbicide treatments and two hoe weeding at 3 and 6 WAS, while in 2018, all the treatment combinations significantly ($P < 0.05$) reduced weed dry matter compared to the weedy check at 6 WAS. At 12 WAS, in 2017, plots treated with primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, two hoe weeding at 3 and 6 WAS and primextra + nicosulfuron at lower rates had weed dry matter significantly ($P < 0.05$) lower than weedy

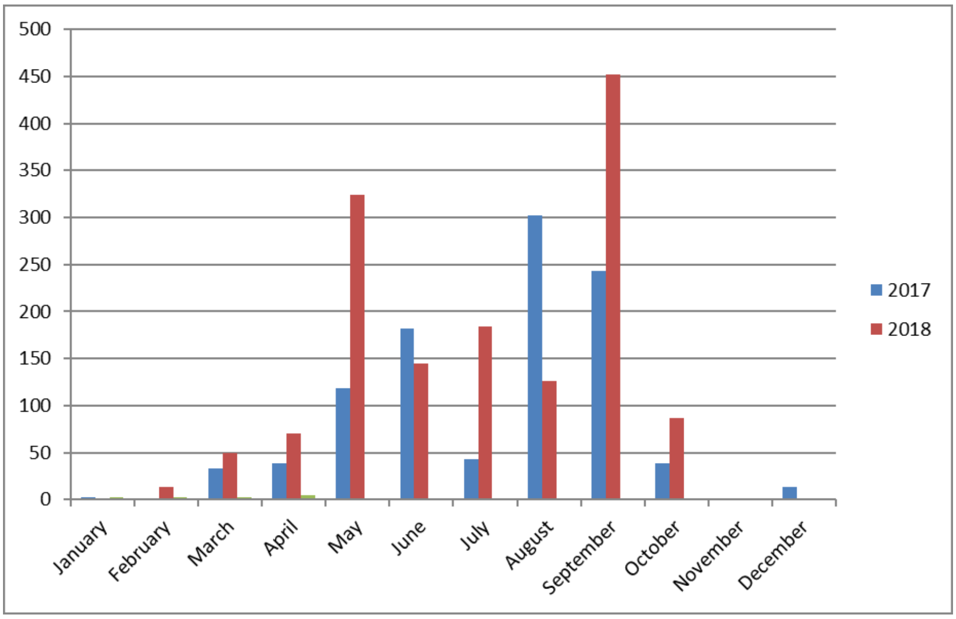

Figure 1. Rainfall figures for 2017 and 2018 Rainy Seasons (mm)
Source: Lower Niger River Basic and Rural Development Authority, Hydrology Section, Ilorin, Kwara State.

Table 1. Effect of weed control methods on weed dry matter in maize 2017 and 2018

		Weedy Dry Matter (g m^{-2})			
		6 WAS		12 WAS	
Treatment	Rate (kg ha^{-1})	2017	2018	2017	2018
P+2,4-D	1.5 + 1.5	75.3^{ab1}	293.8^{b}	79.8^{ab}	2519.7^{a}
P+2,4-D	2.0 + 2.0	91.4^{ab}	367.1^{b}	94.7^{ab}	1458.9^{bc}
P+2,4-D	2.5 + 2.5	159.4^{ab}	362.0^{b}	173.6^{ab}	1027.7^{bc}
P+N	1.5 + 0.03	58.0^{b}	445.3^{b}	59.1^{b}	1572.9^{bc}
P+N	2.0 + 0.05	60.1^{ab}	347.1^{b}	68.3^{b}	1060.7^{bc}
P+N	2.5 + 0.07	88.8^{ab}	238.7^{b}	91.4^{ab}	1745.8^{ab}
P+ 1SHW	1.5	44.0^{b}	382.3^{b}	53.8^{b}	505.8^{bc}
3 & 6 WAS	-	62.5^{ab}	123.4^{b}	70.4^{b}	340.2^{c}
Weedy Check	-	195.5^{a}	976.5^{a}	214.6^{a}	2518.6^{a}

WAS = Weeks after Sowing
1 = Means having the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).
P = Primextra; N = Nicosulfuron; SHW = Supplementary hoe weeding

check but was not statistically different from other herbicide treatments, whereas in 2018, hoe weeding at 3 and 6 WAS provided effective weed control by significantly ($P < 0.05$) reducing weed dry matter compared to the weedy check, but was comparable to other treatments except primextra + 2,4-D at 1.5 + 1.5 kg a.i. ha^{-1} and primextra + nicosulfuron at 2.5 + 0.07 kg a.i. ha^{-1} which gave significantly ($P < 0.05$) higher weed dry matter comparable to weedy check. The same trend was observed regarding weed cover score as all herbicide treatments, two hoe weedings at 3 and 6 WAS and primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS caused significant ($P < 0.05$) reduction in weed cover in comparison with weedy check in 2017 (Table 2), while in 2018, it was only hoe weeding at 3 and 6 WAS that had a significant ($P < 0.05$) and positive control of weed cover at 6 WAS. At 12 WAS, in 2017, all the herbicide treatments, hoe weeding at 3 and 6 WAS and primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS sustained a significant ($P < 0.05$) reduction in weed cover than the weedy check, however in 2018, all the treatment combinations except primextra +2,4-D at 2.5 + 2.5 and primextra at 2.5 + 0.07 kg a.i. ha^{-1}, provided a better weed control as they significantly ($P < 0.05$) reduced weed cover than the weedy check (Table 2). The treatment combinations of primextra at 1.5 + one SHW at 6 WAS, primextra + nicosulfuron at 1.5 + 0.03, primextra + nicosulfuron at 1.5 + 0.05 kg a.i. ha^{-1} and two hand weeding at 3 and 6 WAS in descending order of effectiveness, provided better and more effective

Table 2. Effect of weed control methods on weed cover score in maize, 2017 and 2018

		Weedy cover score			
		6 WAS		12 WAS	
Treatment	**Rate (kg ha^{-1})**	**2017**	**2018**	**2017**	**2018**
P+2,4-D	1.5 + 1.5	4.3^{b1}	7.0^{a}	4.0^{b}	6.2^{b}
P+2,4-D	2.0 + 2.0	4.3^{b}	7.7^{a}	4.3^{b}	4.2^{bc}
P+2,4-D	2.5 + 2.5	5.7^{b}	7.7^{a}	5.0^{b}	7.5^{ab}
P+N	1.5 + 0.03	2.7^{b}	8.3^{a}	3.5^{b}	6.0^{b}
P+N	2.0 + 0.05	3.0^{b}	7.7^{a}	3.3^{b}	6.3^{b}
P+N	2.5 + 0.07	5.7^{b}	8.7^{a}	4.3^{b}	6.8^{ab}
P+ 1SHW	1.5	4.7^{b}	8.0^{a}	5.7^{b}	1.8^{c}
3 & 6 WAS	-	5.0^{b}	2.7^{b}	5.7^{b}	1.2^{c}
Weedy Check	-	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}

WAS = Weeks After Sowing; 1-Means having the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).
P = Primextra; N = Nicosulfuron; SHW = Supplementary hoe weeding

Table 3. Shannon Weiner diversity index H^1 of weed species at 12 WAS in maize, 2018

Species	**Weed form**	**P+2,4-D 1.5+1.5**	**P+2,4-D 2.0+ 2.0**	**P+2,4-D 2.5 +2.5**	**P+N at 1.5+0.03**	**P+N at 2.0+0.05**	**P+N at 2.5+0.07**	**3 & 6 WAS**	**P at 1.5 + ISHW**	**Weedy check**
Brachiaria alata	G	18	3	-	-	7	-	-	1	4
Paspalum scrobiculatum	G	59	64	62	76	12	158	33	123	102
Cyperus esculentus	G	-	-	-	-	-	-	1	-	-
Commelina benghalensis	BL	3	-	-	-	3	-	-	2	8
Pycreus lanceolatus	BL	-	-	-	-	-	-	31	15	33
Rottboellia cochinchinensis	G	33	28	-	2	4	-	-	1	-
Digitaria horizontalis	G	65	108	117	85	60	55	6	8	91
Hyptis suaveolens	BL	-	-	4	1	4	-	-	1	-
Gomphrena celosiodes	BL	-	-	-	-	-	-	-	-	-
Grass (unidentified)	G	-	-	-	-	-	-	-	-	-
Dactyloctenium aegyptium	G	-	-	-	-	-	5	-	2	2
Broad leaf (unidentified)	BL	-	-	-	-	-	-	-	1	-
Chloris pilosa	G	-	-	-	-	-	-	-	1	-
Cyperus rotundus	S	-	-	-	-	-	-	-	3	-
Kyllinga squamulata	S	-	-	-	-	-	-	1	11	-
Kyllinga erecta	S	-	-	-	-	-	-	21	-	
Setaria barbata	G	-	-	-	-	-	-	-	8	
Shannon Weiner Index H'		1.3	1.8	0.762	0.6	1.1	0.7	1.3	1.1	

G = Grass. BL = Broadleaved S = Sedges

weed control than other treatments in maize plots. These weed control methods can be applied in rotation in maize fields for weed control. Imoloame (2014), reported that two hand weedings at 3 and 6 WAS and a combination of herbicide plus hand weeding at 6 WAS significantly reduced weed infestation in soybean production. The rotation of the above methods of weed control will help to minimize the chances of herbicide resistant weeds or weed flora shift. The higher amount of weed biomass observed in 2018 compared to 2017 could be due to the higher amount of rainfall in that year.

Diversity Index (H^1) of Weeds under Different Treatments

Table 3 shows that a total of 16 weed species were observed across treatments. This number is broken down into 9 grass, 5 broadleaved and 2 sedge weed species. It also shows the diversity index (H^1) of weed species under different treatments. The weed flora diversity (1.8) was highest in plots with primextra +2,4-D at 2.0 + 2.0 kg a.i. ha^{-1}, while the lowest diversity was (0.6) in plots treated with primextra + nicosulfuron at 2.0 + 0.03 kg/ha. The Shannon-Weiner diversity index (H^1) ranged from 0 to 4.6. A value near 0 indicates

Table 4. Effect of Weed Control Methods on Leaf Area in maize, 2017 and 2018

Treatment	Rate (kg ha^{-1})	Leaf area (cm^2) 6 WAS[1]		12 WAS	
		2017	2018	2017	2018
P+2,4-D	1.5 + 1.5	139.3^{a1}	255.1^{b}	152.7^{a}	351.3^{abc}
P+2,4-D	2.0 + 2.0	117.0^{abc}	288.3^{ab}	138.1^{a}	386.6^{ab}
P+2,4-D	2.5 + 2.5	112.9^{abc}	278.3^{ab}	105.4^{bc}	334.8^{bc}
P+N	1.5 + 0.03	129.3^{ab}	287.9^{ab}	132.2^{ab}	352.4^{abc}
P+N	2.0 + 0.05	81.3^{c}	318.0^{a}	108.0^{bc}	392.8^{ab}
P+N	2.5 + 0.07	88.1^{c}	274.6^{ab}	102.4^{bc}	325.0^{c}
P+ 1SHW	1.5	127.9^{ab}	295.0^{ab}	141.6^{a}	380.7^{abc}
3 & 6 WAS	-	109.9^{abc}	307.1^{a}	123.4^{ab}	398.4^{a}
Weedy Check	-	91.5^{c}	273.4^{ab}	90.3^{c}	333.3^{bc}

WAS = Weeks after Sowing; 1 = Means having the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).
P = Primextra; N = Nicosulfuron; SHW = Supplementary hoe weeding

Table 5. Effect of weed control methods on 100 seed weight and grain yield in maize, 2017 and 2018

Treatment	Rate (kg ha^{-1})	100 seed weight (g) 2017	100 seed weight (g) 2018	Grain yield kg ha^{-1} 2017	Grain yield kg ha^{-1} 2018
P+2,4-D	1.5 + 1.5	19.8^{a}	21.5^{a}	736.5^{ab}	1527.2^{b}
P+2,4-D	2.0 + 2.0	18.4^{a}	21.2^{a}	433.9^{ab}	3122.5^{a}
P+2,4-D	2.5 + 2.5	17.4^{a}	19.5^{a}	871.0^{ab}	1834.5^{ab}
P+N	1.5 + 0.03	20.9^{a}	19.9^{a}	1038.2^{ab}	2491.3^{ab}
P+N	2.0 + 0.05	20.0^{a}	21.5^{a}	1160.4^{a}	2793.4^{ab}
P+N	2.5 + 0.07	19.9^{a}	20.3^{a}	977.8^{ab}	2401.7^{ab}
P+ 1SHW	1.5	19.6^{a}	20.0^{a}	1416.2^{a}	2878.7^{a}
3 & 6 WAS	-	21.0^{a}	19.3^{a}	1317.8^{a}	3140.9^{a}
Weedy Check	-	16.6^{a}	20.5^{a}	331.1^{b}	1444.5^{b}

1-Means having the same letter(s) are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).
P = Primextra; N = Nicosulfuron; SHW = Supplementary hoe weeding

that every species in the sample is the same, while a value near 4.6 would indicate that the numbers of individuals are evenly distributed between all the species (Husnatulyusra, 2012). Therefore the Shannon-Weiner diversity index (H^1) recorded ranging from 0.6–1.8 under each treatment indicates that the individual number of weeds species present is not evenly distributed since H^1 is near 0. The low Shannon-Weiner diversity index value (close to 0) of the weed species present under each treatment, explains the dominance of *Paspalum scrobiculatum* across treatments and *Digitaria horizontalis* in the plots treated with primextra + 2,4-D and primextra + nicosulfuron at all rates. The dominance of *Paspalum scrobiculatum* across treatments suggests the ineffectiveness of the various weed options to control this species throughout the season and it is an indication of weed's ability to easily adapt to the environment. The prevalence of the two grass weed species mentioned above in the plots treated with primextra +24-D at all the rates was expected, as the post-emergence herbicide has narrow spectrum of activity for the effective control of only broadleaved and not grass weeds. This result is similar to the findings of Imoloame (2017) who reported the inability of tank mixture of metolachlor + atrazine and pendimethaline + atrazine at 1.0 + 2.0 kg a.i. ha^{-1} plus one SHW at 6 WAS to fully control *Paspalium scrobiculatum*. This information is very useful as it will help in formulation of a better weed strategy for its effective control.

Effect of Weed Control Treatments on Leaf Area

In 2017 and at 6 WAS, plots treated with primextra + 2,4-D at 1.5 + 1.5 kg ha^{-1}, primextra + 2,4-D at 2.0 + 2.0 kg a.i. ha^{-1}, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, primextra + nicosulfuron at 1.5 + 0.03 kg a.i. ha^{-1} and two hand weedings, produced significantly ($P < 0.05$) larger leaves than the weedy check and primextra + nicosulfuron at higher rates. At 12 WAS, in 2017, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS and primextra + 2, 4-D at 1.5 + 1.5 kg a.i. ha^{-1}, as well as primextra + 2, 4-D at 2.0+2.0 kg a.i. ha^{-1} resulted in crops with significantly ($P < 0.05$) larger leaves which were statistically not different from two hand weeding at 3 and 6 WAS and primextra + nicosulfuron at 1.5 + 0.03 kg a.i. ha^{-1} but significantly larger than maize leaves in other treatments and the weedy check. However, in 2018 and at 6 WAS, two hoe weedings at 3 and 6 WAS and primextra + nicosulfuron at 2.5 + 0.05 kg a.i. ha^{-1} gave rise to crops with leaf area that was comparable with other treatment combinations, but significantly ($P < 0.05$) greater than the weedy check.

Table 6. Profitability of Different Weed Control Methods in the Production of Maize in Malete in Naira (₦) and US Dollars ($), 2017 and 2018

Farm Operations/ Hectare	P+2,4-D 1.5+1.5	P+2,4-D 2.0+ 2.0	P+2,4-D 2.5 +2.5	P+N at 1.5+0.03	P+N at 2.0+0.05	P+N at 2.5+0.07	3 & 6 WAS	P at 1.5 + ISHW	Weedy check
Land Preparation	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00
	(50.00)	(50.00)	(50.00)	(50.00)	(50.00)	(50.00)	(50.00)	(50.00)	(50.00)
Seeds	4,200.00	4,200.00	4,200.00	4,200.00	4,200.00	4,200.00	4,200.00	4,200.00	4,200.00
	(11.00)	(11.00)	(11.00)	(11.00)	(11.00)	(11.00)	(11.00)	(11.00)	(11.00)
Planting	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00
	(16.70)	(16.70)	(16.70)	(16.70)	(16.70)	(16.70)	(16.70)	(16.70)	(16.70)
Fertiliser Application	9,000.00	9,000.00	9,000.00	9,000.00	9,000.00	9,000.00	9,000.00	9,000.00	9,000.00
	(25.00)	(25.00)	(25.00)	(25.00)	(25.00)	(25.00)	(25.00)	(25.00)	(25.00)
Cost of Fertiliser (NPK and Urea)	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00
	(209.00)	(209.00)	(209.00)	(209.00)	(209.00)	(209.00)	(209.00)	(209.00)	(209.00)
Cost of First hoe Weeding	-	-	-	-	-	-	10,000.00	10,000.00	-
							(27.78)	(27.78)	
Cost of second hoe weeding	-	-	-	-	-	-	10,000.00	-	-
							(27.78)		
Cost of herbicide application (Pre & Post-emergence)	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	4,000.00	-
	(22.00)	(22.00)	(22.00)	(22.00)	(22.00)	(22.00)	(22.00)	(11.00)	
Cost of herbicide	13,500.00	17,940.00	22,560.00	10,800.00	15,000.00	19,200.00	-	9,000.000	-
	(37.50)	(49.83)	(62.67)	(30.00)	(41.67)	(53.33)	-	(25.00)	-
Cost of insecticide application	3,300.00	3,300.00	3,300.00	3,300.00	3,300.00	3,300.00	3,300.00	3,300.00	3,300.00
	(9.20)	(9.20)	(9.20)	(9.20)	(9.20)	(9.20)	(9.20)	(9.20)	(9.20)
Cost of insecticide	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00	8,000.00
	(22,20)	(22,20)	(22,20)	(22,20)	(22,20)	(22,20)	(22,20)	(22,20)	(22,20)
labour cost for harvesting, processing and bagging	11,601.00	17,655.00	12,175.00	15,888.30	17,792.00	15,208.00	19,327.50	20.000.00	8,362.800
	(32.23)	(49.04)	(38.81)	(44.10)	(49.42)	(42.24)	(53.69)	(55.60)	(23.23)
Total cost of Production (VC)	156,601.00	167,900.0	166,235.00	158,188.30	164,292.00	165,908.00	170,827.50	166,500.00	131,862.00
	(435.00)	(437.80)	(461.76)	(439.40)	(456.37)	(474.20)	(474.52)	(462.50)	(366.28)
Average Yield/ha	1,289.00	1929.5	1352.8	1,764.8	1,976.9	1,689.8	2,147.5	2,229.1	929.2
Selling price (TR)	154,680.00	231,540.00	162,336.00	211,776.00	237,228.00	202,776.00	257,700.00	267,492.00	111,504.00
	(429.66)	(643.12)	(450.93)	(588.27)	(658.0)	(563,26)	(715.83)	(743.03)	(309.73)
Profit (GM)	-1,921.00	63,640.00	-3,899.00	53,587.70	72,936.00	36868.00	86,872.50	100,992.00	-20,358.00
	(-5.33)	(176.78)	(-10.83)	(148.85)	(202.60)	(102.11)	(241.31)	(280.53)	(-56.55)
Benefit: Cost ratio	0.987	1.379	0.976	1.339	1.444	1.00	1.509	1.607	0.8456

1. Average price of maize in the open market in 2018=₦120/kg.
2. Price in parentheses are in United States dollars (USD $), while the ones not in parentheses are in naira (₦)
3. Exchange rate of Naira to Dollars = ₦ 1 = USD 360
Cost of herbicide application (Pre & Post-emergence), Cost of herbicide should be removed from weedy check. It should be half for herbicides and ISHW
Processing and bagging should not be same but be based on quantity (ie per kg) and this will reduce cost for weedy plot
Post-emergence and dose used were varied and the price cannot be same particularly the dose

In the same year and at 12 WAS, the greatest leaf area was detected in the treatment with two hand weedings which was comparable with other treatments but was significantly greater than primextra + 2,4-D at 2.5 + 2.5 and primextra + nicosulfuron at 2,5 + 0.07 kg a.i. ha^{-1}. The larger leaf area of maize in the plots treated with Primextra + 2,4-D at 1.5 + 1.5 kg a.i. ha^{-1}, primextra + 2,4-D at 2.0 + 2.0 kg a.i. ha^{-1}, primextra + nicosulfuron at 1.5 + 0.03 and at 2.0 + 0.05 kg a.i. ha^{-1}, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS and two hand weedings provided a larger surface for the interception of a greater amount of light for increased photosynthesis and higher yields.

Effect of Weed Control Treatments on Yield and Yield Components

Primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, two hand weeding at 3 and 6 WAS and primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1} in 2017 produced the highest maize grain yields which were not statistically different from other herbicide treatments but were significantly ($P < 0.05$) different from weedy check (Table 5). Similar trend was observed in 2018, as, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, two hand weeding at 3 and 6 WAS, and primextra + 2, 4 – D at 2.0 + 2.0 kg a.i. ha^{-1} resulted in grain yield values significantly ($P < 0.05$) higher than weedy check, but were not statistically different from other herbicide combinations except primextra + 2,4-D at 1.5 + 1.5 kg a.i. ha^{-1} which produced significantly ($P < 0.05$) lower grain yield comparable with the weedy check. The significantly higher grain yields produced from the plots treated with the above weed control methods were as a result of their consistency in providing season-long weed control, which could have increased the amount of growth resources available to maize which in turn produced significantly larger leaves for enhanced photosynthesis and grain yield. These treatment combinations can serve as alternative to hoe weeding which could be applied in rotation for effective control of weeds and higher grain yields in maize. The weedy check produced significantly ($P < 0.05$) lower yield as a result of the intense competition between the maize crop and the weeds particularly, *Paspalum scrobiculatum* and *Digitaria horizontalis.*

Economic Evaluation of Different Weed Control Methods in Maize Production

Highest revenues (₦ 267,492.00 / $ 743.03), (₦ 257,700.00 / $ 715.83) and (₦ 237,228.00 / $ 658.00) were obtained from plots treated with primextra at 1.5 kg a.i. ha^{-1} + one SHW, followed by two hand weeding at 3 and 6 WAS and primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1}, while weedy check resulted in lowest revenue (₦ 111,504.00 / $ 309.73) (Table 6). Plots that gave higher revenues produced higher yields of maize. The most expensive weed control method (₦ 170,827.50 / $ 474.52) was two hoe weedings at 3 and 6 WAS, while lowest cost (₦ 131,862.00 / $ 366.28) was incurred under the weedy check. This is in line with the findings of Imoloame (2014, 2017), Imoloame and Ahmed 2018 that hoe weeding is most expensive compared with chemical and integrated weed control methods. The treatment that is most profitable in the production of maize is primextra at 1.5 kg a.i. ha^{-1} + one SHW (₦ 100,992.00 / $ 280.53) followed by two hoe weeding at 3 and 6 WAS (₦ 86,872.00 / $ 241.31), primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1} (₦ 72,936.00 / $ 202.60) and primextra + 2,4-D at 2.0 + 2.0 (₦ 63,640.00 / $ 176.78) in the descending order. This could be due to the ability of these methods of weed control to increase the grain yield of maize, compared with the other treatments like primextra + 2,4-D at 1.5 + 1.5, 2.5 + 2.5 kg a.i. ha^{-1} and weedy check which resulted in losses. Similarly, primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, two hoe weedings at 3 and 6 WAS, primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1} and primextra + 2,4-D at 2.0 + 2.0 kg a.i. ha^{-1} had higher benefit: cost ratio in the descending order, implying that they are more economical and profitable in the production of maize in Malete and southern Guinea savanna zone of Nigeria. The treatment with the lowest benefit: cost ratio was the weedy check (Table 6).

CONCLUSION

This study seeks to compare different methods of weed control and to determine which one of them will give higher yield and economic returns in the production of maize in Malete. Findings show that primextra at 1.5 kg a.i. ha^{-1} + one SHW at 6 WAS, two hand weedings at 3 and 6 WAS, primextra + 2,4-D at 2.0 + 2.0 and primextra + nicosulfuron at 2.0 + 0.05 kg a.i. ha^{-1} are comparable in their performance in promoting effective weed control, better growth and higher yield of maize. Their applications also resulted in higher cash returns and are therefore recommended to farmers as alternatives to hand weeding for the profitable production of maize in Malete.

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