WEED CONTROL AND PRODUCTIVITY OF MAIZE (ZEA MAYS L.)

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Abstract: 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: Primextra + Aminicome at 1.5 + 1.5 kg ha\(^{-1}\) (metolachlor 375 g a.i. ha\(^{-1}\) + atrazine 375 g a.i. ha\(^{-1}\) + 2,4 – D 900 g a.i. ha\(^{-1}\)), Primextra + Aminicome at 2.0 + 2.0 kg ha\(^{-1}\) (metolachlor 500 g a.i. ha\(^{-1}\) + atrazine 500 g a.i. ha\(^{-1}\) + 2,4 – D 1200 g a.i. ha\(^{-1}\)), Primextra + Aminicome at 2.5 + 2.5 kg ha\(^{-1}\) (metolachlor 750 g a.i. ha\(^{-1}\) + atrazine 750 g a.i. ha\(^{-1}\) + 2,4 – D 1500 g a.i. ha\(^{-1}\)), Primextra + Guard force at 1.5 + 0.03 kg ha\(^{-1}\) (metolachlor 375 g a.i. ha\(^{-1}\) + atrazine 375 g a.i. ha\(^{-1}\) + nicosulfuron 1.2 g a.i. ha\(^{-1}\) ), Primextra + Guard force at 2.0 + 0.05 kg ha\(^{-1}\) (metolachlor 500 g a.i. ha\(^{-1}\) + atrazine 500 g a.i. ha\(^{-1}\) + nicosulfuron 2.0 g a.i. ha\(^{-1}\) ), Primextra + Guard force at 2.5 + 0.07 kg ha\(^{-1}\) (metolachlor 750 g a.i. ha\(^{-1}\) + atrazine 750 g a.i. ha\(^{-1}\) + nicosulfuron 2.8 g a.i. ha\(^{-1}\) ), Primextra at 1.5 kg ha\(^{-1}\) (metolachlor 375 g a.i. ha\(^{-1}\) + atrazine 375 g a.i. ha\(^{-1}\) ) + one supplementary hoe weeding (SHW) at 6 weeks after sowing (WAS), two hand weedings at 3 and 6 weeks after sowing (WAS) and a weedy check. These treatments were laid out in a randomized complete block design (RCBD) with three replicates. Data collected were subjected to analysis of variance using the Statistical Analysis Software (SAS) package, after which means were separated using Duncan’s Multiple Range Test (DMRT). Results showed that treatment combinations of Primextra at 1.5 Kg ha\(^{-1}\) + one SHW at 6 WAS, two hoe weedings at 3 and 6 WAS, Primextra + Aminicome at 2.0 + 2.0 kg ha\(^{-1}\) and Primextra + Guard force at 2.0 + 0.05 kg ha\(^{-1}\) gave effective weed control, higher grain yield and cash returns. They are therefore recommended for application in rotation by farmers in Malete.

Key words: integrated weed management, southern Guinea savanna, maize, yield, cash returns.

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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). Ogunnusi 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 an opportunity to increase production per unit area. FAO (2017) reported that 822.7 million metric tons of maize were produced worldwide in 2008 and Nigeria produced 7.3 million tons in 2009. However, this figure was increased to 10.7 and 10.5 million metric tonnes in 2015 and 2017 respectively.

According to Khan et al. (2003), the average production of maize in Africa is still abysmally low, ranging between 1.3 and 1.5 tons/ha and unless the present trends are reversed, 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 farmers in Africa (Chikoye et al., 2002). Past research works have revealed that two hoe weedings at 3 and 6 WAS resulted in effective weed control and higher maize yields (Imoloame, 2016 and 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 cost 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 Nigerian 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 residues in crops and health hazards (Best-Ordinioha, 2017). 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 (Kadil and Kordy, 2013; Imoloame, 2017 and 2018). There is a dearth of information that compares the performance of herbicide at low dose integrated with one SHW at 6WAS 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 an 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 a 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), Nigeria. The experimental site was characterized by two peaks of rainfall in June and September and the soil was sandy loam with low water-retaining capacity.

Treatments and experimental design

The experiment consisted of nine treatments: Primextra + Aminicome at 1.5 + 1.5 kg ha\(^{-1}\) (metolachlor 375 g a.i. ha\(^{-1}\) + atrazine 375 g a.i. ha\(^{-1}\) + 2,4 – D 900 g a.i. ha\(^{-1}\)), Primextra + Aminicome at 2.0 + 2.0 kg ha\(^{-1}\) (metolachlor 500 g a.i. ha\(^{-1}\) + atrazine 500 g a.i. ha\(^{-1}\) + 2,4 – D 1200 g a.i. ha\(^{-1}\)), Primextra + Aminicome at 2.5 + 2.5 kg ha\(^{-1}\) (metolachlor 750 g a.i. ha\(^{-1}\) + atrazine 750 g a.i. ha\(^{-1}\) + 2,4 – D 1500 g a.i. ha\(^{-1}\)), Primextra + Guard force at 1.5 + 0.03 kg ha\(^{-1}\) (metolachlor 375 g a.i. ha\(^{-1}\) + atrazine 375 g a.i. ha\(^{-1}\) + nicosulfuron 1.2 g a.i. ha\(^{-1}\) ), Primextra + Guard force at
2.0 + 0.05 kg ha\(^{-1}\) (metolachlor 500 g a.i. ha\(^{-1}\) + atrazine 500 g a.i. ha\(^{-1}\) + nicosulfuron 2.0 g a.i. ha\(^{-1}\)), Primextra + Guard force at 2.5 + 0.07 kg ha\(^{-1}\) (metolachlor 750 g a.i. ha\(^{-1}\) + atrazine 750 g a.i. ha\(^{-1}\) + nicosulfuron 2.8 g a.i. ha\(^{-1}\)), Primextra at 1.5 (metolachlor 375 g a.i. ha\(^{-1}\) + atrazine 375 g a.i. ha\(^{-1}\)) + one supplementary hoe weeding (SHW) at 6 weeks after sowing (WAS), two hand weedings at 3 and 6 weeks after sowing (WAS) and a weedy check.

These treatments were laid out in a randomized complete block design (RCBD) with three replicates. Data collected were analyzed using the Statistical Analysis Software (SAS) package. Means were separated using Duncan’s Multiple Range Test (DMRT) at 5% level of probability.

The gross area used for the experiment was 567 m\(^2\). This was plowed, harrowed and later demarcated into plots measuring 4 m \(\times\) 4 m each. Three treated seeds of the maize variety SUWAN -1-SR were sown per hole spaced at 75 cm \(\times\) 25 cm, on the 14\(^{th}\) and 11\(^{th}\) 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 application of pre-emergence herbicide (metolachlor + atrazine) was done a day after sowing, while that of post-emergence herbicides (nicosulfuron and 2, 4-D) was 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 at 6 WAS at the rate of 120 kg N, 60 kg P and 60 kg K. Insecticide ‘Strong Force’ (methomyl 90%) as the active ingredient was applied to control armyworm (Spodoptera exempta) at the rate of 10g/15 liters of water. Harvesting of maize was done on the 13\(^{th}\) and 12\(^{th}\) 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-labeled envelopes which were later oven-dried at a temperature of 80°C for 2 days to 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 at 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 quadrat (1 m²), randomly placed in three locations within each plot and the total number of weed species per unit area was recorded.

Shannon-Weiner species diversity index $H'$

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:

$$H' = \sum_{i=1}^{S} \frac{n_i}{N} \ln \frac{n_i}{N},$$

where $n_i$ is the number of individuals of one particular species and $N$ is the total number of all individuals in the sample.

Leaf area (cm²)

Leaf area of maize was determined at 6 and 12 WAS by using the expression.

$$\text{Leaf area (LA)} = \text{Length (L) width (W)} \times 0.75.$$ 

The leaf area was obtained by measuring the length and width of leaves from five randomly selected plants from each plot and the average of these measurements was multiplied by a factor of 0.75 to give the leaf area per plant.

Grain yield (kg ha⁻¹)

Grain yield was determined by weighing the grains with a moisture level of 13%, 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). The benefit: cost ratio was also determined as follows:

\[ \text{GM} = \text{TR} - \text{VC}; \]
\[ \text{TR} = (Ys \times Ps); \]
\[ \text{VC} = M + L; \]

where: \( \text{GM} \) = Gross margin/ha for each treatment;
\( \text{TR} \) = Total revenue (Naira (₦)/United States Dollars ($) for each treatment;
\( \text{VC} \) = Variable cost (Naira (₦)/$) for each treatment;
\( Ys \) = Maize grain yield (Kg ha\(^{-1}\)) for each treatment;
\( Ps \) = Price of maize per kg;
\( M \) = Value of material input (seeds, fertilizer, insecticide, herbicides etc.);
\( L \) = Value of labour (land preparation, planting, insecticide and herbicide, fertilizer application, harvesting, processing and packaging).

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

\[ \text{Benefit-cost ratio} = \frac{I}{TCP} \]

where \( TCP \) is the total cost of production and \( I \) is income.

Results and Discussion

Rainfall figures

Total rainfall of 1014.8 and 1451.1 mm was recorded in 2017 and 2018 respectively. The two peaks of rainfall occurred in August and September in 2017, while May and September recorded the highest rainfall in 2018 (Figure 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 and weed cover score in 2017 and 2018 in Malete (Table 1). In 2017, Primextra at 1.5 kg ha\(^{-1}\) + one SHW at 6 WAS resulted in weed dry matter that was significantly \( (P<0.05) \) lower than the weedy check but was comparable with other herbicide treatments and hoe weeding at 3 and 6 WAS, while in 2018, all the treatment combinations significantly 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 ha\(^{-1}\) + one SHW at 6 WAS, two hoe weedings at 3 and 6 WAS and Guard force at lower rates resulted in weed dry matter that was significantly \( (P < 0.05) \) lower than the weedy check but which was not different from other herbicide treatments, whereas in 2018, hoe weeding at 3 and 6 WAS significantly reduced weed dry matter. This
performance was comparable with other treatments except for Primextra + Aminicome at 1.5 + 1.5 kg ha\(^{-1}\) and all the rates of Primextra + Guard force and the weedy check (Table 1).

![Rainfall Figures for 2017 and 2018 Rainy Seasons (mm)](image)

Source: Lower Niger River Basin and Rural Development Authority, Hydrology Section, Ilorin, Kwara State.

**Table 1. The effect of weed control methods on weed dry matter in maize in 2017 and 2018.**

| Treatment       | Rate (kg ha\(^{-1}\)) | Weed dry matter (g m\(^{-2}\)) 6 WAS | Weed dry matter (g m\(^{-2}\)) 12 WAS |
|-----------------|------------------------|---------------------------------------|---------------------------------------|
|                 |                        | 2017       | 2018       | 2017       | 2018       |
| P+A             | 1.5 + 1.5              | 75.3\(^{ab}\) | 293.8\(^{a}\) | 79.8\(^{ab}\) | 2519.7\(^{a}\) |
| P+A             | 2.0 + 2.0              | 91.4\(^{ab}\) | 367.1\(^{b}\) | 94.7\(^{ab}\) | 1458.9\(^{bc}\) |
| P+A             | 2.5 + 2.5              | 159.4\(^{ab}\) | 362.0\(^{b}\) | 173.6\(^{ab}\) | 1027.2\(^{bc}\) |
| P+GF            | 1.5 + 0.05             | 58.0\(^{b}\) | 445.3\(^{b}\) | 59.1\(^{b}\) | 1572.9\(^{b}\) |
| P+GF            | 2.0 + 0.05             | 60.1\(^{b}\) | 347.1\(^{b}\) | 68.3\(^{b}\) | 1060.7\(^{ab}\) |
| P+GF            | 2.5 + 0.07             | 88.8\(^{b}\) | 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\(^{b}\) | 123.4\(^{b}\) | 70.4\(^{b}\) | 340.2\(^{c}\) |
| Weedy check     | -                      | 195.5\(^{a}\) | 976.5\(^{b}\) | 214.6\(^{c}\) | 2518.6\(^{d}\) |

**Notes:**
- WAS = Weeks after sowing
- 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; A = Aminicome; GF = Guard force; SHW = Supplementary hoe weeding.

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The same trend was observed regarding weed cover as all herbicide treatments, two hoe weedings and Primextra at 1.5 kg ha\(^{-1}\) + one SHW at 6 WAS caused a significant reduction in weed cover in comparison with weedy check in 2017, while in 2018, it was only hoe weeding at 3 and 6 WAS that had a significant and positive influence on weed cover at 6 WAS. At 12 WAS in 2017, all herbicide treatments, two hoe weedings and a combination of herbicide and 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 caused a significant (\(P<0.05\)) reduction in the weed cover except for Primextra + Aminicome at 2.5+2.5 and Primextra + Guard force at 2.5 + 0.07 kg ha\(^{-1}\) which had significantly higher weed cover that was comparable with the weedy check (Table 2). Generally, the amount of weed biomass and weed cover recorded under the treatments was greater in 2018 than in 2017. The treatment combination of Primextra at 1.5 kg ha\(^{-1}\)+ one SHW at 6 WAS, Primextra + Aminicome at 2.0 + 2.0 kg ha\(^{-1}\) and two hand weedings at 3 and 6 WAS were consistent in providing more effective and season-long weed control in maize plots.

Table 2. The effect of weed control methods on weed cover score in maize in 2017 and 2018.

| Treatment  | Rate (kg ha\(^{-1}\)) | 6 WAS\(^{1}\) | 12 WAS | 6 WAS\(^{1}\) | 12 WAS |
|------------|-----------------------|--------------|--------|--------------|--------|
| P+A        | 1.5 + 1.5             | 4.3\(^{bc}\) | 7.0\(^{a}\) | 4.0\(^{b}\) | 6.2\(^{a}\) |
| P+A        | 2.0 + 2.0             | 4.3\(^{b}\)  | 7.7\(^{a}\) | 4.3\(^{b}\) | 4.2\(^{bc}\) |
| P+A        | 2.5 + 2.5             | 5.7\(^{b}\)  | 7.7\(^{a}\) | 5.0\(^{b}\) | 7.5\(^{ab}\) |
| P+GF       | 1.5 + 0.03            | 2.7\(^{b}\)  | 8.3\(^{a}\) | 3.5\(^{b}\) | 6.0\(^{b}\) |
| P+GF       | 2.0 + 0.05            | 3.0\(^{b}\)  | 7.7\(^{a}\) | 3.3\(^{b}\) | 6.3\(^{b}\) |
| P+GF       | 2.5 + 0.07            | 5.7\(^{b}\)  | 8.7\(^{a}\) | 4.3\(^{b}\) | 6.8\(^{ab}\) |
| P+ SHW     | 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; A = Aminicome; GF = Guard force; SHW = Supplementary hoe weeding.

These weed control methods can be applied in rotation in maize fields for weed control. Imoloame (2014) reported that two hand weedings and a combination of herbicide + 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 ($H'$) 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 ($H'$) of weed species under different treatments. The weed flora diversity (1.7) was the highest in plots with Primextra + Aminicome at 2.0 + 2.0 kg ha$^{-1}$, while the lowest diversity was (0.6) in plots treated with Primextra + Guard force at 2.0 + 0.03 kg ha$^{-1}$.

Table 3. Shannon Weiner diversity index ($H'$) at 12 WAS in maize in 2018.

| Species | Weed form | P+A 1.5+1.5 | P+A 2.0 | P+A 2.5+0.03 | P+GF at 2.0+0.05 | P+GF at 2.5+0.07 | 3 + 6 WAS | P at 1.5 | Weedy check |
|---------|-----------|-------------|---------|--------------|-----------------|-----------------|----------|---------|-------------|
| Brachiaria alata | G | 18 | 18 | 3 | - | - | 7 | - | - | 1 |
| Paspalum scrobiculatum | G | 59 | 59 | 64 | 62 | 76 | 12 | 158 | 33 | 123 |
| Cyperus esculentus | - | - | - | - | - | - | 1 | - | - | - |
| Commelina benghalensis | BL | 3 | 3 | - | - | - | 3 | - | - | 2 |
| Pycreus lanceolatus | BL | - | - | - | - | - | - | 31 | 15 | - |
| Rotboellia cochinchinensis | G | 33 | 33 | 28 | - | 2 | 4 | - | - | 1 |
| Digitaria horizontalis | G | 65 | 65 | 108 | 117 | 85 | 60 | 55 | 6 | 8 |
| Hyptis suaveolens | BL | - | - | - | 4 | 1 | 4 | - | - | 1 |
| Gomphrena Celosiodes | BL | - | - | - | - | - | - | - | - | - |
| Grass (unidentified) | G | - | - | - | - | - | - | - | - | - |
| Dactyloctenium aegyptium | G | - | - | - | - | - | 5 | - | 2 | - |
| Broad leaf (unidentified) | BL | - | - | - | - | - | - | - | - | 1 |
| Chloris pilosa | G | - | - | - | - | - | - | - | - | 1 |
| Cyperus rotundus | S | - | - | - | - | - | - | - | - | 3 |
| Kyllinga squamulata | S | - | - | - | - | - | - | 1 | 11 | - |
| Kyllinga erecta | S | - | - | - | - | - | - | - | 21 | - |
| Seteria barbata | G | - | - | - | - | - | - | - | - | 8 |

Shannon weiner index ($H'$) | 1.3 | 1.3 | 1.8 | 0.762 | 0.6 | 1.1 | 0.7 | 1.3 | 1.1 |

The Shannon – Weiner diversity index ($H'$) ranged from 0 to 4.6. A value near 0 indicates 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') recorded ranging from 0.6 to 1.7 under each treatment indicates that the individual number of present weed species is not evenly distributed since H is near 0. The low Shannon Weiner diversity index value (close to 0), explains the dominance of *Paspalum scrobiculatum* across treatments and *Digitaria horizontalis* in the plots treated with Primextra + Aminicome and Primextra + Guard force 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 ability to easily adapt to the environment. The prevalence of the two grass weed species mentioned above in the plots treated with Primextra + Aminicome at all the rates was expected as the post-emergence herbicide has a narrow spectrum of activity for the effective control of only broadleaved but not grass weeds. This result is similar to the findings of Imoloame (2017), who reported the inability of tank mixture of metolachlor + atrazine and pendimethalin + 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 the formulation of a better weed strategy for its effective control.

Effect of weed control treatments on leaf area

There was a significant (p<0.05) difference in the leaf area among treatments (Table 4).

Table 4. The effect of weed control methods on leaf area in maize in 2017 and 2018.

| Treatment | Rate (kg ha⁻¹) | 6 WAS | 12 WAS |
|-----------|---------------|-------|-------|
|           |               | 2017  | 2018  | 2017  | 2018  |
| P+A       | 1.5 + 1.5     | 139.3 | 275.1 | 152.7 | 351.3 |
| P+A       | 2.0 + 2.0     | 117.0 | 288.3 | 138.1 | 386.6 |
| P+A       | 2.5 + 2.5     | 112.9 | 278.3 | 105.4 | 334.8 |
| P+GF      | 1.5 + 0.03    | 129.3 | 287.9 | 132.2 | 352.4 |
| P+GF      | 2.0 + 0.05    | 81.3  | 318.0 | 108.0 | 392.8 |
| P+GF      | 2.5 + 0.07    | 88.1  | 274.6 | 102.4 | 325.0 |
| P+1SHW    | 1.5           | 127.9 | 295.0 | 141.6 | 380.7 |
| 3 + 6 WAS | -             | 109.9 | 307.1 | 123.4 | 398.4 |
| Weedy check | -       | 91.5  | 273.4 | 90.3  | 333.3 |

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; A = Aminicome; GF = Guard force; SHW = Supplementary hoe weeding.

In 2017 and at 6 WAS, plots treated with Primextra + Aminicome at 1.5 + 1.5 kg ha⁻¹, Primextra + Aminicome at 2.0 + 2.0 kg ha⁻¹, Primextra at 1.5 kg ha⁻¹ + one
SHW at 6 WAS, Primextra + Guard force at 1.5 + 0.03 kg ha\textsuperscript{-1} and two hand weedicings, produced significantly (p < 0.05) larger leaves than the weedy check and Primextra + Guard force at higher rates. At 12 WAS, in 2017, Primextra at 1.5 kg ha\textsuperscript{-1} + one SHW and Primextra + Aminicome at 1.5 + 1.5 kg ha\textsuperscript{-1}, as well as Primextra + Aminicome at 2.0 + 2.0 kg ha\textsuperscript{-1} resulted in crops with significantly larger leaves which were statistically different from other treatment combinations and significantly larger than the weedy check. However, in 2018 and at 6 WAS, two hoe weedicings at 3 and 6 WAS and Primextra + Guard force at 2.5 + 0.05 kg ha\textsuperscript{-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. In the same year and at 12 WAS, the highest leaf area was detected in the treatment with two hand weedicings. The larger leaf area of maize in the plots treated with Primextra + Aminicome at 1.5 + 1.5 kg ha\textsuperscript{-1}, Primextra + Aminicome at 2.0 + 2.0 kg ha\textsuperscript{-1}, Primextra + Guard force at 1.5 + 0.03, Primextra + Guard force at 2.5 + 0.05 kg ha\textsuperscript{-1}, Primextra at 1.5 kg ha\textsuperscript{-1} + one SHW at 6 WAS and two hand weedicings 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 ha\textsuperscript{-1} + one SHW at 6 WAS and two hoe weedicings at 3 and 6 WAS in 2017 produced the highest maize grain yields which were not statistically different from the other herbicide treatments but were significantly (p < 0.05) different from the weedy check (Table 5).

Table 5. The effect of weed control methods on 100-seed weight and grain yield in maize in 2017 and 2018.

| Treatment   | Rate (kg ha\textsuperscript{-1}) | 100-seed weight (g) | Grain yield kg ha\textsuperscript{-1} |
|-------------|----------------------------------|----------------------|--------------------------------------|
|             |                                  | 2017     | 2018     | 2017     | 2018     |
| P+A         | 1.5 + 1.5                        | 19.8\textsuperscript{a} | 21.5\textsuperscript{a}   | 736.5\textsuperscript{ab}     | 1527.2\textsuperscript{b} |
| P+A         | 2.0 + 2.0                        | 18.4\textsuperscript{a} | 21.2\textsuperscript{a}   | 433.9\textsuperscript{ab}     | 3122.5\textsuperscript{a} |
| P+A         | 2.5 + 2.5                        | 17.4\textsuperscript{a} | 19.5\textsuperscript{a}   | 871.0\textsuperscript{ab}     | 1834.5\textsuperscript{b} |
| P+GF        | 1.5 + 0.03                       | 20.9\textsuperscript{a} | 19.9\textsuperscript{a}   | 1038.2\textsuperscript{ab}    | 2491.3\textsuperscript{ab} |
| P+GF        | 2.0 + 0.05                       | 20.0\textsuperscript{a} | 21.5\textsuperscript{a}   | 1160.4\textsuperscript{ab}    | 2793.4\textsuperscript{ab} |
| P+GF        | 2.5 + 0.07                       | 19.9\textsuperscript{a} | 20.3\textsuperscript{a}   | 977.8\textsuperscript{ab}     | 2401.7\textsuperscript{ab} |
| P+SHW       | 1.5                              | 19.6\textsuperscript{a} | 20.0\textsuperscript{a}   | 1416.2\textsuperscript{a}     | 2878.7\textsuperscript{a} |
| 3 + 6 WAS   | -                                | 21.0\textsuperscript{a} | 19.3\textsuperscript{a}   | 1317.8\textsuperscript{a}     | 3140.9\textsuperscript{a} |
| Weedy check | -                                | 16.6\textsuperscript{a} | 20.5\textsuperscript{a}   | 331.1\textsuperscript{b}      | 1444.5\textsuperscript{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; A = Aminicome; GF = Guard force; SHW = Supplementary hoe weeding.
While in 2018, a similar trend was observed as Primextra at 1.5 kg ha\(^{-1}\) + one SHW at 6 WAS, two hand weedings at 3 and 6 WAS and Primextra + Aminicome at 2.0 + 2.0 kg ha\(^{-1}\) and other herbicide combinations resulted in grain yield values significantly (p < 0.05) higher than the weedy check and Primextra + Aminicome at 1.5 + 1.5 kg ha\(^{-1}\). The significantly higher grain yields produced from the above-mentioned plots were a result of the ability of the above weed control methods to consistently provide season-long weed control, which could have increased the amount of growth resources available to maize, which in turn led to the production of significantly larger leaves for enhanced photosynthesis and grain yield. The above treatment combinations can serve as an alternative to hoe weeding which could be applied in rotation for effective weed control and higher grain yields in maize. The weedy check produced significantly lower yields as a result of the intense competition between the maize crop and the weeds particularly *Paspalum scrobiculatum* and *Digitaria horizontalis* for growth resources.

Economic evaluation of different weed control methods in maize production

The 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 ha\(^{-1}\) + one SHW, followed by two hand weedings at 3 and 6 WAS and Primextra + Guard force at 2.0 + 0.05 kg ha\(^{-1}\), while the weedy check resulted in the 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 (₦173,900.00/$451.70) was the treatment combination of Primextra + Aminicome at 2.5+ 2.5 kg ha\(^{-1}\), while the lowest cost (₦143,900.00/$399.72) was incurred under the weedy check in which weeds were not controlled at all. The next plot treated with herbicides with the lowest cost in the production of maize was Primextra at 1.5 kg ha\(^{-1}\) + one SHW. This is at variance with the findings of Imoloame (2014, 2017, 2018) that hoe weeding is most expensive compared with chemical and integrated weed control methods. This demonstrates the fact that chemical weed control becomes more expensive as application rates are increased. The treatment that is the most profitable in the production of maize is Primextra at 1.5 kg ha\(^{-1}\) + one SHW (₦109,592.00/$302.42) followed by two hoe weedings at 3 and 6 WAS (₦93,700.00/$260.00), Primextra + Guard force at 2.0+0.05 kg ha\(^{-1}\) (₦70,328.00/$ 195.36) and Primextra + Aminicome at 2.0 + 2.0 kg ha\(^{-1}\) (₦63,640.00/$ 176.78) in the descending order. The other treatments like Primextra + Aminicome at 1.5 + 1.5 kg ha\(^{-1}\), Primextra + Aminicome at 2.5 + 2.5 kg ha\(^{-1}\) and the weedy check resulted in losses. 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 + Aminicome at 1.5 + 1.5 kg ha\(^{-1}\), 2.5 + 2.5 kg ha\(^{-1}\) and the weedy check. Similarly, these methods of weed control, Primextra at 1.5 kg
1. The average price of maize in the open market in 2018 = N120/kg. 2. The prices in parenthesis are in United States dollars (USD $), while the ones not in parenthesis are in naira (₦). 3. The exchange rate between the naira and the US dollars = 1 N = USD 0.036.

Table 6. The profitability of different weed control methods in the production of maize in Malete, Nigeria.

| Farm operations/ha | P + A | P + A | P + A | P + GF at 1.5 + 0.03 | P + GF at 2.0 + 0.05 | P + GF at 2.5 + 0.07 | 3 & 6 WAS | P at 1.5 + ISWH | Weedy check |
|-------------------|-------|-------|-------|----------------------|----------------------|----------------------|----------|-----------------|------------|
| Land preparation  | 18,000.0 | 18,000.0 | 18,000.0 | 18,000.0             | 18,000.0             | 18,000.0             | 18,000.0 | 18,000.0        | 18,000.0   |
| Seeds             | 4,200.0  | 4,200.0 | 4,200.0 | 4,200.0              | 4,200.0              | 4,200.0              | 4,200.0  | 4,200.0         | 4,200.0    |
| Planting          | 6,000.0  | 6,000.0 | 6,000.0 | 6,000.0              | 6,000.0              | 6,000.0              | 6,000.0  | 6,000.0         | 6,000.0    |
| Fertilizer       | 9,000.0  | 9,000.0 | 9,000.0 | 9,000.0              | 9,000.0              | 9,000.0              | 9,000.0  | 9,000.0         | 9,000.0    |
| Cost of fertilizer (NPK and urea) | 75,000.0 | 75,000.0 | 75,000.0 | 75,000.0 | 75,000.0 | 75,000.0 | 75,000.0 | 75,000.0 | 75,000.0 |
| Cost of the first hoe weeding | -      | -      | -      | -                   | 10,000.0             | 10,000.0             | -       | -               | -          |
| Cost of the second hoe weeding | -      | -      | -      | -                   | 10,000.0             | 10,000.0             | -       | -               | -          |
| Cost of herbicide application (Pre- and post-emergence) | 8,000.0 | 8,000.0 | 8,000.0 | 8,000.0             | 8,000.0             | 8,000.0             | 8,000.0  | 8,000.0         | 8,000.0    |
| Cost of herbicide | 13,500.0 | 13,500.0 | 13,500.0 | 13,500.0            | 13,500.0            | 13,500.0            | 13,500.0 | 13,500.0       | 13,500.0   |
| Cost of pesticide application | 3,300.0 | 3,300.0 | 3,300.0 | 3,300.0             | 3,300.0             | 3,300.0             | 3,300.0  | 3,300.0         | 3,300.0    |
| Cost of pesticide | 8,000.0  | 8,000.0 | 8,000.0 | 8,000.0             | 8,000.0             | 8,000.0             | 8,000.0  | 8,000.0         | 8,000.0    |
| Labour cost for harvesting, processing and bagging | 20,000.0 | 20,000.0 | 20,000.0 | 20,000.0            | 20,000.0            | 20,000.0            | 20,000.0 | 20,000.0       | 20,000.0   |
| Total cost of production (VC) | 165,700.0 | 167,900.0 | 173,900.0 | 162,700.0           | 166,900.0           | 170,700.0           | 164,000.0 | 157,900.0       | 143,900.0  |
| Average yield/ha | 1,289.00 | 1,929.5 | 1,352.8 | 1,764.8             | 1,976.9             | 1,689.8             | 2,147.5  | 2,229.1         | 929.2      |
| Selling price (TR) | 154,680.0 | 231,540.0 | 162,336.0 | 211,776.0           | 237,228.0           | 202,776             | 257,700.0 | 267,492.0       | 111,504.0  |
| Profit (GM) | -11,020.0 | -11,640.0 | -12,320.0 | -17,760.0           | -70,328.0           | -32,076             | 93,700.0  | 109,592.0       | -32,396.0  |
| Benefit: cost ratio | 0.933   | 1.379   | 0.933   | 1.302               | 1.421               | 1.00                | 1.571    | 1.694           | 0.775      |
Conclusion

The findings show that Primextra at 1.5 kg ha⁻¹ + one SHW at 6 WAS, two hand weedicings at 3 and 6 WAS, Primextra + Aminicom e at 2.0 + 2.0 and Primextra + Guard force at 2.0 + 0.05 kg 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.

References

Ali, R.S., Khalil, K., Raza, S.M.D., & Khan, H. (2003). Effect of herbicides and rows spacing on maize (Zea mays L.). Pakistan Journal of Weed Science Research, 9 (3-4), 171-178.

Best, Ordinioha, J.C., & Ataga, E.A. (2017). The effect of the application of different rates of herbicides on the residual level of the herbicides and their metabolites in harvested maize cobs. Port Harcourt Medical Journal, 11 (3), 122-126.

Chikoye, D., Manyong, V.M., Carsky, R.J., Ekeleme, F., Gbehouou, G., & Ahanchebe, A. (2002). Response of speargrass (Imperata Cylindrica (L.) Raeusch) to cover crops integrated with hand weeding and chemical control in maize and cassava. Crop Protection, 21, 154-156.

Chikoye, D., Schulz, S., & Ekeleme, F. (2004). Evaluation of Integrated Weed Management Practices for maize in the northern Guinea savanna of Nigeria. Crop Protection, 23, 895-900.

Darkwa, E.O., Johnson, B.K., Nyalemegbe, K., Yagyuoru, M., Oti-Boateng, C., Willcocks, T.J., & Terry, P.J. (2001). Weed Management on vertisols for small-scale farmers in Ghana. International Journal of Pest Management, 47, 299-303.

Ekeleme, F. (2009). Major weeds of legumes and cereals and weed contrl measures In: Ajiegbe, H.A., Abdoulaye, T., & Chikoye, D. (Eds.). Proceedings of the training workshop on production of legume and cereal seeds. (pp 29-33). Ibadan, Nigeria: International Institute of Tropical Agriculture.

F.A.O. (2017). Global information and early warning system (GIEWS). Country Briefs, Nigeria. http://www.fao.org/grews/country/brief/country.jsp?code=NGA.

Haider, S.M.S., Karim, M.M., Ahmed, M.I., Shaheb, M.R., & Shaheenuzzaman, M. (2009). Efficacy of different herbicides on the yield and yield components of maize. International Journal of Sustainable Crop Production, 4 (2), 14-16.

Hall, M.K., Swanton, C.J., & Anderson, G.W. (1992). The critical period of weed control in grain corn (Zea mays). Weed science, 40, 441-447.

Husnatulyusra, B.S. (2012). Diversity of weed flora in different stages of oil palm plantation. B.Sc. Project. Department of Plant Science and Environmental Ecology, University of Malaysia.

Iken, J.E., & Amusa, N.A. (2004). Maize research and production in Nigeria. African Journal of Biotechnology, 3 (6), 302-307.

Imoloame, E.O. (2014). Economic evaluation of methods of weed control in soybeans (Glycine max (L) Merril.) production in the southern Guinea savanna of Nigeria. Nigeria Journal of Experimental and Applied Biology, 14, 81-85.

Imoloame, E.O., & Omolaiye, J.O. (2016). Impact of different periods of weed interference on growth and yield of maize (Zea Mays L.). Tropical Agriculture, 93 (4), 245-257.

Imoloame, E.O. (2017). Evaluation of herbicide mixtures and manual weed control method in maize (Zea mays L.) production in the southern Guinea agro-ecology of Nigeria Cogent Food and Agriculture, 3, 1-17.
Imoloame, E.O., & Ahmed, M. (2018). Weed biomass and productivity of okra (Abelmoschus esculentus (L) Moench) as influenced by spacing and pendimethalin-based weed management. *Journal of Agricultural Science, 63* (4), 379-398.

Jones, P.G., & Thornton, P.K. (2003). The potential impacts of climate change on maize production in Africa and Latin America in 2055. *Global Environmental Change, 13*, 51-59.

Kardil, E.E., & Kordy, A.M. (2013). Effect of hand hoeing and herbicides on weeds, growth and yield of Maize (Zea mays L). *Journal of Applied Science and Research, 9* (4), 3075-3082.

Khan, M.A., Marwat, K.B., & Khanu, Khan, I.A. (2003). Efficacy of different herbicides on yield and yield components of maize. *Asian Journal of Plant Science, 2*, 300-304.

Mwangi, W. (1995). Low use of fertilizer and low productivity in sub-Saharan Africa. Paper presented at the IFPRI/FAO workshop on plant nutrition management food, security and agriculture and poverty, alleviation in developing countries (pp. 23–31) Viterbo, Italy.

Ogunsami, L.O., Ewuola, S.O., & Daramola, A.G. (2005). Social–economic impact assessment of maize production technology on farmers’ welfare in south west Nigeria. *Journal of Central European Agriculture, 6* (1), 15-26.

Okoruwa, V.O., Obadaki, F.O., & Ibrahim, G. (2005). Profitability of beef cattle fattening in the cosmopolitan city of Ibadan, Oyo State. *Moor Journal of Agricultural Research, 6* (1), 45-51.

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SUZBIJANJE KOROVA I PRODUKTIVNOST KUKURUZA (ZEA MAYS L.)

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R e z i m e

Poljski ogledi su sprovedeni na Nastavno-istraživačkom imanju Državnog univerziteta u Kvari, Malete, kako bi se odredio metod suzbijanja korova koji će biti efikasniji u suzbijanju korova i uz pomoć kojeg će se postići viši prinos zrna i prihod u proizvodnji kukuruza. Ogleđ se sastojao od 9 tretmana: Primextra + Aminicome u dozi od 1,5 + 1,5 kg ha⁻¹ (metolahlor 375 g a.s. ha⁻¹ + atrazin 375 g a.s. ha⁻¹ + 2,4 – D 900 g a.s. ha⁻¹), Primextra + Aminicome u dozi od 2,0 + 2,0 kg ha⁻¹ (metolahlor 500 g a.s. ha⁻¹ + atrazin 500 g a.s. ha⁻¹ + 2,4 – D 1200 g a.s. ha⁻¹), Primextra + Aminicome u dozi od 2,5 + 2,5 kg ha⁻¹ (metolahlor 750 g a.s. ha⁻¹ + atrazin 750 g a.s. ha⁻¹ + 2,4 – D 1500 g a.s. ha⁻¹), Primextra + Guard force u dozi od 1,5 + 0,03 kg ha⁻¹ (metolahlor 375 g a.s. ha⁻¹ + atrazin 375 g a.s. ha⁻¹ + nicosulfuron 1,2 g a.s. ha⁻¹), Primextra + Guard force u dozi od 2,0 + 0,05 kg ha⁻¹ (metolahlor 500 g a.s. ha⁻¹ + atrazin 500 g a.s. ha⁻¹ + nicosulfuron 2,0 g a.s. ha⁻¹), Primextra + Guard force u dozi od 2,5 + 0,07 kg ha⁻¹ (metolahlor 750 g a.s. ha⁻¹ + atrazin 750 g a.s. ha⁻¹ + nicosulfuron 2,8 g a.s. ha⁻¹), Primextra u dozi od 1,5 kg ha⁻¹ (metolahlor 375 g a.s. ha⁻¹ + atrazin 375 g a.s. ha⁻¹) + jedno dodatno okopavanje 6 nedelja posle setve, dva ručna plevljenja 3 i 6 nedelja posle setve i kontrola bez uklanjanja korova. Ovi tretmani bili su postavljeni u randomiziranom potpunom blok dizajnu sa tri ponavljanja. Prikupljeni podaci su obrađeni analizom varijanse uz pomoć softverskog paketa za statističku analizu (SAS), posle čega su srednje vrednosti odvojene korišćenjem Dankanovog testa višestrukog poređenja. Rezultati su pokazali da se kombinacijama tretiranja primenom Primextra u dozi od 1,5 kg ha⁻¹ + jedno dodatno okopavanje 6 nedelja posle setve, dva okopavanja 3 i 6 nedelja posle setve, Primextra + Aminicome u dozi od 2,0 + 2,0 kg ha⁻¹ i Primextra + Guard force u dozi od 2,0 + 0,05 kg ha⁻¹ postiže efikasno suzbijanje korova, veći prinos zrna i novčani prihod. Poljoprivrednici u Maleteu ih zato preporučuju za primenu u rotaciji.

Ključne reči: integralna kontrola zakorovljenošću, savana južne Gvineje, kukuruz, prinos, novčani prihod.

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