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Evaluation of Selected Weeding Methods for Weed Control and Performance of Maize in South Western Nigeria

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ABSTRACT

Two field experiments were conducted each in 2011 and 2012 in Akure, Ondo State, located in the rain forest zone of Nigeria. The study evaluated the efficacy of some selected herbicides for weed control in maize (Zea mays L). Each experiment was laid out in a randomized complete block design (RCBD) involving four replications per treatment. The treatments were: (1) weedy check where no weeding occurred, (2) glyphosate only at 1.44kg a.e ha^{-1}, (3) glyphosate at 1.44kg a.e ha^{-1} + weeding at four weeks after planting (4WAP), (4) glyphosate at 1.44kg a.e ha^{-1} + weeding at 7 WAP, (5) paraquat only at 0.41kg a.i ha^{-1}, (6) paraquat at 0.41kg a.i ha^{-1} + weeding at 4 WAP, (7) paraquat at 0.41kg a.i ha^{-1} + weeding at 7 WAP, (8) atrazine (80 WP) at 3.00kg a.i ha^{-1}, (9) Primextra (500 F) at 3.00kg a.i Ha^{-1} and (10) hand weeding at 3 & 7 WAP, respectively. Data were collected on maize plant height, stem girth, number of leaves, maize cob length and girth, grain yield as well as weed flora, weed density, and percentage herbicidal efficacy on weed density. Results showed that weed flora identified with maize production were different for both locations; plots treated with atrazine plus metolachlor (Primextra) gave better performance in terms of maize growth. Maize cob length and grain weight were higher in plots treated with atrazine (80WP) at 0.41kg a.i/ha. Results further indicated that herbicidal efficacy was higher (61%) in plots treated with glyphosate plus weeding at 4 WAP but did not differ significantly ($p<0.05$) from other treatments. It was therefore concluded that glyphosate supplemented with hand weeding at good timing can be adopted for effective weed control in maize.

Keywords: Glyphosate, Primextra, Atrazine, Herbicidal efficacy.

INTRODUCTION

The cultivation of maize was previously for subsistence purposes in Africa, but it has gradually become an important commercial crop on which many agro-allied industries depend as their raw-material (Iken and Amusa, 2004). There is a high demand for maize, and opportunity exists to increase production per unit area. Global production average is put at 4.3 t/ha and yield can be as high as 8.6 tonnes per hectare in developed countries (Jones and Thornton, 2003). Although a yield potential of between 3 and 8 tonnes per hectare has also been projected for African soils (Sakala and Kabambe, 2004), average production of maize in Africa is still abysmally low, ranging between 1.3 and 1.5 tonnes per hectare (Khan *et al*., 2003); and unless present trends are reversed, Africa will have the world's largest net deficit in cereals in the near future (Mwangi, 1995).

Prominent among the factors implicated for the high discrepancy between potential and actual yields of maize in Africa is weed infestation. Maize is very susceptible to competition from weeds especially in the early stages of growth (Hall *et al*., 1992). The majority of farmers in Africa identify weeding as the major constraint in their farming systems, and yield losses due to weeds range from 25% to total crop failure if weeds are not removed within the first six weeks (Vissoh, *et al*, 2004). Manual weeding is the predominant method of control used by smallholder farmers in Africa (Chikoye *et al*., 2002). This method has been found to loosen the soil surrounding the crop rhizosphere and enhances crop growth and yield (Iremiren, 1988). However, this method is time-consuming, labourious and very expensive. Hand weeding one hectare of land cropped to maize may require as much as 25–40 man-days, representing approximately 50–80% of the total labour budget (Chikoye *et al*., 2002; Darkwa *et al*., 2001). Labour is often in short supply during the early stages of crop growth when weeds must be controlled. Weeds that are allowed to grow tall demand more time and labour for effective control, while untimely weeding causes significant crop losses (Chikoye *et al.*, 2004).

In spite of criticism that it leaves toxic residues in the environment (Aladesanwa and Adejoro, 2009), chemical control has been identified as a better alternative to manual weeding because it is cheaper, faster, and gives better control as well as increases biological yield and decreased weed biomass (Chikoye *et al.*, 2002; 2004; Ali *et al.*, 2003; Haider *et al*., 2009). Atrazine, because of its ready availability, cheapness and effectiveness over the years (Aladesanwa, 2005) is the most widely used herbicide for weed control in maize by farmers in Southwestern Nigeria. However, its failure to provide season-long weed control in maize in recent times has been reported (Aladesanwa and Adejoro, 2009), which has necessitated a search for an alternative weed control program by maize farmers in Africa. One of such alternatives is pimestra – a combination of atrazine with metolachlor (Anonymous, 1994). Glyphosate and paraquat, though not registered for maize are quite effective and protect arable crops against early competition from annual grasses and broadleaved weeds when applied pre-plant. Application of a good contact or systemic herbicide prior to planting will ensure that maize field is free from weeds during the critical growth stage of the crop, which is up to about four weeks after planting (Hall *et al*., 1992). Theyhowever need to be supplemented with hoe weeding to control perennial weeds or weeds emerging after the herbicides have dissipated (Akinyemiju, 1988), because it is necessary to protect maize crop from weed competition throughout most of its growth to ensure maximum yield (Aladesanwa and Adejoro, 2009). Kandil and Kordy (2013) that herbicides combined with supplementary weeding control weeds efficiently by way of eradication and growth stunting of weeds. Also Nasir (2013) emphasized that herbicides with one or two hand weeding ensures a broad spectrum for weed control over a longer period of time.

The objective of this study was to provide African maize farmers a chemical weed control package, identifying the most appropriate time to introduce hand weeding supplement for optimum grain yield and effective weed control.

MATERIALS AND METHODS

Field experiments were conducted in two locations in the rain forest zone of Nigeria. The first experiment was conducted at the Teaching and Research Farm of the Federal University of Technology, Akure (7°16′N, 5°12′E) Ondo State in 2011 cropping season, while the second experiment was carried out at Awule (7^0 3^1 N, 6^0 5^1 N) area, Akure Ondo State in 2012. Each experiment was laid out in a randomized complete block design (RCBD) involving four replications per treatment. The treatments were: (1) weedy check where no weeding occurred, (2) Glyphosate at 1.44 kga.e ha^{-1}, (3) Glyphosate at 1.44 kga.e ha^{-1} + weeding at four weeks after planting (WAP), (4) Glyphosate at 1.44 kg a.i ha^{-1} + weeding at 7 WAP, (5) Paraquat at 0.41kg a.i ha^{-1}, (6) paraquat at 0.41kg a.i ha^{-1} + weeding at 4 WAP, (7) Paraquat at 0.41kg a.i ha^{-1} + weeding at 7WAP, (8) Atrazine (80 WP) at 3.00 kg a.i ha^{-1}, (9) Primextra (500WF) at 3.0 kg a.i ha^{-1} and (10) hand weeding at 3 and 7 WAP, respectively. The land was mechanically prepared before planting; plot size measured 2m x 7m. The Suwan -1- maize variety obtained from Ondo State Agricultural Development Project was planted at a spacing of 75x 25cm. Herbicides were applied using a knap sack sprayer fitted with polijet nozzles calibrated to deliver 250 L/ha of the spray solution at a pressure of 2.5kg cm-^{2}. Preliminary weed assessment was conducted before herbicide application to determine the weed spectrum, density and totalweight as well as individual weed species using three fixed 50 x 50cm quadrat along a diagonal in each plot from which weed samples were collected for analysis. Weed control assessment was carried out 4weeks and 7weeks after treatment (WAT) by taking weed samples at 2 sites along a second diagonal in a 50 x 50cm fixed quadrat from each plot. Weed samples were bulked, identified and separated by species, counted and oven dried at 80ºC for 48hrs and subsequently weighed and recorded. The fresh and dry weights of weed shoot biomass (gm^{-2}) were determined.

Maize growth parameters such as plant height, stem girth, number of leaves were taken at 3, 5 and 7weeks after planting were determined from five plants of maize randomly taken from each plots (Sharara *et al* 2005). Yield parameters such as cob length, 1000- grain, weight and grain yield were also determined from ten randomly selected plant per plot (Hassan and Ahmed,2005). The harvested cobs were shelled, weighed and grain weight was adjusted to 13% moisture. (Aladesanwa and Akinbobola, 2008). Percentage herbicidal efficacy on total as well as on individual weed populations was determined using the Henderson-Tilton formula (Puntener, 1981) based on the non-uniform weed infestation in the plots before herbicide application. Data collected on maize growth and yield parameters, weed density and weed weight were subjected to analysis of variance (ANOVA), and treatment means showing significant differencewere separated using Duncan Multiple Range Test (DMRT) at 5% level of probability (Steel and Torie,1997).

RESULTS

Data collected on maize growth and yield parameters of maize as well as on weed infestation parameters during the experiments are given in the tables that follow. In both years, there were significant ($P < 0.05$) differences in leaf number per plant of maize monitored at 3, 5 and 7 weeks after planting (WAP) among the treatments with the weedy check recording the lowest number of leaves throughout the evaluation periods (Table 1). All the treatments gave higher number of leaves per plant in 2012 compared with 2011. Treatment effects on leaf number were not consistent in both years at 3 WAP. In 2011 Glyphosate applied singly, atrazine and hand weeding at 3 and 7 WAP were weaker in terms of leaf number per plant than Glyphosate plus weeding at 4 and 7 WAP, or paraquat applied singly or in combination with supplementary weeding at 4 and 7 WAP,

Table 1: Effects of selected herbicide and weeding regime on number of maize leaves in Akure, Ondo State.

Treatments	Weeks after planting					
	2011 (FUTA)			2012 (AULE)		
	3	5	7	3	5	7
Weedy check	6.00e	7.83c	5.58d	9.90b	10.30d	10.40a
Glyphosate @ 1.44kg a.e ha^{-1}	7.95bcd	9.15b	8.20cd	11.60ab	11.58bcd	11.08a
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 4WAP	9.20a	10.45a	9.98a	11.58ab	12.18abc	10.70a
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 7WAP	8.60abc	10.23a	8.80bc	11.68ab	11.53cd	10.43a
Paraquat @ 0.41kg a.e ha^{-1}	8.45abcd	9.68ab	9.43ab	10.60b	11.38cd	10.93a
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4WAP	8.78ab	10.25a	9.28abc	11.28ab	11.20cd	10.93a
Paraquat @ 0.41kg a e ha^{-1} + weeding @ 7WAP	8.10bcd	9.55ab	8.98ab	10.75b	10.88cd	10.65a
Atrazine @ 3.00 kg a.e ha^{-1}	7.62d	9.00b	8.40bcd	12.75a	13.30a	11.33a
Primextra @ 1.8kg a.i ha^{-1}	8.27abcd	10.20a	8.75bc	12.80a	12.88ab	10.68a
Hand weeding @ 3 and 7 WAP	7.77cd	9.08b	8.43bcd	10.53b	11.25cd	10.50a

Means followed by the same letter in each column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 2: Effects of selected herbicide and weeding regime on the height (cm) of maize in Akure, Ondo State.

Treatments	Weeks after planting					
	2011 (FUTA)			2012 (AULE)		
	3	5	7	3	5	7
Weedy check	79.45d	136.98c	170.28d	80.83b	189.03d	199.55c
Glyphosate @ 1.44kg a.e ha^{-1}	100.75bc	178.50b	204.63bc	123.25ab	218.03abcd	225.30ab
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 4 WAP	124.35a	208.43a	234.18a	110.38b	221.13abc	224.33ab
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 7 WAP	115.05ab	190.85ab	214.05abc	116.33ab	240.63ab	225.90ab
Paraquat @ 0.41kg a.e ha^{-1}	114.40ab	187.68ab	217.80abc	105.40b	214.98abcd	231.55ab
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4 WAP	106.60abc	192.43ab	210.13bc	95.28b	213.78bcd	220.03abc
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 7 WAP	103.90bc	181.45b	214.65abc	111.48b	222.40abc	225.28ab
Atrazine @ 3.00kg a.e ha^{-1}	100.88bc	177.33b	196.88c	158.05a	242.95ab	231.38ab
Primextra @ 3.00kg a.i ha^{-1}	111.58ab	191.28ab	223.20ab	118.50ab	246.38a	242.28a
Hand weeding @ 3 and 7 WAP	88.93cd	177.80b	199.93c	103.95b	198.28cd	219.30bc

Means followed by the same letter in each column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

or Primextra. In 2012, a different trend occurred with atrazine and Primextra resulting in the highest numbers of leaves, while sole paraquat, paraquat plus weeding at 7 WAP and hand weeding at 3 and 7 WAP were weaker treatments. Similar trends occurred in treatment effects on leaf number at 5 and 7 WAP leaf number was found to increase steadily in all treatments from 3 to 5 WAP, but declined at 7 WAP in all treatments except for the weedy check that recorded an increase in 2012. Significant increases in maize plant height over the weedy check were obtained for all the treatments throughout the evaluation periods in 2011, but not in 2012 when differences between the weedy check and some other treatments were not statistically significant (Table 2). Glyphosate plus weeding at 4 WAP recorded the highest plant height throughout the evaluation periods in 2011, but it was not statistically different from primextra and some of the paraquat treatments. In 2012, atrazine resulted in the significantly highest plant height, but it was statistically similar to some of the glyphosate and paraquat treatments. Plant height in all treatment was observed to vary in a manner consistently related with leaf number per plant as the plant aged.

Table 3: Effects of selected herbicide and weeding regime on the stem girth (cm) of maize

Treatments	Weeks after planting					
	3	5 2011 (FUTA)	7	3	5 2012 (AULE)	7
Weedy check	3.75a	4.25c	4.58a	5.25d	6.15c	6.63a
Glyphosate @ 1.44kg a.e ha^{-1}	5.18a	5.25b	5.60a	6.50c	6.58a	6.80abc
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 4 WAP	5.58a	6.20a	6.20a	6.33bc	7.15a	8.45a
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 7 WAP	5.08a	5.75ab	6.20a	6.58abc	6.73bc	6.95a
Paraquat @ 0.41kg a.e ha^{-1}	5.50a	5.60ab	5.70a	6.08cd	6.48bc	7.65a
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4 WAP	5.43a	5.83ab	6.15a	6.25cd	6.68abc	6.93a
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 7 WAP	5.48a	5.48a	5.33b	6.48c	6.73abc	6.78a
Atrazine @ 3.00kg a.e ha^{-1}	5.03a	5.65a	5.38b	7.43a	7.73ab	8.43a
Primextra @ 3.00kg a.i ha^{-1}	5.33a	6.18a	5.93ab	7.43a	7.85a	7.93a
Hand weeding @ 3 and 7 WAP	5.38a	6.30a	5.68ab	6.48c	7.13ab	7.25a

Means followed by the same letter in each column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 4: Effects of selected herbicide and weeding regime on the yield parameters of maize

Treatments	Days to 50% flowering	Cob length (cm)	Grain weight (g)	Days to 50% flowering	Cob length (cm)	Grain weight (g)
		2011 (FUTA)			2012 (FADAMA)	
Weedy check	41.50e	3.94d	0.30d	48.75c	13.13d	1.25d
Glyphosate @ 1.44kg a.e ha^{-1}	47.50cd	5.40c	0.50cd	53.25b	16.00cd	1.68abc
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 4 WAP	53.25a	8.69b	1.00ab	55.50ab	21.19a	1.80abc
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 7 WAP	49.50bc	8.12b	0.75bc	54.00b	20.27ab	1.65bc
Paraquat @ 0.41kg a.e ha^{-1}	47.25d	8.00b	0.88b	53.25b	17.25bc	1.65bc
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4 WAP	54.25a	9.48b	1.00ab	55.50b	20.21ab	1.55c
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 7 WAP	50.25b	8.28b	0.75bc	53.75b	18.00abc	1.73abc
Atrazine @ 3.00kg a.e ha^{-1}	48.00cd	11.50a	1.30a	56.00ab	21.21a	1.98a
Primextra @ 3.00kg a.i ha^{-1}	48.00cd	9.44b	0.88b	55.75ab	19.44abc	1.93ab
Hand weeding @ 3 and 7 WAP	53.75a	11.19a	1.23a	58.00a	20.40ab	1.75abc

Means followed by the same letter in each column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

Results of the effects of treatments on stem girth are presented in Table 3. Although all treatments appeared to increase stem girth over the weedy check, large variation in result indicated no significant difference due to the treatment at 3 and 5 WAP in 2011 and at 5 WAP in 2012. Significant increases in stem girth over the weedy check were obtained with all treatments at 7 WAP in 2011, with glyphosate treatments, hand weeding at 3 and 7 WAP, and primextra being the best treatment. No statistically detectable differences in stem girth occurred among the treatments at 5 WAP in 2012, while atrazine, Primextra, hand weeding at 3 and 7 WAP and glyphosate plus weeding at 4 WAP were the best treatments. In most cases stem girth as affected by treatments was found to increase between 3 and 5 WAP, but subsequently declined at 7 WAP in all treatments.

Effects of the selected herbicides and weeding regimes on yield parameters are shown in Table 4. Significant increases in days to 50% flowering were obtained with all the treatments over the weedy check in both years. In 2011, glyphosate plus weeding at 4 WAP, and hand weeding at 3 and 7 WAP recorded the significantly highest number of days to 50% flowering, followed by glyphosate or paraquat plus weeding at 7 WAP. In 2012, hand weeding at 3and 7 WAP, atrazine, Primextra, and glyphosate plus weeding at 4 WAP resulted in the significantly highest number of days to 50% flowering followed by the other treatments. There were also significant differences in cob length and cob weight among the treatments in both years with the weedy check resulting in the significantly lowest values with atrazine gave the highest, closely followed by hand weeding at 3 and 7 WAP and then remaining treatment.

Table 5: Effects of selected herbicide and weeding regime on the weed species in 2011

Treatments	Weed species / density (no/m^2)									
	Chromolaena odorata		*Euphorbia heterophylla*		*Panicum maximum*		*Panicum plectostachuss*		*Talinum triangulare*	
	3WAP	6WAP	3WAP	6WAP	3WAP	6WAP	3WAP	6WAP	3WAP	6WAP
Weedy check	24b	14a	35a	18a	16a	13a	17a	15a	36a	22a
Glyphosate @ 1.44kg a.e ha-1	19c	8c	23c	11b	3e	4c	6de	5d	23cd	8c
Glyphosate @ 1.44kg a.e ha-1 + weeding @ 4 WAP	7f	9c	16d	7c	3e	5c	8d	2d	10f	12b
Glyphosate @ 1.44kg a.e ha-1 + weeding @ 7 WAP	28a	11b	33a	8c	17a	7b	13bc	8c	24c	8c
Paraquat @ 0.41kg a.e ha^{-1}	21c	11b	22c	11b	12b	4c	11c	9c	27b	11b
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4 WAP	11e	14a	14de	11b	10bcd	4c	8d	12b	11ef	6c
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 7 WAP	29a	9c	28b	11b	17a	11a	14b	8c	21d	13b
Atrazine @ 3.00kg a.e ha^{-1}	14d	4d	11ef	2d	11bc	5c	14b	7c	21d	13b
Primextra @ 3.00kg a.i ha^{-1}	9ef	6e	13def	3d	9cd	6c	14b	7	21d	11b
Hand weeding @ 3 and 7 WAP	10e	13a	9f	13b	8d	8b	5e	14a	13e	23a

Means followed by same letter in a column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 6: Effects of selected herbicide and weeding regime on the weed species in 2012

Treatments	Weed species / density (no/m2)											
	A. tectorum		*A. africana*		*C. mucunoides*		*P. commensalis*		*P. equilinium*		*S. acuta*	
	3WAP	6WA	3WA	6WA	3WAP	6WA	3WA	6WA	3WAP	6WAP	3WA	6WA
Weedy check	14a	17a	25a	32a	13ab	20a	11ab	16a	16a	22a	19a	24a
Glyphosate @ 1.44kg a.e ha^{-1}	1c	9b	24a	31a	17a	23a	2c	9b	10b	18ab	12ab	19b
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 4 WAP	5b	3c	7c	13c	8b	7c	4cd	1d	7c	7c	4c	5d
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 7 WAP	8b	12ab	18ab	25ab	16a	20a	4cd	9b	6c	22a	10ab	19b
Paraquat @ 0.41kg a.e ha^{-1}	6b	13ab	18ab	26ab	12ab	22a	6c	14ab	6c	16ab	11ab	21a
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4 WAP	20a	4c	17ab	11c	13ab	8c	9b	5c	6c	6c	7b	5d
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 7 WAP	7b	13ab	17ab	26ab	14ab	18ab	7b	14ab	7c	19ab	8b	14bc
Atrazine @ 3.00kg a.e ha^{-1}	7b	12ab	8c	16b	6c	17ab	4cd	10b	7c	17ab	7b	11c
Primextra @ 3.00kg a.i ha^{-1}	6b	13ab	5d	16b	8b	14b	14a	16a	4d	11b	3c	12c
Hand weeding @ 3 and 7 WAP	11ab	8b	12b	11c	14ab	10bc		10b		8c		9cd

Means followed by same letter in a column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 5 shows the density of prominent individual weed species in the experimental plots as affected by the various treatments at 3 and 6 WAP in 2011. At 3 WAP, in terms of relative abundance paraquat plus weeding at 7 WAP, glyphosate plus weeding at 7 WAP, weedy check and sole paraquat recorded in descending order of activity more *Chromolaena*. *odorata* than the remaining treatments. *C. odorata* was least prevalent in plots treated with glyphosate plus weeding at 4 WAP. *Euphorbia*. *heterophylla* was more prevalent in the weedy check and plots treated with glyphosate or paraquat plus weeding at 7 WAP than the remaining treatments. *Panicum*. *maximum* and P. *plestostachuss* were higher in density in the weedy check, glyphosate plus weeding at 7 WAP and sole paraquat than the other treatments. *Talinium*. *triangulare* was more common in the weedy check, sole paraquat and sole glyphosate than the rest of the treatments. At 6 WAP, among the most prevalent weed species in the experimental plots were *E. heterophylla*, C. *odorata* and T. *triangulare*; all of which were highest in abundance in the weedy check.

Table 7: Effects of selected herbicide and weeding regime on fresh and dry weed weight

Treatments	Weed density (no. m^2)	Weed fresh weight (g)	Weed dry weight (g)	Weed density (no. m^2)	Weed fresh weight (g)	Weed dry weight
	2011 (FUTA)					2012 (AULE)
Weedy check	83.50a	1012.25a	394.25a	132.00a	1798.50a	634.25ab
Glyphosate @ 1.44kg a.e ha^{-1}	46.50cd	789.50c	343.00a	110.50b	1235.50abc	532.00bc
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 4 WAP	44.50cd	440.00c	197.75b	39.00e	927.50cd	421.50cde
Glyphosate @ 1.44kg a.e ha^{-1} + weeding @ 7 WAP	43.75cd	446.75c	144.00bc	104.00b	616.50cd	259.25ef
Paraquat @ 0.41kg a.e ha^{-1}	48.25cd	726.75b	313.25a	111.00b	1691.00ab	718.75a
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 4 WAP	47.50cd	651.75b	170.00bc	39.75e	1046.00cd	436.50cd
Paraquat @ 0.41kg a.e ha^{-1} + weeding @ 7 WAP	52.50bc	324.00cd	124.50bc	105.50b	558.50d	203.25f
Atrazine @ 3.00kg a.e ha^{-1}	38.25cd	295.50cd	100.00c	90.50c	1159.80bcd	322.75def
Primextra @ 3.00kg a.i ha^{-1}	36.00d	296.25cd	118.50bc	81.50c	788.00cd	341.50def
Hand weeding @ 3 and 7 WAP	66.00b	183.50d	85.75c	57.00d	537.50d	252.00ef

Means followed by the same letter in each column are not significantly different from each other by Duncan Multiple Range Test (DMRT) at 5% level of probability

Table 6 also shows the density of prominent weed species in the various treatments at 3 and 6 WAP, in 2012 respectively. At 3 WAP, *Andropogon*. *tectorum* was more prevalent in the weedy check and hand weeding at 3 and 7 WAP than the remaining treatments. Sole qlyphosate recorded the lowest density of a tectorum among the treatments, the weedy check and sole glyphosate resulted in the highest density of *A. africana* followed by both the glyphosate and paraquat treatments, atrazine and *primextra*, *C. mucunoides* was found to be most common in plots treated with sole glyphosate and glyphosate plus weeding at 7 WAP while atrazine recorded the least figure. *P. comminealis* was most prevalent in the weedy check while sole glyphosate recorded the lowest density. *P. equilinuim* and *S. acuta* were more common in the weedy check, sole glyphosate and hand weeding at 3 and 7 WAP than the remaining treatments.

The effects of the selected herbicides and weeding regimes on weed density, weed fresh weight and weed dry weight are given in Table 7. Significant differences were found in the foregoing parameters among the treatments in both years. More weed growth occurred in 2012 than 2011. In 2011, all the weeding treatments imposed resulted in weed density, weed fresh weight and weed dry weight significantly greater than the weedy check. Glyphosate and paraquat applied singly recorded much heavier weed weight than when they were supplemented with hand weeding at 4 and 7 WAP. Atrazine and primextra resulted in much lighter weed weights than glyphosate and paraquat treatments. The least weed growth was given by hand weeding at 3 and 7 WAP. A similar trend occurred in 2012, although all the treatments recorded much heavier weed weights than 2011.

In 2012, different weed species such as *Andropogon tectorum, Aspilia Africana, Calopogonium spp, Paspalum comensalis, Pteridium equilinium,* and *Sida acuta* dominates the experimental sites (Table 7 & 8). Weedy check and hand weeding at 3 and 7 WAP recorded the highest weed density. At 6 WAP, weedy check also recorded the highest weed density while glyphosate and paraquat plus weeding at 4 WAP recorded the least weed density. The effects of selective herbicide and hand weeding regimes on the fresh and dry weight of the weed species is presented in Table 7. In 2011, weed fresh weight and dry weight was higher in the weedy check and differ significantly across treatments. The results also showed that weed fresh weight and dry weight of weeds obtained from glyphosate treated plots were lower compared to the plots treated with paraquat; plots treated with atrazine, primextra, and hand weeding at 3 and 7 WAP recorded lower fresh and dry weed weight. Similar trends were also observed in 2012 cropping season. Hand weeding at 3 and 7 WAP recorded lower fresh weed weight while the weedy check recorded very high fresh and dry weights.

DISCUSSIONS

This study provides empirical evidence that glyphosate and paraquat applied singly or in combination with supplementary weeding compared favorably with atrazine, primextra or hoe-weeding in reducing total weed growth and weed dry matter, which culminated in significant increases in growth and yield parameters over the weedy check. The higher numbers of leaves per plant recorded in 2012 than in 2011 could be as a result of relative differences in weather conditions, which is more or less likely to influence herbicide actions on weed with attendant effects on crop performance. This is generally consistent with the observation that soil properties including physical, chemical, biological and environmental conditions affect herbicide action which in turn may affect crop performance through inhibition of weed growth (Akobundu, 1987).

The significant increases in maize plant height obtained with all treatments over the weedy check reflect the reduced effects of weed competition as affected by the various treatments in the experimental plots. Higher weed densities compete with maize for nutrients, soil, moisture, light and carbon dioxide and considerably reduce plant growth including plant height (Hussain, 1983). The variation in the plant height of maize in all weed control treatments could be attributed to varying effects of weed competition for available resources offered by different weed densities in different weed control practices. These results are in line with Akhtar *et al.* (1998) and Hussain *et al*. (1998). The significant increases in maize stem girth as observed in weed control plots against weedy check plots was mainly due to improved growth as a consequence of effective control of weeds and reduction in crop weed competition which might have enabled the maize crop to take up more nutrients (Babiker *et al*, 2012). The decrease in growth parameters recorded between 5 and 7 WAP such as number of leaves and stem girth may be due to the fact that the plants are now being ready to change from the growth phase to reproductive phase.

The better performance of maize in terms of growth and yields in the plots where primextra was applied might be associated with the ability of primextra to prevent weed seeds to germinate thereby favoring maize performance; this results was similar to this finding of khan *et al*, (1991) who reported that pre-emergence herbicides, metolachlor plus atrazine, pendimethaline and cyanacin plus atrazine decreased weed population and increase grain yield over weedy control. Although, most of the treatments proved highly effective in reducing weed population in treated plots compared with the weedy check, high weed density recorded in glyphosate plus hand weeding at 7 WAP indicated that delayed weeding up to 7 WAP may lead to the spread of weeds.

Glyphosate and paraquat plus weeding at 4 WAP reduced incidence of weeds than other forms of glyphosate and paraquat treatments, however hand weeding at 3 and 7 WAP significantly reduced weed growth than other treatments, this may be attributed to more mortality due to uprooting and mechanical injury sustained by weeds during weeding operation, this is in line with findings of Djurkic *et al* (1997) and Vanbijon *et al* (2007). Similar results were reported by James *et al* (2006) that all weed control practices decreased with the weed density over weedy check. The maximum density of weeds obtained in weedy check plots was due to undisturbed growth of weeds.

The differences in the percentage reduction of the weed density of *C. odorata*, *E. heterophylla*, *P. maximum*, *P. plestoschus*, and *T. triangulare* at 3 and 6 WAP all the treatments compared with weedy check indicated that each of the treatments has different rate of herbicidal effects on the weed density. This is similar to the findings of Dugjei *et al* (2008) who confirmed that grass weeds are tolerant and resistant to certain herbicides like paraquat while broad leaves are easily controlled by certain herbicides. Higher density of *C. mucuoides* in the plots treated with glyphosate singly, paraquat sole, and paraquat with supplementary weeding could be explained by ineffectiveness of these treatments in controlling *C. mucunoides*. The effectiveness of atrazine and primextra in reducing *C. odorata* and *E. heterophylla* densities than glyphosate solely or combined with hand weeding at 6 WAP indicated that the two herbicides have better residual herbicidal effects.

Glyphosate and paraquat individually combined with hand weeding at 4 WAP are more effective in controlling the six weed species identified than other treatments including weedy check which was the least. This confirms the assertion of Kandil and Kordy (2013) that herbicides combined with supplementary weeding control weeds efficiently by way of eradication and growth stunting of weeds. The differences between number of days to 50% flowering in all treatment over the weedy check and significant performances in terms of cob length and grain weight was mainly due to weed free environment for maize to perform optimally, this is in line with the assertion of Kolo *et al* (2012) who observed that application of herbicides and other weed management practices increases maize yield components. Also Kany and Knorchy (2013) confirmed that effective weed management provides water supply balanced nutrition for maize to perform optimally since there was little or no weed competition. The higher grain yield observed in 2011 and 2012 in atrazine, hand weeding at 3 and 7 WAP, glyphosate plus hand weeding at 4 WAP in that order may be largely due to weed management intervention at the appropriate time.

CONCLUSION

The findings of this study indicate that glyphosate and paraquat supplemented with hand weeding at good timing compared favourably with sole application of atrazine or primextra. These herbicides though not registered for maize cultivation has also been reported to control a broad spectrum of annual and perennial weeds in arable crops as well as protect crops against early weed competition when applied preplant. Other merits of these herbicides are that they have not been reported to leave phytotoxic residues in soil that can cause significant damage to sensitive crops in rotational cropping systems involving maize. In view of the foregoing reasons, preplant application of glyphosate and paraquat may be proposed to maize growers in the southwestern Nigeria as substitute for atrazine, which has been implicated for not providing season-long weed control in maize in this region.

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