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Evaluation of Selected Post-Emergence Herbicides for Weed Management in Maize at Different Agroecological Zones of Nigeria

Muniru B. AKADIRI[1], Olatunde P. AYODELE[2,*], Rex D. ALADESANWA[1]

[1]Department of Crop, Soil and Pest Management, The Federal University of Technology, P.M.B 704 Akure, Ondo State, Nigeria
[2]Department of Agronomy, Adekunle Ajasin University Akungba-Akoko, Ondo State, Nigeria
*Corresponding author: olatunde.ayodele@aaua.edu.ng

Abstract Effects of some post-emergence herbicides on growth and yield of maize was studied at rainforest, (7 16 N, 5 12 E) and rainforest-savanna transition (7 31 N, 5 45 E) agro-ecological zones of Nigeria. Atrazine at 3.0 g a.i/ha, nicosulfuron at 7.5 and 40 g a.i/ha, 2,4-D at 0.80 kg a.i /ha, and weedy check were laid out on the field in Randomized Complete Block Design with three replicates. Data collected were subjected to Analysis of variance (ANOVA) using Minitab 17 statistical software. Treatments mean were separated using Turkey test (P= 0.05). Results revealed that herbicides reduce the effect of weed competition, thereby allowing crop to perform optimally. Excellent weed control by density, weed fresh weight and weed dry weight occurred with nicosulfuron treatments, followed by 2,4-D and atrazin. However, atrazine is more effective than 2,4-D in reducing weed growth in rainforest agro-ecology. Nicosulfuron was more effective for weed control than other herbicides in both agro-ecologies of Nigeria and was recommended for successful weed management.

Keywords: *herbicides, maize, weed control, nicosulfuron*

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1. Introduction

Maize *(Zea mays* L.*)* is a member of the grass family *Poaceae,* that is cultivated in the rainforest and derived savannah zones of Nigeria. It was a subsistence crop that gradually risen to become a commercial crop that serves as raw materials for many agro-based industries [1]. A total production of about 7.2 million metric tonnes of maize was reported in 2016 in Nigeria, rating the country as the 15th most important world producer of maize and the second highest in Africa after South Africa [2].

Increase in maize production in Nigeria has been achieved greatly through expansion of cultivated land area rather than increase in yield per hectare [3]. Weed infestation is of supreme importance, among various factors responsible for maize low yield per hectare. Excessive growth of weeds in maize field leads to 66 - 80% reduction in crop yield [4]. Weeds reduce crop yield by competing for light, water, nutrients and carbon dioxide. Therefore, weed control in maize fields is very essential in obtaining good harvest.

Many studies have shown the usefulness of herbicides for weed control in maize [5,6,7]. In Nigeria, atrazine, nicosulfuron and 2-4 D are popular post-emergence herbicides used in maize production among others. The chemical structures of these herbicides are presented in Figure 1. Atrazine, 2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine, is a selective systemic herbicide that has both knockdown and residual effects [8]. Hence, it functions as pre-emergence and early post-emergence herbicide. The mechanism of action of atrazine involves the blocking of the Hill reaction and Photosystem II during the non-cyclic electron flow in photosynthesis [9].

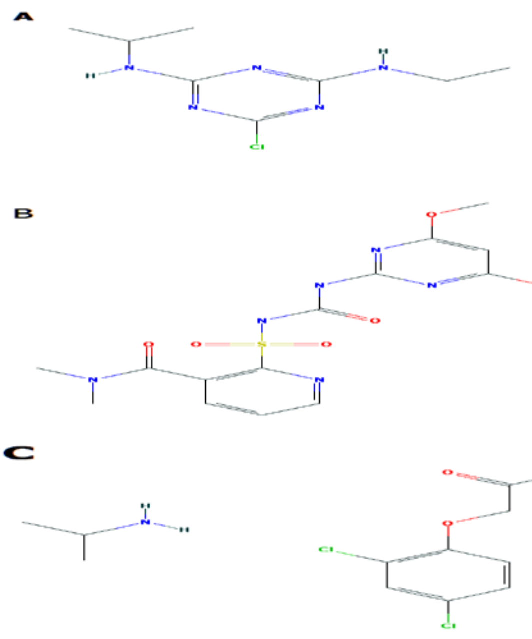

Figure 1. Chemical structure of Atrazine (**A**), nicosulfuron (**B**) and 2-4 D (**C**). The molecular Formulae are $C_8H_{14}ClN_5$ **(A)** $C_{15}H_{18}N_6O_6S$ **(B)** and $C_{11}H_{15}Cl_2NO_3$ **(C)**

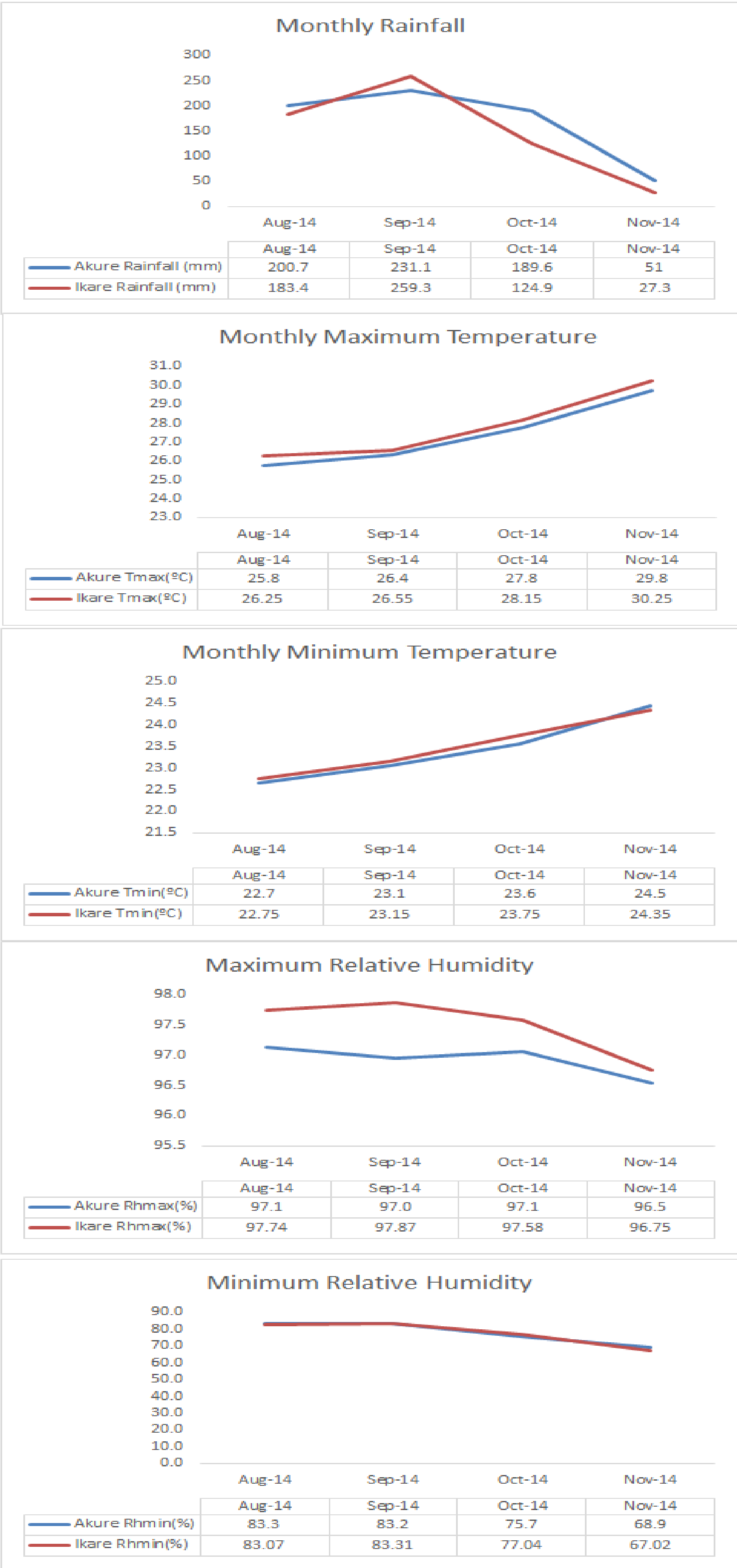

Figure 2. Weather information of Akure and Ikare Sites from August 2014 – November 2014. Source: Climate Research Unit, University of East Anglia, Norwich, UK [17]

Nicosulfuron, 1-(4,6-dimethoxypyrimidin-2-yl)-3-(3-dimethylcarbamoyl-2-pyridylsulfonyl) urea, is also a selective systemic herbicide. Uniquely, this sulfonylurea herbicide displays genera-selectivity [10]. Therefore, it is effective at controlling narrow-leaf weeds, even some members of *Poaceae* family that are closely related to maize and broad-leaf weeds. Maize can metabolise nicosulfuron into harmless compounds by converting the parent herbicide to non-phytotoxic 5-pyrimidine-OH metabolite [11]. The mode of action of nicosulfuron is based on the inhibition of acetolactase synthase, a key enzyme required for cell division and plant growth [12].

2,4-Dichlorophenoxyacetic acid, commonly known as 2,4-D, is an herbicide in the phenoxy class of chemicals [13]. Its formulations include acids, esters and several salts. These formulations vary in their chemical properties, environmental behaviour and to a lesser extent toxicity [14]. Dimethyl-amine salt and 2-ethylhexyl ester forms account for approximately 90-95% of the total global use [15]. 2,4-D is effective on wide variety of broadleaf weeds, while its effect is mild on grasses. [16]. Its mode of action in pant involves uncontrolled cell division in vascular tissue resulting from abnormal increases in cell wall plasticity, biosynthesis of proteins, and production of ethylene [16].

The climatic elements of rainforest and rainforest-savanna transition agroecological zones of Nigeria vary (Figure 2) [17]. Also, herbicidal efficacy is influenced by weed specie, herbicide concentration, herbicide type and climatic elements [18], therefore this research work aimed at studying the response of maize to the weed control offered by the post-emergence application of atrazine, nicosulfuron and 2-4 D in rainforest and rainforest-savanna transition agroecological zones of Nigeria.

2. Materials and Methods

Field experiment was conducted in two different locations; the Teaching and Research Farm of The Federal University of Technology, Akure (7 16 N, 5 12 E) and Farm Service Centre, Ikare Akoko (7 31 N, 5 45 E), located in rainforest and rainforest-savanna transition agroecology of southwestern Nigeria respectively.

Experimental site in these locations were ploughed, harrowed and marked out into plots in Randomized Complete Block Design (RCBD) with three replicates. The size of each plot was 2m x 3m with a 50cm alleyway between the plots and 1m between the blocks. Analysis of the soil physiochemical properties was carried out in the soil laboratory of Department of Crop, Soil and Pest Management, The Federal University of Technology Akure, using soil samples collected from the experimental sites at the depth of 0 - 15cm before sowing.

Maize seeds were obtained from the International Institute of Tropical Agriculture (IITA) Ibadan. The seeds were treated with Apron plus before sowing on 28th and 30th of August 2014 at the Teaching and Research Farm (Crop section) of the Federal University of Technology, Akure and Farm Service Centre, Ikare Akoko Ondo State respectively. Two seeds were sown per hole at a spacing of 75cm x 25cm which was later thinned to one plant per stand at 2 weeks after planting. Experimental treatments comprised of four herbicide treatments (Atrazine at 3.0 g a.i/ha, Nicosulfuron at 7.5g a.i/ha, 2, 4-D at 0.80 kg a.i/ ha, and Nicosulfuron at 40 g a.i/ha) and a weedy check.

Preliminary weed assessment was conducted before herbicide application to determine the weed spectrum, density and weight of total weed as well as individual weed species. Weed samples were collected and analysed for the foregoing parameters from two 50 x 50cm quadrats fixed along a diagonal in each plot. Herbicide treatments were applied with a knapsack sprayer fitted with prolijet nozzles calibrated to deliver 250 l/ha of the spray solution at a pressure of 2.5 kg/cm^3 at 2 weeks after planting. The field borders were kept clean to minimize encroachment by insects and rodents. Subsequently, weed control assessment was carried out at six (6) weeks after treatment (WAT) application. At this stage, weed samples were collected from two 50 x 50cm quadrat fixed along the second diagonal of each plot. Collected weed samples were bulked, separated by species, counted, oven- dried at 80°C for 48 hours and weighed.

Percentage herbicidal efficacy on total and individual weed populations was determined using the Henderson-Tilton formula [19] based on non-uniform weed infestation in the plots before application. Henderson-Tilton's formula correct arithmetically the various intial weed infestation numbers without separating sampling errors from the actual differences in infestation [20]. The same formula used for calculating herbicidal efficacy on weed density was adopted for computing efficacies on both weed fresh weight and weed dry weight.

Data collection on maize growth parameters started three weeks after planting. Growth and yield parameters recorded at different stages of crop growth and development were: Plant height, number of leaves, stem girth, leaf area, cob length, cob girth, number of grains per ear, weight of grains per cob, weight of grain per plot, weight of 1000-grain and grain yield. These parameters were determined in the following ways: Plant height was taken from a sample of ten selected maize plants marked within each plot. Similarly, other growth and yield parameters were determined using the arithmetic mean of these sample plants. Leaf area was calculated by non-destructive method using the length and the width of the leaves and the correction constant prescribed by Saxena et al. [21]. Weight of grains per plot was obtained from the grains of ten ears in each treatment. 1000-grain weight was determined by randomly selecting and weighing 1000 grains from each plot.

Data collected from both crop and weed components were subjected to analysis of variance (ANOVA). Counted and percentage data were normalized prior to ANOVA using square root and arcsine transformations respectively. Turkey test at 5% level of probability was used for the treatment mean separations.

3. Results

The chemical and physical composition of the top soil at the depth of 0-15cm is shown in Table 1. Soil particle fractions showed that the soil texture of the locations are sandy clay loam, that is low in organic content The soil in Ikare location has lower organic carbon, total N, available P, and exchangeable K than that of Akure location.

Table 1. Pre-planting physical and chemical properties of soil used in the two locations

Soil Physio-chemical Properties	Locations	
	Ikare	Akure
Sand (g/kg)	84.4	85.4
Silt (g/kg)	6.3	4.3
Clay (g/kg)	9.3	10.3
pH (H_2O)	7.0	7.3
Organic carbon (%)	1.8	2.4
Total N (%)	0.5	0.7
Ogarnic matter (%)	2.9	4.1
K (cmol/kg)	0.04	0.1
Ca (cmol/kg)	1.7	3.4
Mg (cmol/kg)	1.0	2.1
P (mg/kg)	6.6	8.0
Na (cmol/kg)	0.7	0.5

The preliminary weed assessment conducted before treatment application revealed the following predominant weed species in descending order at Akure site; Euphorbia heterophilla, Mariscus alternifolius, Ageratum conyzoides, Talinum fruticosum, Amaranthus spinosus, Aspilia africana, Eleusine indica and Biden pilosa. In lkare, the predominant weed species were Euphorbia heterophylla, Ageratum conyzoides, Panicum maximum and Eleusine indica (Table 2).

Prior to treatment application, more weed infestation was recorded at Akure than Ikare in the experimental plots. The effects of herbicide treatments on weed growth as determined by weed density, weed fresh weight and weed dry weight at six weeks after treatment application in both locations are summarized in Table 3. There were significant differences in weed density, weed fresh weight and dry weight in both locations amongst the treatments with the weedy check consistently recording the highest value and nicosulfuron treatments recording the least. Plot sprayed with atrazine recorded higher weed density in Ikare than in Akure. In contrast, plot that received nicosulfuron treatments and 2,4-D had lower weed densities in Ikare than Akure. The weedy check plot at Akure site recorded higher weed density when compared with Ikare site that is characterized with higher weed weight.

Assessment of herbicidal efficacy based on the Herderson – Tilton formular showed that there were significant differences amongst treatments in term of percentage weed controlled by density, weed fresh weight and weed dry weight (Table 4). Excellent weed control as measured by density, weed fresh weight and weed dry weight occurred with the nicosulfuron treatments, followed by 2,4-D and atrazine in Ikare while atrazine proved to be significantly more effective than 2,4-D in reducing weed growth in Akure. In both site, nicosulfuron treatments recorded the highest weed control efficacies.

There were significant differences among the treatments base on the density of individual weed species recorded in both locations (Table 5 and Table 6). Excellent control of all the prominent weed species with the exception of Talinum fruticosum was achieved with nicosulfuron treatments while atrazine and 2,4-D treatments were not effective against all weed species. Atrazine was not effective against Panicum maximum and Mariscus alternifolius at the Ikare location. Similarly, 2,4-D proved ineffective against Euphorbia heterophylla and Mariscus alternifolius at both locations.

Table 2. Weed flora composition and density before and after treament application at the experimental sites

S/No	Weed Species	Family	Growth Form	Weed Density (plant/m2) Ikare		Weed Density (plant/m2) Akure	
				Before	After	Before	After
1	*Euphorbia heterophyilla*	Euphorbiaceae	ABL	474	23	255	64
2	*Mariscus alternifolius*	Cyperaceae	PS	11	51	137	66
3	*Ageratum conyzoides*	Asteraceae	ABL	11	51	88	43
4	*Talinum fruticosum*	Portulacaceae	ABL	1	128	80	-
5	*Amaranthus spinosus*	Amarathaceae	ABL	-	-	59	2
6	*Aspilia africana*	Compositae	ABL	-	40	30	-
7	*Eluesine indica*	Poaceae	AG	-	19	24	-
8	*Panicum maximum*	Poaceae	PG	1	128	21	55
9	*Biden pilosa*	Asteraceae	ABL	-	108	13	1
10	*Chromolaena odorata*	Asteraceae	ABL	-	15	4	-
11	*Calopogonium mucunoides*	Fabaceae		-	11	-	3
12	*Synedrella nodiflora*	Asteraceae	ABL	-	35	-	-
13	*Phasalis angulata*	Asteraceae		-	4	-	-
14	*Tridax procumbense*	Asteraceae	ABL	-	20	-	-
15	*Sida acuta*	Malvaceae		-	7	-	-
16	*Mariscus flaberlliformis*	Legummoceae	PS	-	6	-	-
17	*Eragrostis tenella*	Poaceae	AG	-	113	-	-

ABL = Annual Broad Leaf, PBL = Perennial Broad Leaf, PG = Perennial Grass, PS = Perennial Sedges, AG = Annual Grass, PSP = Perennial Sedge

Table 3. Weed density, weed fresh weight and dry weight at six weeks after treatment application

Treatment	Weed density (plants/m^2)		Weed fresh weight (g/m^2)		Weed dry weight (g/m^2)	
	Ikare	Akure	Ikare	Akure	Ikare	Akure
Atrazine @ 3.0 g a.i/ha,	55.0b	38.0c	205.0b	145.0c	51.3b	29.2c
Nicosulfuron @7.5g a.i/ha	0.0d	13.1d	0.0d	19.0d	0.0d	4.2d
2,4-D @ 0.80 kg a.i/ ha	47.1c	60.6b	146.7c	189.5b	35.8c	37.8b
Nicosulfuron @ 40g a.i/ha	0.0d	15.2d	0.0d	9.1e	0.0d	4.6d
Weedy check	121a	134.0a	483.0a	413.1a	116.4a	81.0a

Means with the same letters wthin a column are not significantly different according to Tukey test (P= 0.05).

Table 4. Percentage herbicidal efficacy based on Henderson- Tilton formula at six weeks after treatment application

Treatment	% Control by density		% Control by fresh weight		% control by dry weight	
	Ikare	Akure	Ikare	Akure	Ikare	Akure
Atrazine @3.0 g a.i/ha,	50.36c	71.62c	57.6c	64.9c	55.9c	64.0b
Nicosulfuron@7.5g a.i/ha	100.0a	90.3a	100.0a	95.4b	100.0a	94.8a
2,4-D @ 0.80 kg a.i/ ha	61.1b	54.8d	69.6b	54.1d	69.2b	53.3c
Nicosulfuron @ 40g a.i/ha	100.0a	88.6b	100.0a	97.8a	100.0a	94.3a
Weedy check	0.0d	0.0d	0.0d	0.0e	0.0d	0.0d

Means with the same letters within a column are not significantly different according to Tukey test (P= 0.05).

Table 5. Herbicidal efficacy (%) on individual weed species based on percent control by density at Ikare

Treatment	*E. heterophylla*	*A. conyzoides*	*P. maximum*	*M. alternifolius*	*Bryophilum*
Atrazine @ 3.0 g a.i/ha,	100.00a	55.00c	33.33c	43.75b	39.23b
Nicosulfuron @ 7.5 g a.i/ha	100.00a	100.00a	100.00a	100.00a	100.00a
2,4-D @ 0.80 kg a.i/ ha	46.68b	77.50b	50.00b	31.25c	100.00b
Nicosulfuron @ 40g a.i/ha	100.00a	100.00a	100.00a	100.00a	100.00a
Weedy check	0.00c	0.00d	0.00d	0.00d	0.00c

Mean in a column followed by the same letter(s) are not significantly different according to Tukey test (P=0.05).

Table 6. Herbicidal efficacy (%) on individual weed species based on percent control by density at Akure

Treatment	*A. Spinosus*	*E. heterophylla*	*T. fruticosum*	*M. alternifoliuos*	*P. maximum*	*A. conyzoides*	*A. africana*
Atrazine @ 3.0 g a.i/ha,	88.10b	69.23b	33.33b	72.84b	87.85b	100.00a	50.00b
Nicosulfuron @7.5 g a.i/ha	100.00a	100.00a	31.82c	100.00a	100.00a	100.00a	100.00a
2,4-D @0.80 kg a.i/ ha	56.70c	46.23c	36.56a	59.09c	38.46c	46.56b	100.00a
Nicosulfuron @ 40g a.i/ha	100.00a	100.00a	20.45d	100.00a	100.00a	100.00a	100.00a
Weedy check	0.00d	0.00d	0.00e	0.00d	0.00d	0.00c	0.00c

Mean in a column followed by the same letter(s) are not significantly different according to Tukey test (P=0.05).

Table 7. Effects of herbicides treatment on the growth parameters of maize in Ikare

Treatments	Plant height^{-1} (cm)			Number of leaves plant^{-1}			Stem girth plant^{-1} (cm)		
	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
Atrazine @ 3.0 g a.i/ha,	30.02a	122.32ab	159.92c	6.38b	10.29ab	11.91a	1.41a	2.08ab	2.20b
Nicosulfuron @7.5 g a.i/ha	33.96a	134.56a	198.52a	6.87ab	10.38ab	12.62a	1.55a	2.18a	2.53a
2,4-D @ 0.80 kg a.i/ ha	30.02a	110.43b	159.92c	6.50ab	9.60b	11.71a	1.46a	1.93b	2.07b
Nicosulfuron @ 40g a.i/ha	34.90a	129.99ab	192.01ab	7.12a	10.64a	12.58a	1.54a	2.06ab	2.53a
Weedy check	21.33b	70.38c	119.30d	5.43c	7.88c	9.48b	1.20b	1.64c	1.87c

Mean in a column followed by the same letter(s) are not significantly different according to Tukey test (P= 0.05).

Table 8. Effects of herbicides treatment on the growth parameters of maize in Akure

Treatments	Plant height^{-1} (cm)			Number of leaves plant^{-1}			Stem girth plant^{-1}(cm)		
	3 WAS	6 WAS	9 WAS	3 WAS	6WAS	9 WAS	3 WAS	6 WAS	9 WAS
Atrazine@ 3.0 g a.i/ha	23.03bc	88.13bc	170.94bc	6.18a	8.71a	8.31b	1.17bc	1.85b	2.11a
Nicosulfuron@7.5ga.i/ha	29.16a	111.02a	202.61a	6.47a	9.09a	9.85a	1.52a	2.32a	2.27a
2,4-D @ 0.80 kg a.i /ha	22.70bc	85.74bc	163.83c	6.29a	8.61a	8.61ab	1.24bc	1.95ab	2.22a
Nicosulfuron @40g a.i/ha	27.19ab	108.90ab	192.09ab	6.21a	8.71a	9.30ab	1.43ab	2.22ab	2.22a
Weedy check	19.10c	66.34c	126.58d	4.79b	8.26a	6.66c	0.99c	1.35c	1.55b

Means with the same letters within a column are not significantly different according to Tukey test (P= 0.05).

Table 9. Effects of herbicide treatments on maize yield parameters in Ikare

Treatments	Grain weight (g)	1000 grain weight (g)	Cob weight (g)	Cob girth (cm)	Cob length (cm)
Atrazine @3.0 g a.i/ha	825.00a	253.33a	109.53bc	42.71a	13.89b
Nicosulfuron@ 7.5g a.i/ha	830.11a	270.11a	135.44a	44.97a	14.80a
2,4-D @ 0.80 kg a.i/ ha	817.67a	252.22a	100.14bc	41.96a	13.03c
Nicosulfuron @ 40g a.i/ha	819.17a	266.11a	121.51ab	44.39a	14.53ab
Weedy check	746.93b	212.33b	91.66d	34.71b	10.35d

Means with the same letters within a column are not significantly different according toTukey test (P= 0.05).

Table 10. Effects of herbicide treaments on the yield parameters of maize in Akure

Treatments	Grain weight (g)	**1000**-grain weight (g)	Cob weight (g)	Cob girth (cm)	Cob lenght (cm)
Atrazine@ 3.0 g a.i/ha,	382.56b	232.33ab	171.34c	44.09c	15.87b
Nicosulfuron @7.5 g a.i/ha	568.44a	260.56a	211.11a	48.47a	17.86a
2,4-D @0.80 kg a.i /ha	381.56b	221.11bc	173.57bc	44.92bc	16.07b
Nicosulfuron @ 40g a.i/ha	486.33ab	242.78ab	201.25ab	47.14ab	17.60ab
Weedy check	231.44c	197.78c	134.82d	39.00d	13.05c

Means with the same letters wthin a column are not significantly different according to Tukey test (P= 0.05).

Furthermore, the control of *Euphorbia heterophylla, Talinum fruticosum*, *Panicum maximum* and *Ageratum conyzoides* with 2,4-D was extremely poor.

Effects of herbicide treatments on plant height, number of leaves per plant and stem girth of maize in both locations were presented in Table 7 and Table 8. Significant increase in growth parameters over the weedy check were obtained for all the treatments throughout the eveluation period across location. The nicosulfuron treatments were more effective than atrazine and 2,4-D in their effects on maize growth parameters.

Also, herbicide treatments resulted in significantly higher yield of maize than the weedy checks in both locations. Maize plots treated with nicosulfuron consistently gave higher yield in term of grain weight, 1000 grain weight, cob weight, cob girth and cob length while the least yield parameters was recorded in weedy checks. (Table 9 and Table 10).

4. Discussion

The study demonstrated that herbicides treatment is critical for optimum growth and yield of maize. It also confirmed the potential of nicosulfuron a sulfonylurea herbicide as an effective and suitable post-emergence herbicides in controlling weeds in maize field. More weed growth occurred in Akure than Ikare location as a result of favourable weather conditions which were more conducive to prolific weed growth.

The significant differences recorded amongst the treatments in herbicidal efficacy on individual weed species showed that there was considerable variation among the weeds in term of relative susceptibility. It is evident from the results that all the three herbicides reduced weed infestation in the maize crop in comparison to weedy check. However, the highest control of weeds was obtained from Nicosulfuron while 2,4-D and atrazine did not give a satisfactory control. Nicosulfuron was highly effective in reducing the number of weed species while 2,4-D and atrazine were less efficient. The low herbicidal efficacies recorded in all herbicide treated plots with respect to *Talinum fruticosum* may be related to the poor permeability of herbicides into this weed [22]. This result is in accordance with Aladesanwa and Ayodele [17], who reported the tolerance of *Talinum triangulare* to the synergetic actions of glyphosate and paraquat mixtures. Weed number per meter square was highest in weedy check plots and lowest in herbicide treated plots. This agrees with the findings of Fathi et al., [23], Khan *et al.*, [24] who reported same. It is an indication that herbicides can reduce weed infestation.

The increase recorded in herbicide treatments in terms of plant height, number of leaves and stem girth over that of weedy check indicates that increase in weed density led to serious competition for available nutrients, space, moisture and light. This might have retarded the growth of maize for these growth parameters. This observation is similar to the report of Anwar *et al.* [25] that weed competition effect is reflected in poor crop establishment. Plant height reflects the efficiency of plant for photosynthetic radiation interception and vegetative growth character of crop plants in response to applied inputs. Higher plant height recorded at maturity in herbicide treated plots could be attributed to less weed competition compared to weedy check. This is in line with the report of Hassan *et al*. [5], that maize plant height was comparatively higher in plots sprayed with herbicides than control plots where no herbicide was sprayed.

Grain yield of cereal crops depends on the 1000-grain weight. The higher 1000-grain weight recorded in herbicide treated plots implies that vigorous growth and development of maize plant resulted in more photosynthates assimilation in the grains. This agrees with the findings of Hussain *et al*. [26] and Baye and Bouchache [27], who concluded that 1000-grain weight of maize was greater in various weed control treatments than in weedy check.

Cob length is also a very important factor determining maize yield. The longer the cob length, the more the number of grains per cob and consequently, the higher the grain yield. Nicosulfuron plots had the highest cob length due to the timely and efficient control of weeds. Thus, less weed competition period in these treatments allowed maize plant to produce more photosynthetic material by using available nutrients. This result agrees with that of Stefanovic *et al*. [28] that found greater cob length in weed control treatments and smallest cob length in weedy check plots.

Grain yield is also a function of the number of cobs per plants and the number of grains per cob. Greater values recorded for these parameters in herbicide treated plots imply that decrease in weed density favours these parameters. The lowest grain yield that was recorded in weedy check could be attributed to the associated highest weed density and the concomitant greatest competition for moisture, light and nutrients that suppressed the growth and development of maize.

The efficiency of various chemicals and other weed control practices in enhancing grain yield had also been observed by Toloraya *et al*. [7] and Stefanovic *et al*. [28]. In this study, all the yield parameters were statistically different from weedy check. This indicates that when weeds are controlled at early stages of plant development, weed competition with crop are reduced.

5. Conclusion and Recommendation

Weed control through herbicides application contributed immensely to the growth and yield of maize by reducing the competition offered by weed growth. Therefore, the use of nicosulfuron in rainforest and rainforest-savannah transition agroecological zones of Nigeria is recommended for successful weed control and increase in grain yield of maize.

References

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

[2] Shiyam, J. O., Garjila, Y. A. & Bobboyi, M., (2017). Effect of Poultry Manure on Growth and Yield of Maize (Zea mays Var Praecox) in Jalingo, Taraba State, Nigeria. Journal of Applied Life Sciences International, 10 (4), pp. 1-6.

[3] Amudalat, B., (2015). Maize: Panacea of hunger in Nigeria. *African Journal of Plant Science*, 9 (3), pp. 155-174.

[4] Adigun, J.A., (2001). Control of weeds with pre-emergence herbicides in maize-pepper mixture in the Nigerian northern Guinea Savanna: Journal of Sustainable Agriculture and Environment, pp. 378-383.

[5] Hassan, G., Tanveer, S., Khan, N.U. and Munir, M., (2010). Integrating cultivars with reduced herbicide rates for weed management in maize. *Pakistan Journal of Botany*, 42(3), pp. 1923-1929.

[6] Singh, D., Tyagi, R.C. and Agarwal, S.K., (1998). Weed Control Methods in Spring Maize. Haryana *Agric. Uni. J. Res.*, 28(1), pp. 21-25.

[7] Toloraya, T.R., Malakanova, V.P. and Akhtyrtsev, M.G., (2001). Effectiveness of dates, methods and doses of applying zinc sulphate and its combination with the selective herbicides (Titus) in maize sowings. Kukuruza-I-Sorgo, 2, pp. 5-7.

[8] Olabode, O.S., Adesina, G.O., and Babajide, P.A., (2010). Weed control efficiency of reduced atrazine doses and its effect on soil organisms in maize (Zea mays L.) fields of south western Nigeria. *Journal of Tropical Agriculture* 48 (1-2), pp 52-54.

[9] Aladesanwa, R.D., Adenawoola, A.R., and Olowolafe, O.G., (2001). Effects of atrazine residue on the growth and development of celosia (Celosia argentea) under screenhouse conditions in Nigeria, *Crop Protection 20*, pp. 321-324.

[10] O'Sullivan J., Sikkema P.H. and Thomas R.J., (2000) Sweet corn (Zea mays) cultivar tolerance to nicosulfuron. *Canadian. Journal of Plant Science,* 80, pp. 419-423.

[11] Sun, L., Wu, R., Su, W., Gao, Z. and Lu, C. (2017). Physiological basis for isoxadifen-ethyl induction of nicosulfuron detoxification in maize hybrids. PloS one, 12(3), e0173502.

[12] Russell, M. H., Saladini, J. L., & Lichtner, F., (2002). Sulfonylurea herbicides. *Pesticide Outlook*, 13(4), 166-173.

[13] Tomlin, C. D. S., (2006). The Pesticide Manual: A World Compendium, 14th ed.; British Crop Protection Council: Surrey, UK.

[14] WHO (1989). Environmental Health Criteria 84, Environmental Aspects - 2,4-Dichlorophenoxyacetic acid (2,4-D); International Programme on Chemical Safety, World Health Organization: Geneva, Switzerland.

[15] Charles, J. M., Hanley, T. R., Wilson, R. D., Van Ravenzwaay, B. and Bus, J. S., (2001). Developmental Toxicity Studies in Rats and Rabbits on 2,4-Dichlorophenoxyacetic Acid and its Forms. *Toxicological. Science*, 60, pp. 121-131.

[16] Vencill, W. K., (2002). *Herbicide Handbook* 8th ed. Weed Science Society of America. pp 113-115.

[17] CRU (2017) Climate Research Unit, University of East Anglia, Norwich, UK. *http://www.cru.uea.ac.uk/data*

[18] Aladesanwa, R.D. and Ayodele, O.P., (2011). Weed Control in the Long-Fruited Jute (Corchorus olitorius L.) with Paraquat alone and in combination with Glyphosate at varying doses including their effects on its growth, development, yield and nutritional quality in South-western Nigeria. *Applied Tropical Agriculture*, 15: (1 & 2) pp. 65-75.

[19] Puntener, W., (1981). Manual for Field Trials in Plant Protection.Ciba-Geigy Limited, Basle, Switzerland 205 pp.

[20] Aladesanwa, R.D. and Oladimeji, M.O., (2005). Optimizing herbicidal efficacy of glyphosate isopropylamine salt through ammonium sulphate as surfactant in oil palm (*Elaeis guineensis*) plantation in a rainforest area of Nigeria. *Crop Protection*, 24 (12), pp. 1068-1073.

[21] Saxena, M.C. and Singh, Y., (1965). A note on leaf area estimation of intact maize leaves. Indian Journal of Agronomy, 10, pp. 437-439.

[22] Rola, H., Badowski, M., Bekierz, G. and Naraniecki, B., (1999). Influence of IR-516 on the enhance efficacy of sulfonylurea herbicides-Apyros 75 WG, Chisel 75 WG, Titus 25 WG, Safari 50 DF, *Journal of Plant Protection Research*, 39(2), pp. 639-641.

[23] Fathi, G., Ebrahimpoor, F. and Siadat, S.A., (2003). Efficiency of single and integrated methods (chemical-mechanical) for weed control in Corn SC704 in Ahvaz climatic conditions. *Iran. Journal. Agricultural Science*, 34(10), pp. 187-197.

[24] Khan, M.A., Marwat, K.B., Hassan, G. and Khan, N., (2002). Impact of weed management on maize (Zea mays L.) planted at night. *Pakistan Journal of Weed Science Research*, 8(1-2), pp. 57-62.

[25] Anwar, S.A., Zia, A., Hussain, M. and Kamran, M., (2007). Host suitability of selected plants to Meloidogyne incognita in the Punjab, Pakistan. International Journal of Nematology, 17(2), p. 144.

[26] Hussain, M., Jamshaid, E. and Akhtar, K., (1998). Response of maize (Zea mays L.) cv." Golden" to different doses of some pre-emergence herbicides. *Journal of Animal and Plant Sciences*, 8 pp. 41-42.

[27] Baye, Y. and Bouhache, M., (2007). Study of the competition betwenn silverleaf nightshade (Solanum elaeagnifolium Cav.) and spring maize (Zea mays L.). *French. Bulletin OEPP/ EPPO Bulletin, 37*, pp. 129-131.

[28] Stefanovic, L., Milivojevic, M., Husic, I., Samic, M. and Hojka, Z., (2004). Selectivity of the sulfonylurea herbicide group in the crop of commercial KL maize inbred lines. Institute-ze-Kukuruz, Herboglia, Serbis and Montenegro, 5 (1), pp. 53-63.