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Weed Control in Maize (*Zea mays*) with Reduced Rates of Herbicides Mixture and Tillage Methods

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Abstract—*Ineffective weed control due to inadequate household labour, constitutes major factor causing poor maize grain yields among small scale farmers in Nigeria. Use of herbicides is a very promising alternatives but the detrimental effects of herbicides on soil, water bodies, crop products and applicators are reasons for reduced and responsible usage.. However, there is little information on herbicides rates under various tillage regimes in North-Eastern Nigeria. A field experiment was conducted at the College of Agriculture Teaching and Research Farm, Jalingo, Taraba State, Nigeria between 2007 and 2009, to evaluate herbicides rates and tillage methods using split plot design. Tractor Tillage (TT) and Manual Tillage (MT) were the main plots. Herbicides, as sub-plot factors, included 100, 75, 50 and 25% recommended rates of 2.0 + 2.0 ai kg/ha Atrazine + Pendimethalin (AP_4, AP_3, AP_2, AP_1) and 2.5 ai kg/ha of Primextra (PX_4, PX_3, PX_2, PX_1). Data on growth and yield parameters of maize, weed density (WD) and biomass as well as weed control efficacy were collected and subjected to analysis of variance (ANOVA) with mean separated using DMRT at 5% probability level. Weed control from herbicide treatments were 10.0% higher under MT than TT. The WD was significantly higher (32.7%) in TT than MT. Weed control was not significantly improved when higher rates of herbicides were applied. Though Atrazine-Pendimenthalin and primextra can be reduced to 25.0% recommended rate without significant reduction in weed control, highest maize grain yield. of 3203.2 kg/ha was obtained in the 50 % (AP_2.) rate and thus recommended.*

Keywords*: Herbicide mixture, Reduced rate, Tillage, Maize*

1. INTRODUCTION

Agriculture in the developed economy passed through the chemical age before achieving commercialized scale [21, 16] The economic advantage of chemical weed control over hoe-weeding in the production of various crops in Nigeria has been reported [38, 31, 20, 1]. However, [22] observed that preemergence herbicides such as atrazine, pendimethalin and primextra are applied without regard to weed population, and some of these applications may not be necessary [35, 12]. Herbicides used in maize have been among the pesticides most frequently detected in ground water [26, 37] and may adversely affect the environment (land, water, crop and Livestock product) as well as reproductive potential in human [17]. These call for a reduction in the level of herbicide usage without significantly reducing its effect on weed. The possibility of using lower than labelled herbicide doses for weed control has been reported [2, 8, 43, 23, 41, 13].This is yet to be investigated in Taraba State

Another important factor in maize production is the choice of type of tillage method (which includes conventional, single ploughing, hoe-mechanized ridging, animal drawn tillage/ploughing, zero tillage, e.t.c). The intensity and method of tillage affect weed seed bank, weed density, weed shift, herbicide dosage and efficacy [15, 4, 36] as well as crop establishment [28, 14]. Integrated Weed Management (IWM) is the best, as no one single weed control method can give adequate solution. The most appropriate IWM system is integrating crop competitiveness with reduced herbicidal mixture and optimum dosage which could control weed in maize effectively without environmental pollution and soil erosion [5]. Information on the impact of various herbicide mixtures under different tillage systems is needed for developing a reliable integrated weed management.

Given, this challenge, field experiments were conducted at Jalingo, Taraba State, north-eastern Nigeria between 2007 and 2009 to Assess the effectiveness of reducing rate (100,75, 50 and 25 %) of selected herbicides mixtures (atrazine-pendimethalin or primextra) under manual and tractor tillage methods on weed control and performance of maize.

2. MATERIALS AND METHODS.

The Field trials were conducted at the Teaching Farm of Taraba State College of Agriculture (08^0 50' N, 11^0 50' E) Jalingo in the northern Guinea savanna ecological zone. Jalingo has a wet and dry tropical climate with rainy season of about 150 days and an average annual rainfall of about 700 mm – 1000 mm. Mean annual temperature of Jalingo is about 28^{o}C with maximum temperature ranges between 30 ^{o}C and 39.4^{o}C and minimum temperature range between 15^{o}C to 23^{o}C. Annual rainfall was 903.4, 808.9 and 1063.2 mm for 2007, 2008 and 2009 respectively. The rainy season is between May and October while the dry season is from November to April. The soil is derived from Calcareous rocks in ferro-magnisium mineral-lithomorphic vertisols.

Maize seeds, an open pollinated and early maturing variety 95-TZEE-W1 were collected from International Institute of Tropical Agriculture (IITA), Ibadan. This was the test crop in all the plots.

The land used for the experiment was cleared manually using cutlass to reduce the few shrubs scattered on the field. The fields were laid out in two strips, Manual Tillage (MT) and Tractor Tillage (TT). Ploughing was done on strips in alternate replicates. Manual tillage was accomplished using big hand-held hoes to make 4 ridges per plots of 4m x 4m.

The experiment was laid out using a randomized complete block design with a split plot arrangement and replicated three times. Tillage systems (Tractor Tillage (TT) and Manual Tillage (MT)) were the main plot treatments. Herbicide rates constituted sub-plot treatments at 100, 75, 50 and 25% recommended rates of 2.0 + 2.0 ai kg/ha Atrazine + Pendimethalin (AP_4, AP_3, AP_2, AP_1) and 2.5 ai kg/ha of Primextra (PX_4, PX_3, PX_2, PX_1) . Plots that were hand-weeded 3+6 weeks after planting (WAP) and unweeded plots were controls. Atrazine(6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine) formulation used was 50% SC (500g/L), pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) as pendilin was 500 EC while primextra (atrazine (290g/L) + metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)-acetamide (370g/L)) Gold, with 660g a.i./L.

Maize seeds were sown on 16^{th}, 30^{th} and 12^{th} June in 2007, 2008 and 2009 respectively. Maize was sown three seeds per hole at 25cm x 100cm spacing, to give a population of 40,000 plants/ha in all the plots and the seedlings were latter thinned to one plant per stand. The plot size was 4m x 4m. There were 64 stands of maize per plot (i.e 4 rows of 16 stands/ row). Maize cobs were harvested dry on 1^{st}, 12^{th} (14 WAP) and 2^{nd} (16 WAP) October of 2007, 2008 and 2009 respectively and shelled.

The preemergence herbicides, atrazine + pendimethalin or primextra was mixed to give 100, 75, 50 or 25 percent rates based on the treatments and applied within 48 hours of planting of maize with a CP 15 knapsack sprayer calibrated to deliver 300 L ha^{-1} spray solution.

Manual weeding was carried out at 3 and 6 WAP on hand-weeded control plots, fertilizer application and harvest of maize were as in experiment 1. Manual weeding was carried out twice at 3 and 6 WAP on hoe-weeded control plots. Fertilizer was applied to maize at the recommended rate of 120 kgN/ha (192.0 g per 16 m^{-2} plot). Fertilizers were applied split at 5 and 7 WAP. NPK 15-15-15 and Urea were used in 2007, while NPK 20-10-10 and Urea in the last two years.

Data were collected on maize growth and yield parameters, as well as weed characteristics and subjected to statistical analysis using the ANOVA procedure of the SAS generalized linear model. Herbicide efficacy and weed control effectiveness was assessed visually at 4 and 10 WAP, on a scale of '0-100', where 0 indicates no weed control while 100 indicates maximum weed control. The average of five independent Raters was used to estimate the weed control effectiveness of each treatment.

3. RESULTS

3.1. Weed control rating

Weed control rating (%) of herbicide rates and tillage methods at 4 and 10 weeks after planting (WAP) in 2007-2009 is presented in Tables 1a and 1b below.At 4 WAP, averaged over the three years, all the herbicide treatments were significantly better in weed control than unweeded check (C_2) as presented Table 1a. There was no significant interaction between tillage and weed control treatments (WCTs) and no significant differences among the various herbicide rates. Weed control were 29.1, 31.4 and 28.2 % better in AP, PX and C_1 plots respectively when compared with the unweeded. At 10 WAP, averaged over the three years, WCR in manual-tilled plots was 10.0% better than the tractor-tilled plot. Weed control in herbicide treated plots were similar and were significantly higher than weed control in C_2. But C_1 gave the highest weed control of 64.3% which was significantly higher than all the herbicide treated plots. The AP and PX treated plots were 54.1% and 45.5% better in controlling weed when compared to C_2.

Table 1a. Weed control rating (%) of herbicide rates and tillage methods at 4 and 10 weeks after planting (WAP) in 2007-2009

Treatment Herbicide	4WAP	10WAP
AP_4	80.4a	47.4b
AP_3	82.3a	49.0b
AP_2	81.5a	48.6b
AP_1	80.2a	50.3b
PX_4	87.6a	50.1b
PX_3	82.8a	46.0b
PX_2	80.2a	44.4b
PX_1	79.5a	44.0b
C_1	80.5a	64.3a
C_2	62.9b	31.7c
Tillage		
TT	79.9a	45.3b
MT	79.7a	49.8a
Tillage x Herbicide	NS	*

Table 1b. Table of interaction of herbicide rates and tillage methods on weed control rating (%) at 4 and 10 weeks after planting (WAP) in 2007-2009

Herbicide rate	TT	MT
AP_4	47.6cd	47.1cde
AP_3	48.5bcde	49.5bcde
AP_2	47.3cde	50.0bcde
AP_1	49.5bcde	51.1abcd
PX_4	42.0def	58.1abc

PX_3	40.7def	51.3abcd
PX_2	41.1def	47.7cde
PX_1	42.9cde	45.2cde
C_1	65.3a	63.3a
C_2	28.2f	35.2ef

Means followed by the same letter (s) in the same column are not significantly different by DMRT at 5% probability AP = Atrazine + Pendimethalin AP_4 = 2.0 + 2.0 kg a.i./ha (100 %), AP_3 =1.5 + 1.5 kg a.i./ha (75 %), AP_2 =1.0 + 1.0 kg a.i./ha (50 %), AP_1 = 0.5 + 0.5 kg a.i./ha (25 %),PX = Primextra PX_4 =2.5 kg a.i./ha(100%), PX_3 =1.875 kg a.i./ha (75%), PX_2 =1.25 kg a.i./ha (50%), PX_1 = 0.625 kg a.i./ha (25%), C1 = Weeded control (3 + 6 WAP), C_2 = Unweeded control

3.2 Weed density, weed biomass and maize grain yield

At 4 WAP, the mean weed density (WD) over the three years, shows that there was a significant tillage by treatment interaction. Manual tillage significantly reduced WD by 48.7% when compared with tractor tillage. All the herbicide treated plots had WD, which were comparable with C_1, but significantly less than the C_2. Herbicides, AP and PX significantly reduced WD by 48.2% and 48.1% respectively when compared with the unweeded

At 10 WAP, averaged, over the three years, MT significantly reduced WD by 24.6% when compared with TT. Herbicide treatments had similar effect on WD, but significantly reduced WD than unweeded control. About 24.99% and 29.1% reduction (though not significant) in WD were observed in AP and PX treated plots respectively when compared with unweeded. All herbicide treated plots were comparable to hand-weeded control (C_1).

At 4 WAP, the mean weed biomass over the three years indicates there was no significant tillage treatment interaction. However, MT reduced weed biomass by 16.8% compared with TT. All the herbicide treated plots had similar mean weed biomass and were comparable to C_1, but significantly less when compared with the unweeded plot. AP, PX and C_1 respectively caused 49.1%, 45.4% and 78.3% reduction in mean weed biomass compared with unweeded. At 10 WAP, averaged over three years, all the herbicide treatments, except PX_2 significantly reduced WB than unweeded. The hand weeded plot (C_1) gave the least mean WB of 40.01g/m2 which was significantly less than all the treatments. The treatments AP_4 and PX_4 had WD similar to AP_1 and PX_1 respectively.

Averaged over the three years, there was no significant tillage by treatment interaction on maize grain yield (MGY). The highest MGY was recorded in C_1, (3.6 t/ha), was comparable only with AP_2 (3.2 t/ha).These were significantly better than MGY in all primextra treated plots and AP_1. Though, the lowest MGY were recorded in AP_1 (2.4 t/ha) and PX_1 (2.3 t/ha), they were not significantly different from MGY in AP_4 (2.7 t/ha) and PX_4 (2.6 t/ha) respectively. Percentage increase of 79.1, 57.4 and 130.1 in MGY were recorded in AP, PX and C_1 plots when compared with the unweeded plot.

Table 2a. Effects of herbicides and tillage methods on mean weed density (No m^{-2}) , weed biomass (g m^{-2}) and maize grain yield (kg/ha) 2007-2009

	Weed density		Weed biomass		Grain yield
Herbicide rate	4 WAP	10 WAP	4 WAP	10 WAP	
AP_4	51.0b	92.2ab	78.4b	109.3b	2743.2bc
AP_3	56.9b	91.9ab	102.6b	128.0b	2792.3bc
AP_2	65.7b	90.9ab	84.2b	127.6b	3203.2ab
AP_1	65.0b	87.9b	85.0b	120.0b	2370.3c
PX_4	43.6b	81.4b	88.8b	144.9b	2601.7c
PX_3	67.0b	94.1ab	99.6b	143.6b	2346.8c
PX_2	66.1b	89.1b	100.8b	166.3ab	2564.8c
PX_1	62.7b	78.6b	87.1b	132.9b	2253.0c
C_1	54.1b	80.5b	37.3b	40.0c	3568.1a
C_2	115.2a	121.0a	172.2a	203.8a	1550.9d
Tillage					
TT	85.6a	103.4a	102.2a	124.6a	2494.6a
MT	43.9b	78.0b	85.0a	138.6a	2704.3a
Tillage x Herbicide	*	*	NS	*	NS

Table 2b. Table of interaction of herbicides and tillage methods on mean weed density (No m^{-2}) , weed biomass (g m^{-2}) and maize grain yield (kg/ha) 2007-2009

	Weed density				Weed biomass	
	4 WAP		10 WAP		10 WAP	
	TT	MT	TT	MT	TT	MT
AP_4	71.5abcd	30.6cd	94.9bc	88.6bc	116.7bcde	101.9cde
AP_3	81.3abcd	32.4bcd	100.0bc	83.9bc	122.9bcd	133.0ab
AP_2	93.8abc	37.7bcd	104.3abc	77.6bc	147.3abc	108.0bcde
AP_1	86.8abcd	43.2bcd	108.9ab	67.0bc	106.3bcde	133.7bc
PX_4	69.7abcd	17.4d	107.0ab	55.8c	136.1abc	153.6bc
PX_3	101.3abc	32.8bcd	95.1bc	93.1bc	127.5bc	159.7abc
PX_2	87.0abcd	45.2bcd	88.0bc	90.1bc	139.8abc	192.8ab
PX_1	93.0abc	32.3bcd	95.9bc	61.3bc	124.6bcd	141.2abc
C_1	64.6abcd	43.5bcd	95.1bc	65.9bc	37.0e	43.0de
C_2	106.6ab	123.9a	145.1a	97.0bc	188.0abc	219.5a

Means followed by the same letter (s) in the same column are not significantly different by DMRT at 5% probability AP = Atrazine + Pendimethalin AP_4 = 2.0 + 2.0 kg a.i./ha (100 %), AP_3 =1.5 + 1.5 kg a.i./ha (75 %), AP_2 =1.0 + 1.0 kg a.i./ha (50 %), AP_1 = 0.5 + 0.5 kg a.i./ha (25 %),PX = Primextra PX_4 =2.5 kg a.i./ha(100%), PX_3 =1.875 kg a.i./ha (75%), PX_2 =1.25 kg a.i./ha (50%), PX_1 = 0.625 kg a.i./ha (25%), C1 = Weeded control (3 + 6 WAP), C_2 = Unweeded control

4. DISCUSSION

Herbicide efficacy was not consistent under the various tillage systems and no herbicide treatment performed consistently better than the other. However, at 10WAP the significantly enhanced efficacy of herbicide in MT than TT shows the quality of the land preparation. Excessive surface moisture, crop and weed residues, surface unevenness and cloddiness can all impair the effectiveness of soil – applied herbicides [30].The cleaner hand-made ridges, with properly buried weeds might have been responsible for the enhanced efficacy of the herbicides in MT. This explains why the efficacy of herbicide was significantly enhanced in manually tilled plots than in tractor tilled system at 10 WAP in 2007 and 2009 Tillage practices influence the efficacy of soil applied herbicides [25, 3, 39, 6]

Herbicide dissipation in soil is influenced by volatilization, leaching, surface run-off, plant uptake and degradation. These dissipation processes are influenced by factors such as soil water content, temperature, soil management practices, cropping systems and cultural practices such as tillage [33, 18]. The dissipation processes were reduced in the ridge tilled system used in this study. This is in line with [23] who reported that tillage enhances the efficacy of atrazine + pendimethalin and primextra where weeds are adequately buried.

In this experiment, the similarity in the efficacies of the various rates of atrazine + pendimethalin or primextra shows that efficacy is more influenced by the nature of the active ingredient rather than the dosage. In a research in south west Nigeria, [23], investigating atrazine + pendimethalin and primextra at half and full recommended rates in four tillage regimes concluded that weed control rating of each herbicide at the two rates were similar at 8 WAP. In the same vein, [19] working on the effectiveness of Horizon, Achieve, Assert and Puma on wild oat control reported that the control of wild oat was unaffected for all 4 herbicides when rates were dropped from full rate to 2/3 rate. [13] comparing the effectiveness of full (6L/ha), Half and one-third rates of primextra in southwestern Nigeria, conluded that the lowest rate was as effective as the full dose and recommended such for farmers.

In the same vein, hand weed control recorded the highest weed control compared with herbicide treatment because it has just been weeded twice, the last was just four weeks before the assessment. Similar findings were noted by [10, 7, 11]. [32] found that hand hoeing twice was more effective in controlling weeds in maize growing in clay soil as compared with herbicide treatments. [42] stated that if human labor is abundant and labor cost is not high, hand hoeing can be an acceptable method for weed control.

The effect of tillage on weed density and biomass reflected the cleanliness of the system. The manual tillage ridges (1m x 4m) were made with big heavy hoes which probably made it possible for effective covering and burying of weeds when compared with the single ploughed tractor tillage. Deep tillage (as in tractor ploughing) has been reported to increased weed seed population by bringing buried weed seeds to the surface [27]. Changes in tillage can have a significant effect on weed control and weed populations [40]. In situations with a uniform soil seed density, cultivation generally stimulates weed emergence compared to treatments without cultivation. [29] found greater weed emergence in cultivated compared to undisturbed plots resulting in a faster decline of the soil seed reserves in cultivated plots. The tractor ploughed plots were more pulverized.

The weed density and biomass in AP or PX treated plots being similar show that the rates were equally effective when compared with the unweeded at 4 WAP. Sublethal exposure to atrazine or pendimethalin had been reported to significantly reduce velvet leaf competitiveness in corn. Weed control of 93% and 100% were observed for 3 and 6 kg a.i/ha atrazine at 6 WAP in maize in forest zone of south Western Nigeria [2]. Doubling the rate, made no significant different in weed control. In a research in North-eastern Nigeria, [24] reported that though 125 % rates of atrazine or primextra gave the best weed dry matter reduction, each were comparable with their respective 75% recommended rates. The present study showed this same trend.

Pulverizing the soil as obtained in TT tend to increase weed pressure promoting rapid weed seed germination and growth which compete with the maize plants for nutrients and water, resulting in poor maize grain yield (though not statistically significant) when compared with MT. [9] observed than corn grain yields were similar among tillage treatments after 22 years, as long as weeds were controlled. This was confirmed in this study, yields were not different between the two tillage methods on the average. Though weed control reflected tillage qualities, yields were simillar because weeds were controlled.

Higher rates of herbicides did not produce significant yield difference in maize when compared with lower rates of a given herbicide because uniformity of herbicide application which will give equal early control of weeds. Uniform applications of reduced label rate pre or post herbicides have been reported to provide equivalent yields when compared with full label rate applications [34]. The significantly higher maize grain yield in AP_2 plot when compared with all the PX treated plots and unweeded showed that full control of weeds is not necessary to obtain maximum yield.

5. CONCLUSION

Weed control was not significantly improved when higher rates of herbicides were applied. Atrazine-Pendimethalin can be reduced to 25.0% recommended rate without significant reduction in weed control. Weed control using 25.0% recommended rate of Primextra was similar to 100.0%. Low herbicide rates were better than unweeded plots.

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