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Influence of Tillage and Weed Management on Weed Growth and Maize (*Zea mays* L.) Grain Yield in Southwestern Nigeria

Smith, M.A.K.; Emiju, C.O. and Aduloju, S.O.
Department of Crop, Soil & Pest Management, The Federal University of Technology, Akure, Nigeria.
Corresponding Author: Smith, M.A.K.: masmith@futa.edu.ng

ABSTRACT: This paper evaluates the influence of tillage and weed management system on weed growth, and maize growth and grain yield of maize. Field experiments were carried out in early 1999 and late 2000 maize growing seasons in Ayegunle-Oka (416 m above sea level; Long. 5^0 43' 60N, Lat. 7^0 28' 00N), Akoko, in the forest-savanna transition zone of Southwestern Nigeria. Each experiment was arranged as a split plot with tillage methods [tilled (TL); untilled (NT)] as main plots and weed management methods [No weeding (NW); weeding once at 3+6 weeks after sowing, WAS, (W_2); pre-emergence (PE) application of Primextra^R at 3 kg ai/ha^{-1} (PR) as subplots. Weeds were destructively sampled at 3 and 6 WAS for the determination of weed density and dry weight. Maize vegetative growth and grain yield were recorded from a central sample area of 2 m^2 in each plot. Weed growth and maize performance were significantly ($p \leq 0.05$) affected by tillage and weed management method. TL plots had more weed growth than NT plots but weed growth decreased in the order of NW, W_2 and PR. Contrarily, maize vegetative growth increased significantly ($p \leq 0.05$) in the order of NW, W_2 and PR in both TL and NT plots. Grain yield and yield parameters of maize were distinctly lower in NW than in both W_2 and PR, but maize ear yield was better in PR than in W_2. The yield-improving effect of weed removal was greater in W_2, especially under tillage. Factor interactions influenced maize growth and yield more in the late season than in the early season. Tillage combined with either weed removal or PE application of PR is recommended for effective weed control and optimum maize performance under the conditions of this study.

Keywords: Maize, tillage, weed control, season.

JoST. 2021. 11(2): 45-54
Accepted for Publication: September 09, 2021

INTRODUCTION

Maize (*Zea mays* L.) is widely cultivated in all ecological zones of Nigeria. However, it has the greatest potential in the savanna zone (Ologunde, 1981), particularly in areas where optimum inputs of fertilizer, planting date, plant population, weed control and other crop protection measures are adopted. Weeds interfere seriously with maize growth, because the crop does not completely cover the soil until two or three months after sowing (Lavabre, 1991). The period between emergence and tasseling is most critical for weed competition in maize. Lagoke *et al.* (1981) recorded 74% yield loss due to weeds in maize in the northern Guinea savanna. Inefficient weed control is one of the limiting factors to maize grain yield in Africa (Onwueme and Sinha, 1999), while the introduction of improved crop production practices aggravates weed problems due to improved growth responses of both crops and weed associates (Diaz *et al.*, 1972; Sweeney *et al.*, 2008; Schonbeck, 2020).

In all crops, tillage ensures the production of fine tilth, weed control, organic matter incorporation, soil and water conservation and improved soil conditions (Wasaya *et al.*, 2011; Weber *et al.*, 2017; Wilson, 2017; Jorgensen, 2018). No-tillage (NT) production of maize often gives slower early plant growth, lower stand establishment and population, lower yields and reduced profitability (Kapusta *et al.*, 1999; Vetsch and Randall, 2000), regardless of fertilizer treatments and the effects are severe on fine-textured soils (Drury *et al.*, 1999). In Nigeria, maize grain yield in ridged soil is 60% higher than in non-ridged soil due to 15-30% increase in moisture storage in the 0-45 cm depth (Adeoye and Mohammed-Saleem, 1990). Land cultivation generally stimulates weed emergence, increases weed pressure and competition with maize for growth factors. Reduced tillage causes serious weed problems (Vogel, 1994) while burying weeds and their seeds in mounds reduces weed pressure on crops compared to flat land, where weed infestation is most severe (Akobundu, 1987). Also, Wilson (1993) reported that cultivation in maize reduced weed density by 86%, but weeds that remained after cultivation reduced grain yields by 40%, compared with a hand-weeded control. In East Africa, Mloza-Banda and Materechera (1999) found that tillage did not influence weed biomass yield but the highest yields of maize were obtained in plots where ridges were re-made and when weeds were removed early in the season. Changing tillage system caused increase in weed densities (Derksen *et el.*, 1995), but Stefanic and Stefanic (1996) recorded significant losses of gross margins in no-tillage maize compared to other tillage systems. However, tillage is highly desirable for good maize growth (Kapusta *et al.*, 1999) and when combined with weed control, could ensure optimum grain yield.

A variety of non-chemical methods is available for weed control in Nigerian maize farms (Akobundu, 1987). The National Advisory Committee on Weed Control (NACWC, 1994) recommended various herbicides and herbicide mixtures for weed control in maize. At 2.5-3.0 kg ai ha^{-1}, both Primextra^R and Primagram^R control most annual weeds pre-emergence (PE) in all ecological zones, except *Rottboellia cochinchinensis*, sedges and *Striga* spp. Primextra^R at 2 kg ai ha^{-1} PE in maize gave higher yields than the same rate of either atrazine or cyanazine and even two handweedings (Choudhary *et al.*, 1979), in spite of the presence of problem weed associates. In the forest-savanna transition zone of Nigeria, both Primextra^R Gold^{TM} and Primextra^R 500 FW applied at the recommended rate (2.5 kg ai ha^{-1}) gave good weed control ratings (<80%) in maize (Chikoye *et al.*, 2002). Effects of herbicides varie with herbicide types, but hand-weeded control and Primextra^R Gold^{TM} gave similar yields. In a rainforest environment, Olatunji *et al*. (2016) demonstrated that Primextra^R 500 FW gave similar efficacy of weed control, but with better maize growth than the other weeding methods tested, including atrazine 800 FW, glyphosate + handweeding and two handweedings. In the southern Guinea savanna, Imoloame (2017) recorded significantly reduced weed infestation and higher maize grain yield, and economic returns from metolachlor + atrazine at 1.0 + 2.0 kg ai ha^{-1}. The herbicide mixture was recommended as an alternative to two handweedings at 3 + 6 weeks after sowing (WAS) maize. When combined with one supplementary handweeding, xtra Force^R (metolachlor 1.0 + atrazine 2.0 kg ai ha^{-1}) significantly suppressed weed infestation and provided season-long weed control in maize in Ogbomoso (Olabode *et al*., 2019). Further studies (Imoloame and Issa, 2018) showed that PE application of Primextra^R at 1.5 kg ai ha^{-1} singly, or combined with post-emergence 2, 4-D, nicosulfuron or one supplementary handweeding at 6 WAS gave similar results. In the northern Guinea savanna, Primextra Gold^R at 2.5 kg ai ha^{-1} and Premaize^R at 2.0 kg ai ha^{-1} were recommended as alternative to handweeding in maize (Umeghara *et al*., 2018). Elsewhere, PE herbicides (Primextra^R, Primagram^R, pendimethalin) ± tillage gave considerable increases in maize grain yields compared to handweeding ± tillage, due to effective weed control (Bridgemohan and Braithwaite, 1989; Gill *et al.*, 1992; Yenish *et al.*, 1992; Khan *et al.*, 1993; 1998).

In Nigeria, Ayeni *et al.* (1984) evaluated the interactive effect of tillage and weed interference duration on maize grain yield in the subhumid forest-savanna environment (Ibadan). With minimum or no weed interference, maize performance was better in conventional tillage than in no-tillage but worse with prolonged weed interference. No such report has been documented for the humid forest-savanna. The objective of the current study was therefore, to evaluate the influence of tillage and weed management system on weed growth, and maize growth and grain yield of maize in the latter environment of Southwestern Nigeria.

MATERIALS AND METHODS

Field experiments were carried out during the early 1999 and late 2000 maize growing seasons in Ayegunle-Oka (416 m above sea level; Long. 5^0 43' 60N, Lat. 7^0 28' 00N), Akoko, in the forest-savanna transition zone of Southwestern Nigeria. In both seasons, the soil was a neutral sandy clay with apparently uniform organic matter (1.30-1.55 g/kg^{-1}) and N (0.26-0.31%). Soil samples collected in the early season contained 23.45 mg/kg^{-1} P, 0.60 g/kg^{-1} K, 0.06 g/kg^{-1} Mg and 0.08 g/kg^{-1} Ca, while those collected in the late season contained 7.00 mg/kg^{-1} P, 1.08 g/kg^{-1} K, 0.01 g/kg^{-1} Mg and 0.02 g/kg^{-1} Ca. The area was an arable land under a two-year fallow from cassava and maize crops, predominated by *C. odorata*, *A. africana* and *I. cylindrica*.

The experiment was arranged as a split plot using a randomised complete block design and three replications per treatment. The main plots comprised hoe-tillage (TL) and no-tillage (NT) while the subplots were No weeding (NW), hoeweeding once at 3+6 weeks after sowing, WAS (W_2) and PE Primextra^R 500 FW at 3 kg ai ha^{-1} (PR) one day after sowing maize. The main plots were 6 x 5 m in size and were subdivided into three equal 2 x 5 m subplots. Adjacent main plots and replications were separated by alleyways of 1 m and 0.5 m, respectively. The experimental area was cleared manually and excess plant debris removed to facilitate maize establishment and PE PR application. *Z. mays* DMR-ESRY was sown at a spacing of 90 x 40 cm and thinned to one plant hill^{-1} (27,778 plants ha^{-1}). NPK 20-10-10 at 300 kg ha^{-1} was applied in two split doses at 3 and 7 WAS. Prior to weeding in weeded plots (3 and 6 WAS), three 50 x 50 cm quadrats were laid systematically for weed sampling. Weed counts were recorded and samples oven-dried at 80^0C for 48 hr to determine weed dry weight. At maturity (14 WAS), maize stands were counted to determine percentage plant survival under each treatment. A sample area of 2 m^2 in each plot was marked out for data collection on maize plant height, stem girth, ear height, leaf area, cob length, cob diameter, rachis dry weight, 1000-grain weight and grain yield.

All data collected were analysed statistically using ANOVA procedures. Treatment means were compared using the Least Significant Difference (LSD) test at P= 0.05.

RESULTS AND DISCUSSION

Weed Growth

In both the early and late seasons, weed density and dry weight were significantly ($p \leq 0.05$) influenced by tillage system and weed control method (Tables 1 and 2). However, regardless of weed control method, weed density and dry weight were higher in hoe-tilled plots than in untilled plots. These findings agree with the reports of Derksen *et al*. (1995) that tillage primarily exposes weed propagules, especially buried weed seeds, to the soil surface, and this provides safe sites for their establishment. According to Swanton *et al*. (2000), tillage promotes weed germination and establishment and moving seeds both vertically and horizontally. High weed dry matter in continuously cropped (disturbed) plots are usually due to a combination of high weed density and/or absence of aggressive fallow species to suppress weed growth after crop harvest (Akobundu, 1987).

In the current study, the highest weed density and dry weight within tillage treatments were obtained from unweeded plots, which allowed unhindered weed growth and spread, followed by weeding once at 3+6 WAS and the lowest in PR-treated plots. Yenish *et al*. (2017) reported that PE metolachlor + atrazine decreased weed seed populations by 50% compared with no treatment, over all tillage systems studied. In the current study, the contribution of tillage to high PR activity due to enhanced herbicide incorporation into the soil devoid of surface residues is strongly indicated. The higher weed populations in weeded plots than in PR-treated plots could be attributed to the ineffectiveness of manual weeding in controlling the high native weed infestation, in addition to the inhibitory effect of PR on early weed emergence and establishment. Akobundu (1987), NACWC (1994) and Yenish *et al.* (1992) obtained similar results. Khan *et al.* (1998) recorded the lowest weed dry weight and number in Primextra^{R} compared to unweeded control. However, in the current study, tillage x weed control method interaction significantly ($p \leq 0.05$) influenced only weed dry weight in the early season, compared to early weed emergence in the early season and weed dry weight in the late season. This result confirms the influence of season on weed emergence response to tillage reported by Felix and Owen (2001) and Van den Putte *et al*. (2012).

Table 1: Weed density and dry weight at 3 and 6 weeks after sowing maize in the early 1999 season

Tillage system (T)	Weed control method (W)$^{+}$	Weeks after sowing 3	6	Weeks after sowing 3	6
		Weed density (no m^{-2})		Weed dry weight (g m^{-2})	
Tilled (TL)	No weeding (NW)	1328.0	1549.0	222.8	150.9
	Weeding 3+6 WAS (W_2)	1245.0	595.	220.7	54.7
	Primextra 3 kg ai/ha (PR)	14.7	66.7	1.4	3.5
	Mean	862.6	736.9	148.3	69.7
Untilled (NT)	NW	1097.3	1154.7	174.4	81.8
	W_2	1013.3	625.3	165.7	44.7
	PR	22.7	96.0	2.3	2.0
	Mean	711.1	625.3	114.1	42.8
LSD (0.05)					
Tillage		49.7	96.8	5.0	11.5
Weed control method		18.2	79.1	4.1	9.4
T x W		NS	NS	*	*

$^{+}$WAS= Weeks after sowing. NS= Not significant, *= Significant at P= 0.05.

Table 2: Weed density and dry weight at 3 and 6 weeks after sowing maize in the late 2000 season

Tillage system (T)	Weed control method (W)$^{+}$	Weeks after sowing 3	6	Weeks after sowing 3	6
		Weed density (no m^{-2})		Weed dry weight (g m^{-2})	
Tilled (TL)	No weeding (NW)	728.3	704.0	61.6	94.8
	Weeding 3+6 WAS (W_2)	568.0	257.0	60.3	49.8
	Primextra 3 kg ai ha^{-1} (PR)	26.7	128.0	1.8	10.8
	Mean	441.3	363.0	41.2	51.8
Untilled (NT)	NW	346.7	537.0	36.0	70.7
	W_2	512.0	200.0	48.6	33.6
	PR	36.0	104.0	2.1	1.7
	Mean	298.2	280.3	28.9	35.3
LSD (0.05)					
Tillage		47.7	34.4	8.3	6.7
Weed control method		17.5	28.1	6.8	49.0
T x W		*	NS	NS	NS

$^{+}$WAS= Weeks after sowing. *= Significant at P= 0.05, NS= Not significant.

Maize Vegetative Growth

In both seasons, the vegetative growth of maize was significantly reduced in no weeding compared to other weed control treatments (Tables 3 and 4). Weeding once at 3+6 WAS and application of PR in both hoe-tilled and untilled plots enhanced the vegetative growth of maize. Plant survival was considerably low in both seasons when maize plants were not weeded throughout, especially in untilled plots. In particular, untilled soils potentially have higher surface soil bulk density (Liu *et al*., 2015; Lipiec *et al*., 2006), poor drainage (Liu *et al*., 2015) and higher prevalence of annual and perennial weeds (Pecrun and Claupein, 2004). Higher surface water content causes leaching and denitrification in no-till culminating in slower rate of nitrogen mineralisation (Thomas and Frye, 1984). The cumulative effects of these adverse crop growth conditions, in addition to the severe weed infestation in no-weeding, account for poor maize establishment, growth and production (Olojugba and Olufemi, 2019).

Table 3: Effect of tillage and weed management on vegetative growth of maize in early 1999 season

Tillage system (T)	Weed control method (W)⁺	Plant height (cm)	Stem diameter (cm)	Leaf area (cm^2)	Plant survival (%)	Ear height (m)
Tilled (TL)	No weeding (NW)	1.4	18.5	1140	48	1.10
	Weeding 3+6 WAS (W_2)	2.0	20.0	1863	79	1.50
	Primextra 3 kg ai ha^{-1}(PR)	2.2	19.5	1997	68	1.50
	Mean	1.87	19.3	1666.7	65	1.37
Untilled (NT)	NW	1.3	8.8	772	21	1.00
	W_2	1.8	12.0	1566	66	1.30
	PR	1.9	11.5	1670	60	1.30
	Mean	1.67	10.8	1336	49	1.20
LSD (0.05)	Tillage	0.28	0.85	118.3	6.1	0.27
	Weed control method	0.10	0.75	96.65	5.0	0.22
	T x W	NS	NS	NS	*	NS

⁺WAS= Weeks after sowing. NS= Not significant, *= Significant at P= 0.05.

Table 4: Effect of tillage and weed management on vegetative growth of maize in late 2000 season

Tillage system (T)	Weed control method (W)⁺	Plant height (cm)	Stem diameter (cm)	Leaf area (cm^2)	Plant survival (%)	Ear height (m)
Tilled (TL)	No weeding (NW)	1.3	12.7	1098	41	1.00
	Weeding 3+6 WAS (W_2)	1.8	19.3	1766	72	1.10
	Primextra 3 kg ai ha^{-1} (PR)	1.7	18.3	1456	60	1.20
	Mean	1.60	16.77	1440	61	1.10
Untilled (NT)	NW	1.1	7.8	659	40	0.70
	W_2	1.7	11.6	1616	61	1.10
	PR	1.4	11.1	1259	56	1.10
	Mean	1.41	10.18	1178	52.3	0.97
LSD (0.05)	Tillage	0.41	1.56	120.1	3.75	0.002
	Weed control method	0.33	1.27	98.1	3.06	0.10
	T x W	*	NS	NS	NS	*

⁺WAS= Weeks after sowing. *= Significant at P= 0.05, NS= Not significant.

In early studies, Ayeni *et al.* (1984) demonstrated that with minimum or no weed interference, maize performance was better in conventional tillage than in no-tillage. Jorgensen (2018) emphasized that the primary aims of tillage are improving the soil structure and soil fertility. In the current study, maize plots weeded once at 3+6 WAS gave the highest plant survival, and this was significantly better than in PR-treated plots, indicating possible crop injury due to herbicide application. Except for plant survival in the early season and plant and ear weights in the late season, maize vegetative growth was virtually unaffected by factor interaction. This suggests that, on average, maize vegetative growth response to weed control was apparently not affected by tillage methods.

Grain Yield and Yield Components

Agronomic practices do not only influence crop establishment but are also critical for optimum growth and yield, particularly tillage practices which primarily enhance soil conditions for crop growth (Wasaya *et al*., 2011; Weber *et al*., 2017; Jorgensen, 2018), and weed removal (Mafongoya *et al*., 2016) which prevents full-season weed competition (Reicosky and Allmaras, 2003). In both seasons, yield and yield components of maize were significantly influenced by tillage and weed control method (Tables 5 and 6). Also, grain yield, number of ears per m^2 and grains per cob, 1000-grain weight, cob diameter and grain yield were distinctly lower in unweeded plots, which was less favourable for maize production, than in both hoe-weeded and PR-treated plots, which gave similar values. Chikoye *et al.* (2002) reported similar findings. According to Akobundu (1987) and Mloza-Banda and Materechera (1999), weed removal from field plots, in line with standard recommendations, is critical for optimum maize performance. This accounts for the considerably enhanced maize performance in hoe-weeded and PR-treated plots in the current study, compared to no weeding in both seasons.

The yield-enhancing effect of PR and hoeweeding was more pronounced in manually-weeded hoe-tilled plots than in weeded untilled plots. Senjobi *et al*. (2013) demonstrated that the traditional hoe tillage gave the most favourable soil environment for maize growth and optimum performance, followed by conventional tillage and no tillage. The significant differences in maize yield were attributed to lower soil bulk density, higher water holding capacity and porosity which increased plant root proliferation, microbial activities, organic matter contents and optimum utilization of soil nutrients in tilled plots. Zhang *et al*. (2011), Liu *et al*. (2015) and Olojugba and Olufemi (2019) recorded significantly higher maize grain yields under tillage practices than under no-tillage. Based on this, Olojugba and Olufemi (2019) recommended traditional tillage for optimum efficiency, proper soil management and economic benefits in the savanna maize production systems. Unlike plant survival, maize ear yield was better in PR than in hoe weeding, probably due to greater and sustained weed control efficiency of herbicide application than weeding. Khan *et al.* (1993) and Imoloame (2017) recorded similar observations using the same herbicide formulation and dose.

Only cob diameter, number of grains per cob and ear dry yield were significantly influenced by factor interaction in the early season (Table 5). In the late season, factor interaction significantly influenced weight per ear, number of grains per cob, 1000-grain weight and ear dry yield (Table 6). The parity of grain yields in PR + tillage and hoeweeding + tillage in both seasons strongly indicates the efficiency of tillage in optimum weed management and maize productivity when combined with weed control method than sole application of weed control. Kedebe *et al*. (2020) and Simic *et al*. (2020) demonstrated the implementation of integrated weed management systems to reduce reliance on chemical weed control, to reduce production costs and sustainable maize production. Specifically, Wilson (2017) showed that weed control treatments that integrate cultivation and herbicides controlled a broader spectrum of weed species than cultivation or herbicide treatments alone. These findings may be attributed to the influence of rainfall and soil conditions on maize growth and yield response to the complex effects of tillage and weed control method under the conditions of this study. Mohler (1993), citing several research reports, showed that tillage effects vary with year, sites and weed species.

Table 5: Effect of tillage and weed management on maize yield and yield components in early 1999 season

Tillage system (T)	Weed control method (W)+	Weight ear^{-1} (g)	Cob length (cm)	Cob diameter (cm)	Grains cob^{-1} (no)	1000-grain weight (g)	Ear dry yield (t ha^{-1})	Grain yield (t ha^{-1})
Tilled (TL)	No weeding (NW)	150.0	11.10	8.0	258.0	200.0	2.21	1.20
	Weeding 3+6 WAS (W2)	252.0	18.60	12.5	405.0	240.0	6.73	5.50
	Primextra 3 kg ai ha^{-1} (PR)	205.0	19.20	11.7	322.0	230.0	6.83	5.30
	Mean	202.3	16.30	10.7	323.3	223.3	5.30	4.00
Untilled (NT)	NW	141.0	9.70	5.3	220.0	190.0	1.93	0.98
	W2	230.0	16.30	8.6	326.0	238.0	6.02	4.98
	PR	193.0	16.80	8.4	316.0	230.0	6.21	4.50
	Mean	188.0	14.27	7.4	287.3	219.3	3.46	3.46
LSD (0.05)	Tillage	12.65	1.22	0.99	3.86	17.3	0.07	0.33
	Weed control method	10.32	1.00	0.81	3.16	13.7	0.04	0.27
	T x W	NS	NS	*	*	NS	*	NS

+WAS= Weeks after sowing. NS= Not significant, *= Significant at P= 0.05.

Table 6: Effect of tillage and weed management on maize yield and yield components in late 2000 season

Tillage system (T)	Weed control method (W)+	Weight ear^{-1} (g)	Cob length (cm)	Cob diameter (cm)	Grains cob^{-1} (no)	1000-grain weight (g)	Ear dry yield (t ha^{-1})	Grain yield (t ha^{-1})
Tilled (TL)	No weeding (NW)	135.0	10.8	7.8	217.0	198.0	1.10	0.70
	Weeding 3+6 WAS (W2)	235.0	18.3	11.6	350.0	230.0	5.73	4.74
	Primextra 3 kg ai ha^{-1} (PR)	185.0	19.0	11.4	312.0	205.0	5.80	4.80
	Mean	185.0	16.0	10.3	293.0	211.0	4.21	3.41
Untilled (NT)	NW	120.0	7.8	6.3	158.0	98.0	0.97	0.45
	W2	200.0	16.0	14.8	306.0	191.0	4.60	3.80
	PR	160.0	16.2	14.6	298.0	190.0	4.80	3.90
	Mean	160.0	13.3	11.9	254.0	159.7	3.46	2.72
LSD (0.05)	Tillage	3.19	0.45	1.00	18.16	8.51	0.11	0.29
	Weed control method	2.60	0.36	0.81	12.83	6.50	0.11	0.24
	T x W	*	NS	NS	*	*	*	NS

+WAS= Weeks after sowing. *= Significant at P= 0.05, NS= Not significant.

CONCLUSION

In this study, tillage and weed management method affected weed growth and maize performance considerably. Manual tillage was more effective in weed control in the late season probably due to the harsher conditions for weed growth, than in the early season. Weed growth was considerably minimal in Primextra^{R} –treated plots due to herbicide inhibition of weed emergence and establishment. However, Primextra^{R} + hoe tillage gave a more prolonged weed control in spite of the relatively lower crop stand, and gave comparable grain yield to hoe weeding + tillage. The use of Primextra^{R} + hoe tillage is therefore, recommended as alternative to hoeweeding + tillage in maize production.

REFERENCES

Adeoye, K.B. and Mohammed-Saleem, M.A. (1990). Comparison of effects of some tillage methods on soil physical properties and yield of maize in a degraded ferruginous tropical soil. *Soil & Tillage Research,* **18**: 63-72.

Akobundu, I.O. (1987). Weed Science in the Tropics. Principles and Practice. John Wiley & Sons, Inc. 522 p.

Ayeni, A.O., Duke, W.B., and Akobundu, I.O. (1984). Weed interference in maize, cowpea and maize/cowpea intercrop in a subhumid tropical environment. I. Influence of land preparation. *Weed Research,* **24**: 439-448.

Bridgemohan, P. and Braithwaite, R.A.I. (1989). Weed management strategies for the control of *Rottboellia cochinchinensis* in maize in Trinidad. *Weed Research, (UK)* **29**: 433-440.

Chikoye, D., Udensi, U.E., and Ajayi, E. (2002). Field evaluation of PRIMEXTRA[R] GOLD[TM] for weed control in maize. 30th Annual Conference, Weed Science Society of Nigeria (WSSN), Nov. 3-7, Nigerian Institute of Oil Palm Research (NIFOR), Benin City, Nigeria.

Choudhary, A.H., Lagoke, S.T.O., and Tanko. Y.M. (1979). Maize weed control under partial mechanization. Cereals Improvement Programme Cropping Scheme Meeting, Ahmadu Bello University (ABU), Zaria, Nigeria.

Derksen, D.A., Thomas, A.G., Lafond, G.P., Loeppky, H.A., and Swanton, C.J. (1995). Impact of post-emergence herbicides on weed community diversity within conservation tillage systems. *Weed Research Oxford,* **35**: 311-320.

Diaz, R.O., Pinstrup, P., Andersen, P., and Estrada, R.D. (1972). Costs and use of inputs in cassava production in Colombia. A brief description. Series E.E. No. 5, Centre International de Agriculture Tropical, Cali, Colombia. p 1-40.

Drury, C.F., Tan, C., Welacky, T.W., Oloya, T.O., Hamill, A.S., Weaver, S.E., and Tan, C.S. (1999). Red clover and tillage influence on soil temperature, water content and corn emergence. *Agronomy Journal,* **91**: 101-108.

Felix, J. and Owen, M.D.K. (2001). Weed seedbank dynamics in post conservation reserve program land. *Weed Science,* **49**: 780-787.

Gill, K.S., Arshad, M.A., Chivunda, B.K., Phiri, B., and Gumbo, M. (1992). Influence of residue mulch, tillage and cultural practices on weed mass and corn yield from three field experiments. *Soil & Tillage Research,* **24**: 211-223.

Imiloame, E.O. (2017). Evaluation of herbicide mixtures and manual weed control method in maize (*Zea mays*) production in the Southern Guinea savanna agro-ecology of Nigeria. *Nigerian Journal of Weed Science,* **30**:25-39.

Imoloame, E.O. and Issa, O.I. (2018). Effect of pre- and post-emergence herbicides on maize (*Zea mays* L.) productivity in the Southern Guinea savanna of Nigeria. Book of Abstract/Programme, 46th Annual Conference, Weed Science Society of Nigeria, University of Port Harcourt, Port Harcourt, Nigeria. November 4-7. p 27-28.

Jorgensen, M.H. (2018). The Effect of Tillage on the Weed Control: An Adaptive Approach. Chapter 3. IntechOpen p 17-25. http://dx.doi.org/10.5772/intechopen.76704.

Kapusta, G., Krausz, R.F., and Mathews, J.L. (1999). Corn yield is equal in conventional, reduced and no-tillage after 20 years. *Agronomy Journal,* **18**: 812-817.

Kedebe, M., Bayisa, W., Geberemariam, E., Desalegn, K., Genema, G. and Chemeda, G. (2020). Integrated weed management practices enhance maize (*Zea mays* L.) productivity and weed control efficiency. *Journal of Research in Weed Science* **3(1)**: 582-598.

Khan, M., Noor-Ul-Haq, Khan, M., and Haq, N.U. (1993). The effects of pre-emergence herbicides on weed control and maize grain yield on farmers' field. *Sarhad Journal of Agriculture,* **9**: 415-421.

Khan, S.A., Naseer-Hussain, Khan, I.A., Mustajab-Khan, Maqsood-Iqbai, Hussein, N., Khan, M., and Iqbal, M. (1998). Study on weed control in maize. *Sarhad Journal of Agriculture,* **14**: 581-586.

Lagoke, S.T.O., Kataria, O.P., and Ogungbile, S.A. (1981). Potential for improved weed control practices in field crop production in Nigerian savanna zones. First Seminar on Green Revolution in Nigeria, Sept. 21, Ahmadu Bello University, Zaria, Nigeria.

Lavabre, E.M. (1991). Weed control. *The Tropical Agriculturalist, CTA*, Macmillan. p 50-51.

Lipiec, J., Kus, J., Slowinska-Jurkiewicz, A. and Nosalewicz, A. (2006). Soil porosity and water infiltration as influenced by tillage methods. *Soil Tillage Research,* **89**: 210-220.

Liu, S., Zhang, X., Kravchenko, Y. and Iqbal, M.A. (2015). Maize (*Zea mays* L.) yield and soil properties as affected by no tillage in the black soils of China. *Acta Agriculturae Scandinavica,* Section B- Soil & Plant Science, **65(6)**: 554-565.

Manfongoya, P., Jiri, O. and Phophi, M. (2016). Evaluation of tillage practices for maize (*Zea mays*) grown on different land-use systems in eastern Zambia. *Sustainable Agriculture Research,* **5**: 1.

Mloza-Banda, H.R. and Materechera, S.A. (1999). The effect of tillage, residue management, and weeding practices on weed flora in two agroecological areas in Malawi. 17th East African Biennial Conference Proceedings, September 27-29, Harare, Zimbabwe. p 49-55.

Mohler, C.L. (1993). A model on the effects of tillage on emergence of weed seedlings. *Ecological Applications*, **3**: 53-73.

Olabode, O.S., Adesina, G.O. and Ajibola, A.T. (2019). Evaluation of selected newly introduced herbicides for weed control on maize (*Zea mays*) plot in Ogbomoso, Nigeria. Book of Abstract, 47th Annual Conference, Weed Science Society of Nigeria, University of Ibadan, Ibadan, Nigeria. November 3-7. p 36-37.

Olatunji, A., Adejoro, S.A., Ayelari, O.P. and Aladesanwa, R.D. (2016). Evaluation of selected weeding methods for weed control and performance of maize in southwestern Nigeria. *Applied Tropical Agriculture*, **21**(1): 15-23.

Ologunde, O.O. (1981). Effect of planting date, plant population and fertilizer application on grain yield of maize. Proceedings of the 10th & 11th Annual Conference of the Weed Science Society of Nigeria (WSSN), ABU, Zaria, Nigeria. p 63.

Olojugba, M.R. and Olufemi, I.J. (2019). Interactive effect of tillage and nitrogen fertilizer on maize (*Zea mays* L.) performance on a humid alfisol in southwestern Nigeria. *Asian Journal of Soil Science and Plant Nutrition,* **4(3)**: 1-11.

Onwueme, I.C. and Sinha, T.D. (1999). Field Crop Production in Tropical Africa. CTA, Wageningen, Netherlands. 63 p.

Pardo, G., Cirujeda, A., Perea, A., Verdu, A.M.C., Mas, M.T. and Urbano, J.M. (2019). Effects of reduced and conventional tillage on weed communities: Results of a long-term experiment in Southwestern Spain. *Planta Daninha,* **37**, SCIELO, Brazil. https://www.scielo.br.

Pecrun, C. and Claupein, W. (2004). The effect of stubble tillage and primary tillage on population dynamics of Canada thistle (*Cirsium arvense*) in organic farming. *Journal of Plant Diseases and Protection*, **19**: 483-490.

Reicosky, D.C. and Allmaras, R.R. (2003). Advances in tillage research in North America cropping systems. p 75-125 **In**: Shrestha, A. (Ed.). Cropping Systems; Trends and Advances. Haworth Press, Inc., New York.

Schonbeck, M. (2020). An Ecological Understanding of Weeds. https://www.eorganic.org/node/

Senjobi, B.A., Ande, O.T. and Okulaja, A.E. (2013). Effect of tillage practices on soil properties under maize cultivation on oxic paleustalf in South West Nigeria. *Open Journal of Science,* **3**: 163-168.

Simic, M.S., Dragicevic, V., Chchalis, D., Dolijanovic, Z. and Brankov, M. (2020). Integrated weed management in long-term maize cultivation. *Zemdirbyste-Agriculture,* **107(1)**: 33-40.

Stefanic, E. and Stefanic, I. (1996). Interaction between tillage system and profitability of maize production in North-eastern Croatia. **In:** *Weed Abstracts* Vol. **47**, No. 1, p 43.

Swanton, C.J., Shrestha, A., Knezevic, S.Z., Roy, R.C., and Ball-Coelho, B.R. (2000). Influence of tillage type on vertical weed seedbank distribution in a sandy soil. *Canadian Journal of Plant Science,* **80**: 455-457.

Sweeney, A.E., Renner, K.A., Laboski, C. and Davis, A. (2008). Effect of nitrogen fertilizer on weed and crop growth. *Weed Science*, **56**: 714-721.

The National Advisory Committee on Weed Control (NACWC) (1994). Weed Control Recommendations for Nigeria. *Weed Control Series* No. 3, 111 p.

Thomas, G.W. and Frye, W.W. (1984). Fertilization and liming. **In:** *Soil & Tillage Research,* **51**: 81-90.

Umeghara, U.U., Mohammed, M., Olorukooba, M.M. and Essien, J. (2018). Evaluation of herbicides and manual weed control methods in productivity of maize (*Zea mays*) in the Northern Guinea savanna, Nigeria. Book of Abstract/Programme, 46th Annual Conference, Weed Science Society of Nigeria, University of Port Harcourt, Port Harcourt, Nigeria. November 4-7. p 46-47.

Van Den Putte, A., Govers, G., Diels, J., Langhans, C., Clymans, W., Vanuytrecht, E., Merckx, R. and Raes, D. (2012). Soil functioning and conservation tillage in the Belgian loam belt. *Soil Tillage Research,* **122**: 1-11.

Vetsch, J.A. and Randhall, G.W. (2000). Enhancing no-tillage systems for corn with starter fertilizers, row cleaners and nitrogen placement methods. *Agronomy Journal,* **92**: 309-315.

Vogel, H. (1994). Conservation tillage in Zimbabwe. pp 13-16 **In**: 17th East African Biennial Weed Science Society Conference Proceedings, September 27-29, 1999, Harare, Zimbabwe.

Wasaya, A., Muhammad, T., Abdulmanaf, M.A., Shuaib, K. and Andijaz, A. (2011). Improving maize productivity through tillage and nitrogen management. *African Journal of Biotechnology,* **10(81)**: 19025-19034.

Weber, J.F., Kunz, C., Peteinatos, G.G., Zikeli, S. and Gerhads, R. (2017). Weed control using conventional tillage, reduced tillage, no-tillage, and cover crops on organic soybean. *Agriculture,* **7(43)**: 1-13.

Wilson, R.G. (1993). Effect of preplant tillage, post-plant cultivation, and herbicides on weed density in corn (*Zea mays*). *Weed Technology,* **7**: 728-734.

Wilson, R.G. (1993). Effect of preplant tillage, post-plant cultivation, and herbicides on weed density in corn (*Zea mays*). Published Online by Cambridge University Press. 12 June, 2017.

Yenish, J.P., Doll, J.D., and Buhler, D.D. (1992). Effects of tillage on vertical distribution and variability of weed seed in soil. *Weed Science,* **40**: 429-433.

Yenish, J.P., Doll, J.D., and Buhler, D.D. (2017). Effects of tillage on vertical distribution and variability of weed seed in soil. Published Online by Cambridge University Press. 12 June, 2017.

Zhang, S.L., Zhang, X.Y., Huffman, T., Liu, X.B. and Yang, J.Y. (2011). Soil loss, crop growth, and economic margins under different management systems on a sloping field in the black soil area of Northeast China. *Sustainable Agriculture,* **35**: 293-311.

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