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Effects of tillage systems on soil chemical properties in oxic paleustalf soil of a degraded land in a suburb of southwestern Nigeria

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Abstract
The experiments were conducted to investigate the effects of three different tillage practices on soil physicochemical properties, yield and growth parameters of maize. The study was conducted at the research farm of Institute Of Agricultural Research And Training (I.A.R & T), Ibadan. Nigeria. The trash on slash and burn plots were burnt while trash on zero tillage and conventional tillage were removed. Only conventional tillage plot was ploughed and harrowed. The soils of the study site belong to Oxic Paleustalf and classifies locally as Iwo Series. Soil sample were collected at depth of 0.15cm with a core sampler and 15-30cm with soil auger on all the 12 plots before and after the experiment. Three tillage practices {Conventional Tillage (CT), zero tillage (ZT) and slash and burn (SB)} were evaluated in a split plot design of (2m x 2m size) of four replications. Soil organic carbon, total nitrogen, sodium, calcium, phosphorus, soil organic matter and soil pH were evaluated. Conventional Tillage resulted in compaction of soil and poor soil organic matter status. There were no significant differences in maize plant height and stem girth. In addition, no tillage resulted in greatest organic matter and lowest in maize stem girth, height and yield while CT and SB resulted in higher maize grain and stover yield and soil available phosphorus. SB was significantly higher in calcium, potassium, and exchangeable bases but decreases soil organic carbon. Therefore, for sustainable production in maize yield, ZT and CT is highly recommended over SB except for that, burning helps to release concluded mineral nutrients such as Mg, Ca, and available P

Keywords: soil fertility, zero tillage, soil organic carbon, soil compaction, conventional tillage

INTRODUCTION

Maintenance of soil fertility in Nigeria and the rest of Africa had been the traditional shifting cultivation and bush fallowing system [1-2]. Shifting cultivation is when a piece of land is put under cultivation for one or two years and then abandoned for virgin land in order to revert its fertility for generation of higher yield of crop. The abandoned land is left under natural bush fallow for a period of up to 10 years or more before it is brought into cultivation once again. It has been well estimated that shifting cultivation accounts for about 45% of the total usable land in the World (Nigeria Daily Times, Friday 6, 1984) Over 70% of Nigerian population, whose livelihood depends on farming, lives in the rural areas while the method of land clearing is the traditional slash and burn. This method had been an integral part of shifting cultivation and widely practiced by over 90% of farmers in South Western Nigeria. Conventional tillage ensures less than 15% of crop residue cover on the soil. Soils exposed to conventional tillage operation influences the distribution of roots in the soil profile, produces finer

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root and longer roots. Weed control is one of the main challenges in zero-till farming more than in conventional farming, the prevention of a heavy weed infestation by intensive tillage is important due to the exclusion of synthetic chemicals for weed control. This situation runs in a direction opposite to the common trend in conventional farming where conservation tillage practices have been widely adopted worldwide. Conventional tillage includes various tillage practices that differ in time, frequency and working depth; however, they all possess similar characteristics such as no deep and intensive soil invention by mould board plough. Additional, it can be assumed that N-net mineralization might take place at lower rates if the plough is not used which could affect the nitrogen supply and yield of the crop. Another challenge is the elimination perennial legumes, often grass-closer, as an essential component of the crop rotation in no-till farming. In terms of seed as a source for weeds, the change im primary tillage means a change in depth where seeds are shifted or not to deep layers by tillage operations. Seed with a life would germinate fatally and die if they get buried in the soil deeply by a mould board plough, but seeds with a high longevity due to seed dormancy would survive in deep soil horizon after soil inversion even for many years.

Small seeded weeds can only emerge from soil horizons close to the surface whereas big seeds are able to germinate even from 20cm depth. Seeds with a comparatively low dormancy and seed persistence for instance of gramoid weeds or volunteers would not survive for a longer period. After soil inversion by a mould board plough, seeds are located in deep soil horizon while non-inversion tillage (for instance by a hisel plough) leads to a distribution of seeds in the upper soil horizon, so that differences in weed emergence can be expected due to different operations. Compared with the other major nutrients P is by far the least mobile NS available to plants in most soil conditions, particularly in oxisols and is therefore likely to be great affected by tillage. Mechanical manipulation of soil during tillage may increase the chances of contact between soil solution or fertilizer-derived P and exposed soil particles and this facilities the formation of stable insoluble P compounds. Tillage, notable 'no-tillage', affects some chemical characteristics related to soil acidity that may influence P available, plant growth and yield. Organic matter and P accumulate in the top few centimeters under 'no-tillage' compared with 'conventional tillage' which may reduce Al toxicity [3]. Other nutrients also accumulate near the surface in 'no-tillage' soils, causing increases in the concentration of electrolytes and P sorption. Burning had been identified as one of the degrading practices that result in soil structural degradation [4]. Burning helps in clearing bush debris and reduction in weed infestation that would have been competing for water, sunlight and soil nutrients, with crops. The ash deposit after burning helps to fertilize the soil. This is done by immediate release of the occluded mineral nutrients-Mg, Ca, available P, for crop use [5].

Table 1: Soil chemical properties measured prior to the initiation of the experiment

	SOM	SOC	%N	Mg	H	Na	K	P	Soil pH	Ca	CEC
			cmol/kg	cmol/kg	mg/kg cmol/kg	mg/kg	pH	cmol/kg			
ZT	1.10[a]	0.94[a]	0.095[a]	0.042[a]	0.15[a]	0.34[a]	0.71[a]	7.22[a]	5.5[a]	0.56[a]	2.23[a]
CT	1.06[a]	0.10[a]	0.101[a]	0.41[a]	0.13[a]	0.35[a]	0.77[a]	6.65[a]	6.8[a]	0.67[a]	2.29[a]
SB	1.04[a]	1.94[a]	0.092[a]	0.44[a]	0.10[a]	0.47[a]	0.73[a]	7.41[a]	5.4[a]	0.54[a]	4.47[a]

Significant change at P ≤ 0.05 in soil chemical property of the parameters over the experimental period.
SOM = SOIL ORGANIC MATTER
SOC = SOIL ORGANIC CARBON

ZT= Zero Tillage (control) CT= Conventional Tillage (ploughed and harrowed) SB= Slash and Burn

Table 2: Effect of tillage systems on soil chemical properties after the experiment.

	%C	%N	AVP	Ca	CEC	H	K	SOM	Mg	Na	Soil pH
		cmol/kg		cmol/kg			cmol/kg	cmol/kg		cmol/kg	
SB	1.96[a]	0.01[a]	7.45[a]	0.67[a]	2.47[a]	0.11[a]	0.78[a]	1.05[a]	0.47[a]	0.47[a]	5.5[a]
ZT	0.98[a]	0.09[a]	7.36[a]	0.57[a]	2.24[a]	0.15[a]	0.90[a]	1.06[a]	0.42[a]	0.34[a]	5.6[a]
CT	1.03[a]	0.10[a]	6.72[a]	0.68[a]	2.38[a]	0.14[a]	0.77[a]	1.05[a]	0.46[a]	0.35[a]	7.1[a]

Significant change at P ≤ 0.05 in soil chemical property of the parameters over the experimental period.
SOM = SOIL ORGANIC MATTER

SB = Slash and Burn ZT = Zero Tillage CT = Conventional Tillage

Table 3: Effect of Tillage System on Maize Yield

TILLAGE SYSTEMS	Grain yield (tones/ha)	Stover yield (tones/ha)
CT	3.036^{a}	10.80^{a}
SB	2.942^{ab}	10.72^{a}
ZT	2.164^{b}	8.90^{a}

Mean values with the same superscript are not significantly different at 5%

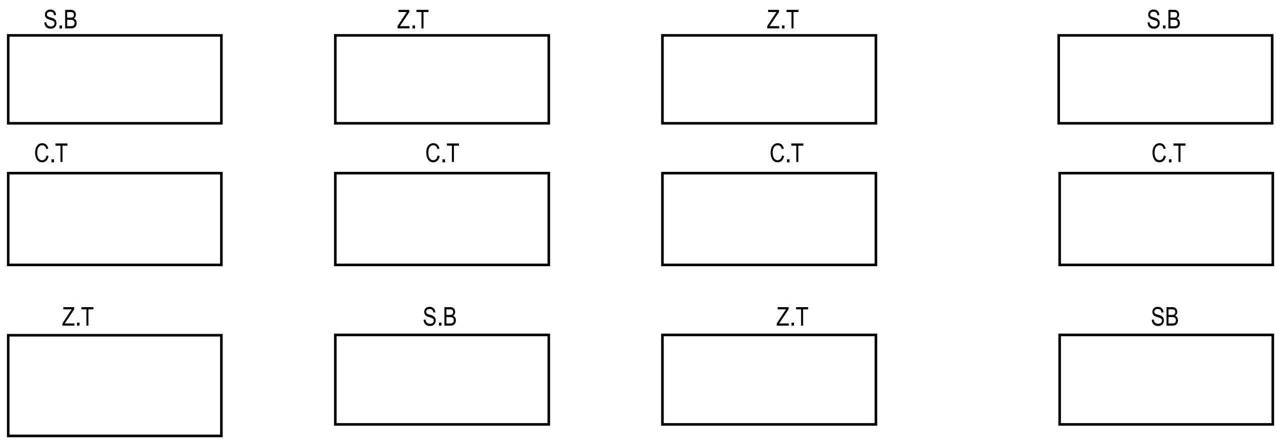
SB = Slash and Burn ZT = Zero Tillage CT = Conventional Tillage

Table 4: Effect of Tillage Systems on Maize Stem Girth and Height.

TILLAGE SYSTEMS	Maize stem girth (cm)	Maize height (cm)
ZT	3.963^{ab}	210.61^{ab}
SB	1.093^{a}	82.915^{a}
CT	1.089^{a}	66.15^{a}

Mean values with the same superscript are not significantly different at 5%

SB = Slash and Burn ZT = Zero Tillage CT = Conventional Tillage



KEY FOR TREATMENT

CT=Conventional Tillage Z.T=Zero Tillage SB=Slash and Burn

Figure 1. Diagram of the experimental layout

MATERIALS AND METHODS

Site description

This study was conducted in the research farm of Institute of Agricultural Research and Training (I.A.R&T) Ibadan. Nigeria. The site is located on $7^{0}23^{N}$, $3^{0}5^{E}$ and 160m above mean sea level. Ibadan has a mean annual rainfall of 1340.4mm recorded for a period of 10 years (ITU-I.A.R&T, 2009). Rainfall peaks occur in June and September. Annual temperature ranges from 21.3°C and April to early August and late (mid-August to October/November) seasons. The study area has a uniform slope of 9% and has been continuously cultivated under maize crop (*Zea mays*) for more than 10 years before this study. The soil of the study site belongs to Oxic Paleustalf (SSS) and classified as Iwo series (Smyth and Montgomery).

Land preparation and treatment

Land preparation began in 21st to 25th of August, 2009 with the slash of re-growth bush using cutlass and axe (the traditional land preparation techniques). The trash was left on the site to dry for about one week before burning on slash while trash on zero tillage and conventional tillage plots were removed. The site was divided into 3 plots of zero tillage, conventional tillage and slash and burn replicated four times making a total of 12 plots as represented diagrammatically in Figure 1.

Each plot size was made 2m x 2m and is demarcated from one another by 1m wide road path around the perimeter of each plot. Only CT plots were ploughed and harrowed while the rest were subjected to burning and untilled seed bed and use of herbicides to control weeds. Post-land preparation samples were taken after two weeks. Two weeks later, maize as a test crop was planted on all the plots at 50cm along the row and 75cm between the rows to give a plant population of 53, 000 plants at 2-3 seeds per hole and 2-3 plants per stands. The planting depth of maize seeds was 5cm deep.

Determination of the soil chemical properties

The pH of pre and post filed soil samples was measured potentiometrically with a digital pH meter in the suspension of 1:1, soil water. The exchangeable basis (Ca, Mg, K and Na0 was extracted with IM ammonium acetate (NH_4OAc) at pH 7. The exchangeable acidity was determined by saturating the soil samples with +N KCL solution and titrating with NaOH. The exchangeable Effective Cation Exchange Capacity (ECEC), Organic Carbon and Total Nitrogen were also determined by Kjedahl method while available Phosphorus (P) was as described by [6] method. Fe and Mn were extracted with 0.01M HCl extracted method.

Parameter measured

The following plant parameters were measured

Plant height and stem girth at 3, 4, 6 and 8 weeks after planting (WAP)

The plants were measured with measuring tapes graduated in centimeter (cm) from soil surface level to the tip of the inner leaf and to the tassel after tasseling and the mean length of the three stand was computed as mean plant height of the maize. Stem girth was measured using Vernier caliper to measure the circumference of maize plant stems (15cm above the ground level) at 3,4,6 and 8 weeks after planting (WAP). The stem girth of three stands was computed as the mean girth.

Maize yield

Maize yield was determined at maturity by measuring the following parameters:

i. Grain yield: Grain yield was determined after shelling the maize grains from the cob. Moisture of the grains was determined in the laboratory using the following equation

$$\%MC = \frac{\text{Initial weight-oven dry weight}}{\text{Oven dried weight}} \times 100\%$$

Where MC is moisture content

The percentage moisture content of the shelled grains was thereafter converted to 13% moisture content, which is the %MC of market grains ready for sales.

ii. Stover weight: The dried maize stems on each plot were harvested, cut into smaller pieces and weighed.

Harvesting of maize involve cutting of maize stands at soil surface after which the parameter above were taken.

Soil sample collection

Soil samples were collected from each experimental plot at a depth of 0-15cm using core sampler and at 15-30cm using soil auger twice before and after planting during the growing season.

Laboratory analysis

The soil samples collected from each experimental plot were taken to the soil laboratory to analyze them for the following properties: Soil organic carbon, Soil pH, Total nitrogen, Soil cation exchange capacity, Available phosphorus, Magnesium, Ca, H, K, Na, Fe and Soil organic matter.

Statistical analysis of experimental data

Analysis of variance (ANOVA) was used to evaluate the treatment effect on soil and plant data collected and Duncan Multiple Range Test (DMRT) was used to compare the mean difference on the effect on soil and plant data.

RESULTS

From Table 1, Soil organic matter was found to be significantly higher under ZT (control) and CT over SB while soil organic carbon was significantly higher under SB and ZT over CT. Percentage nitrogen, calcium, and soil pH were also found to be significantly higher under CT and ZT than SB. Soil pH at 6.8 was acidic. Exchangeable potassium and available phosphorus affected a progressive increment under SB and ZT over CT. Mg was significantly higher in SB and CT over ZT while Hydrogen was higher under ZT and CT than SB. Sodium (Na) and soil cation exchange capacity were significantly higher under SB and CT than ZT.

Available phosphorus resulted in progressive increment in SB and ZT than CT lower main score of 6.7Cmol/kg. Total nitrogen was to increase in CT and ZT than SB with lower mean score 0.096Col/kg while soil organic carbon was higher in SB and CT than ZT. Soil calcium and sodium were significantly higher under CT and SB over ZT (control). Soil organic matter was also found to be significantly higher than ZT and CT over SB while CEC was higher in SB and CT than ZT. Magnesium was significantly higher under SB followed by CT over ZT. Exchangeable potassium and Hydrogen were significantly highest or in excess under ZT but potassium (K) is lower under CT over SB and Hydrogen (H) is lower under SB than CT was found Acidic under SB and ZT.

DISCUSSION

Total Nitrogen and Soil Organic matter contents

Significant differences between tillage management (ZT, CT) were found for total nitrogen content. Soils under ZT showed greater total nitrogen than those of SB and CT. soil organic matter was also found to be higher in content under CT and SB. These findings agree with result reported by [7] who has described zero tillage (ZT) as an efficient soil management practice that improve soil chemical and physical characteristics in low fertility tropical soils.

Total Phosphorus, Sodium, Potassium and Hydrogen contents

Total phosphorus increase also in slash and burn and zero tillage and decrease in CT by 0.05mg/kg. Sodium content was in higher mount in SB and CT than ZT. Ash deposit after burning helps to fertilize the soil and is done through immediate release of occluded mineral nutrient, like phosphorus [8]. Exchangeable potassium and hydrogen increase progressively in ZT and CT except in SB where it decreases slightly.

Soil pH, Cation exchange capacity, Calcium, Magnesium and Organic carbon contents

Soil pH was slightly acidic under SB and ZT but found neutral under CT. spoil calcium, soil organic carbon (SOC), Magnesium and CEC affected a progressive increment under SB and CT over ZT, this also agreed with [9-10] who reported that ash deposit after burning help to fertilize the soil by releasing occluded mineral nutrient such as Mg, Ca and Na. as well as soil carbon.

Maize stem girth, height and yield

Progressive increment was observed in maize stem girth and heights under ZT and SB over CT. Grain and Stover yield were significantly increased in CT and SB than ZT. This observation is in conformity with the findings of [11-12] who find out that, maize toots grew more extensively, finer and longer on tilled soils that no-till soils than or zero-till soils and as a result of this maize roots were able to tap into soil nutrients effectively which are reflected in maize rapid growth, agronomic characters or traits and increased maize and Stover yield.

CONCLUSION

At the end of the research, soil organic matter (SOM) and available phosphorus differed significantly with rapid increase in Zero Tillage and Conventional tillage system. Slash and burn (SB) affected a progressive increment in soil available magnesium (mg) and exchangeable potassium (K) with an increase difference of 0.029 Cmol/kg for magnesium and 0.054Cmol/kg for Potassium (K) indicating that Mg and K increased under SB

Soil pH was slightly acidic in all the three tillage systems initially was brought back to neutral under conventional tillage by increasing from 6-8-7.1 and then found acidic under ZT and SB after the experiment. The optimum pH for maize production in the tropics is between 5.5 to 6.8 therefore the above soil pH will not be suitable for maize production. The mean values of soil calcium and sodium were also high in CT and SB than ZT. Total nitrogen was found to increase under ZT and CT after the experiment than their previous status while soil organic carbon increased in SB and CT over ZT. For improved grain yield of maize, conventional tillage was found to be the best tillage for boosting maize grain and Stover production.

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