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Effect of tillage system on soil properties and yield of Oba 98 maize variety in Zaria

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ABSTRACT

Nigeria loses significant amount of soil, organic matter and plant nutrients to the continuous tilling of soil for various crop production. This leads to declining and stagnation of crop yields. Three year field trials were conducted during 2006, 2007 and 2008 wet seasons at the experimental farm of Institute for Agricultural Research of Ahmadu Bello University, Zaria (Lat. 11° 11' N: Long 7° 38' E: 686 m above sea level) to investigate the effect of tillage system on soil chemical properties, physical properties and grain yield of Oba 98 maize variety. The treatments consisted of six tillage systems laid out in Complete Randomize Block Design and replicated five times. The parameters measured included soil chemical properties such as ions concentrations and Cation Exchange Capacity, soil textural class, soil bulk density and grain yield of the maize under test. The results obtained indicated that GPx (Glyphosate followed by Primextra Gold) and PPx (Paraquat followed by Primextra Gold) tillage systems enhanced soil nutrients with higher Cation Exchange Capacity, highest cations and anions concentrations due to organic matter accumulation in the soil, improved soil structure that resulted to better grain yield of maize. The two types of tillage systems will therefore help in reducing the effect of soil degradation through frequent tilling and also improved soil aggregate and fertility as a result of organic matter accumulation on the soil surface.

Keywords: Tillage, soil, yield, maize.

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INTRODUCTION

Tillage systems are sequences of operations that manipulate soil in order to prepare good seed bed for crop production. The ways in which these operations are implemented affect physical and chemical properties of the soil which in turn affect plant growth (Lindsay et al., 1999). Scott (2008) described various tillage systems as follow: conventional tillage is any system which attempts to incorporate most residues where less than 30% of the soil surface is covered with residue after planting. No-till system left the soil undisturbed from planting to harvest, except for fertilizer incorporation, planting or drilling is accomplished in a narrow seed bed or slot created by coulters, row cleaners, disk openers, in row chisels or rotor tillers. Conservation tillage emphasizes that soil is a living body essential to sustained quality of life on the planet; in particular, it recognizes the importance of the upper 0 to 20 cm of the soil as not only the most active zone, but also the zone that is most vulnerable to erosion and degradation (Anonymous, 2006). Africa's ongoing economic crisis is to a large extent predicted on the continent's inability to supply enough food to her growing population. One of the most critical natural resources base on which African food security depends is the soil. Yet, African soils are relatively more sensitive and fragile than those found in other continents and have over the years been considerably and consistently been eroded by natural and manmade factors (Adedeji, 2001). Nigeria was observed to be among the African countries that have already lost significant amount of soil to various forms of degradation. The most important factor that causes of soil degradation is tillage, which exposes the soil to the action of erosion. Many areas in the country are said to be losing over 25 tonnes of the top soil per hectare per year (Findly, 1998). Another study revealed that African soils have been suffering from degradation for the past 100 years. Most of the soil lost up to half of its native organic matter content along with some plant nutrients. The major contributor to this trend in soil organic matter loss is the tilling of soil with disc, plow and cultivator in preparing the land for seeding (Anonymous, 2006). The impacts of these factors have manifested themselves in stagnating and declining crop yields (Adedeji, 2001). It is in view of the above mentioned situations that this study was designed to investigate the effect of tillage system on soil properties and yield of Oba 98 maize.

MATERIALS AND METHODS

The study was conducted during 2006, 2007 and 2008 wet seasons at the experimental farm of Institute for Agricultural Research (I.A.R.), Ahmadu Bello University, Samaru, Zaria (Lat.11° 11' N: Long 7° 38' E: 686 m above sea level). The site is located in the Northern Guinea savanna whose soil is predominantly sandy loam. The treatments consisted of six forms of tillage system; harrowing followed by weeding (HW), harrowing followed by primextra Gold (HPx), ridging followed by primextra Gold followed by weeding (RPxW), ridging followed by weeding (RW), glyphosate followed by primextra Gold (GPx) and paraquat followed by primextra Gold (PPx). These were laid out in Complete Randomize Block Design. The treatments were replicated five times. The gross plot consisted of 4 rows/ridges (0.75 m apart) by 3 m long of which the total area was 3 m × 3 m = 9 m^2. The seed were sown by hand at the rate of two seed per hole at 3 cm depth and 25 cm between stands. The seedlings were later thinned to one plant per stand at two weeks after sowing which gave a plant population of approximately 53,333 per hectare. Glyphosate was applied (4 L per hectare) a week before sowing in line with the treatments, paraquat was applied (4 L per hectare) a day before sowing while primextra Gold was applied (4 L per hectare) a day after sowing according to the tillage treatments respectively. Manual hoe weeding was conducted on RW and HW plots at 2 and 4 WAS while on RPxW plot weeding took place at 4 WAS only.

Determination of soil nutriments statues

During the first year of the trial, prior to land preparation, random soil samples were taken using augar to a depth of 30 cm and analyzed for their physico-chemical properties. Also, at harvest period of each trial the soil was sampled according to treatment and then analyzed for chemical composition. Soil texture class was determined using Boyoucos (1951) hydrometer method. The textural class was determined using textural triangle (USDA, 1960). Soil pH was measured with the aid of pH meter (Black, 1965) and the organic carbon was determined using the procedure described by Wolf (1982). Total nitrogen and available phosphorus were determined using Micro-Kjeldhal (Bremmer, 1965) and Trough (1950) procedures, respectively. Molydate blue colour method was used to determine the extractible phosphorus (Bray and Kultz, 1945). Exchangeable cations were determined using Reith (1967) method. Atomic absorption spectro-photometry was employed to estimate calcium, potassium and magnesium concentrations using Perkin Elmer model 403.

Determination of soil bulk density

This was determined at the harvest period of each trial. Soil samples were collected from each of the six treatment tillage system. The samples were taken to the laboratory where they were analyzed using core method (Agbenin, 1995). The core sampler was pushed into the soil and the inner cylinder was filled up. It was pressed soft in order not to compact the soil. The core was then dug out carefully to preserve the soil in it. The outer cylinder was separated while the inner one was retained with undisturbed soil. The soil was then trimmed carefully at the two open ends of the cylinder using a knife. The two ends were covered with metal disk and put in plastic bag which was folded to keep the soil in place and the opening of the bag was taped. The samples were then taken to the laboratory (with minimum disturbance). The cylinder and wet soil were weighed and the value recorded. The soil was dried in an oven at 105°C to a constant weight and the bulk density was calculated as follows:

Weight of empty cylinder = X_1g
Weight of wet soil + cylinder = X_2g
Weight of oven dried soil + cylinder = X_3g

$$\text{Bulk density (Bd)} = \frac{X_3 - X_1}{\text{Volume of soil (cm}^3\text{)}}$$

Volume of soil = Volume of cylinder determined from known diameter and length of the cylinder.

The core sampler was carefully pushed into the soil so that it was not compacted, but later the soil sample in the core was pressed hard that the soil became compacted, and carefully removed from the sampler and weighed. The volume of the compressed soil was determined from the volume of the sampler core.

Particle density (Pd) is the ratio of the total mass of solid particles (g) to the total volume:

$$\text{Particle density (g/cm}^{3)} = \frac{\text{Mass of soil sample}}{\text{Vol. of soil sample}}$$

Data collected and statistical analysis

The exchangeable cations, soil textural class, soil bulk density and grain yield were the data collected according to tillage treatments. General Linear Model (GLM) of the statistical analysis system (SAS) package (SAS, 1990) was used for statistical analysis of the data collected and differences between the treatments means were compared using Duncan Multiple Range Test ($P < 0.05$) as described by Duncan (1955).

RESULTS

Table 1 shows the physical and chemical properties of

Table 1. The physical and chemical properties of the soil before commencing the experiment in 2006 at Samaru, Zaria.

Parameter	2006 wet season	
	0 – 15 cm	15 – 30 cm
Particle size distribution		
Sand (%)	58	52
Silt (%)	34	30
Clay (%)	8	18
Texture (%)	Sandy loam	Sandy loam
Exchangeable bases (C.mol kg^{-1})		
Ca	2.50	2.30
Mg	1.21	1.39
K	0.10	0.09
H + Al	0.40	0.40
CEC	5.40	5.80
Chemical property		
pH in water	5.40	5.20
pH in (0.0 m) calcium chloride	4.30	4.50
Organic carbon (%) (OC)	0.40	0.31
Total nitrogen (%) (TN)	0.035	0.030
Avail. exchangeable P. (ppm) (AP)	15.75	10.50

Table 2. Physical and chemical properties of soil at the experiment site as affected by tillage systems during harvest period of 2006, 2007 and 2008 wet seasons at Zaria, Nigeria.

TS	Base cations and cation Exchange Capacity: CEC (Cmolc/kg)														
	2006					2007					2008				
	Ca	Mg	K	Na	CEC	Ca	Mg	K	Na	CEC	Ca	Mg	K	Na	CEC
HW	1.2^{b}	0.9^{b}	0.2^{ab}	0.2NS	5.2^{a}	1.8NS	0.5^{c}	0.3^{a}	0.2^{b}	3.3^{c}	1.8^{b}	0.7^{c}	0.1^{c}	0.2^{b}	4.5^{ab}
HPx	2.0^{a}	0.9^{b}	0.3^{a}	0.2NS	4.1^{ab}	2.0NS	0.7^{c}	0.3^{a}	0.2^{b}	4.0^{b}	2.0^{b}	0.8^{c}	0.4^{a}	0.3^{a}	4.6^{ab}
RW	1.9^{a}	1.2^{ab}	0.2^{ab}	0.2NS	4.0^{ab}	1.9NS	1.2^{b}	0.3^{a}	0.2^{b}	4.2^{b}	1.9^{b}	1.2^{b}	0.2^{b}	0.2^{b}	3.3^{b}
PPx	2.0^{a}	1.4^{a}	0.3^{a}	0.2NS	5.2^{ab}	2.2NS	2.4^{a}	0.3^{a}	0.3^{a}	5.4^{a}	3.1^{b}	2.9^{a}	0.4^{a}	0.3^{a}	5.8^{a}
RPxW	1.9^{a}	1.0^{ab}	0.1^{b}	0.2NS	2.3^{b}	1.9NS	1.0^{b}	0.1^{b}	0.2^{b}	5.2^{a}	1.9^{b}	1.0^{b}	0.4^{a}	0.2^{b}	4.3^{ab}
GPx	2.0^{a}	1.5^{a}	0.3^{a}	0.3NS	4.2^{ab}	2.1NS	2.1^{a}	0.3^{a}	0.3^{a}	4.1^{b}	2.9^{a}	2.7^{a}	0.4^{a}	0.3^{a}	5.1^{a}
SE±	0.21	0.10	0.31	0.11	0.60	0.82	0.41	0.17	0.03	0.70	0.52	0.24	0.03	0.02	0.65
TC	Sandy loam					Sandy loam					Sandy loam				

HW = Harrowing followed by weeding, HPx = Harrowing followed by Primextra Gold, RW = Ridging followed by weeding, PPx = Paraquat followed by primextra Gold, RPxW = Ridging followed by primextra Gold followed by weeding, GPx = Glyphosate followed by primextra Gold, TS = Tillage system.

the soil experimental site during pre-land preparation period in 2006 wet season. The particle size distribution indicated that, sand constituted the highest proportion of over 50% followed by silt which constituted 30% while clay constituted the least proportion. According to the guide of the soil textural triangle (USDA, 1960), the soil has been classified as Sandy loam which is a typical characteristic of Savanna soils of Nigeria (Lombin, 1983). On the exchangeable bases concentrations, calcium had the highest concentration followed by magnesium while potassium had the lowest concentration. The chemical properties indicated that, the soil was slightly acidic with low organic carbon and nitrogen contents. Nitrogen has been identified as the most limiting nutrients for plants in Nigerian Savanna soils (Ogunwale, 2003: Lombin, 1983). Table 2 shows the physical and chemical properties of the experimental site soil (according to the treatments) at harvest period of 2006, 2007 and 2008 wet season. In 2006, the treatments effects was significant ($P < 0.05$) where HPx, RW, PPx, RW and GPx had more calcium concentration than HW. PPx and GPx had significantly more magnesium concentration than HW and HPx. HPx, PPx and GPx had significantly more concentration of potassium than RPxW. Tillage had no significant effect on Sodium concentration while HW and PPx had significantly higher Cations Exchange Capacity (CEC) than RPxW. In 2007, tillage system had no significant effect on the calcium concentration, however it was significant ($P < 0.05$) for other Mg, K, Na and CEC. PPx and GPx had significantly the highest magnesium concentration while HW and HPx had the lowest. HW, HPx, RW, PPx and GPx produced significantly more Potassium concentration than RPxW. PPx and GPx produced significantly more sodium concentration than the other tillage treatments while PPx and RPxW recorded the highest Cations Exchange Capacity (CEC). In 2008, PPx and GPx produced significantly more calcium concentration than the other treatments. PPx and GPx produced significantly the highest concentration of magnesium. HPx, PPx, RPxW and GPx produced significantly the highest concentration of potassium while HW had the least. HPx, PPx, and GPx produced significantly more sodium than the other treatments while PPx and GPx had higher Cation Exchange Capacity (CEC) than RW. The soil textural class is sandy loam. Table 3 shows the soil bulk density at the harvest period of 2006, 2007 and 2008 wet seasons. In 2006 and 2007, tillage system had no significant effect on the soil bulk density while in 2008; GPx and PPx lowered significantly lower soil bulk density than the other treatments. The effect of tillage systems on grain yield is shown in Table 4. In 2006 and 2007, PPx gave significantly higher grain yield while RW gave the least. In 2008, GPx and PPx significantly recorded the highest grain yield while HW and RW had the lowest yield.

Table 3. Effects of tillage systems on soil bulk density of the experimental site soil during harvest period of 2006, 2007 and 2008 at Zaria, Nigeria.

Tillage system	Soil bulk density (gcm^{-3})		
	2006	**2007**	**2008**
GPx	1.38	1.29	1.01^{b}
PPx	1.36	1.28	0.96^{b}
HW	1.37	1.35	1.34^{a}
RW	1.39	1.40	1.38^{a}
RPxW	1.38	1.34	1.33^{a}
HPx	1.39	1.36	1.35^{a}
SE±	0.231	0.118	0.243

HW = Harrowing followed by weeding, HPx = Harrowing followed by Primextra Gold, RW = Ridging followed by weeding, PPx = Paraquat followed by primextra Gold, RPxW = Ridging followed by primextra Gold followed by weeding, GPx = Glyphosate followed by primextra Gold.

Table 4. Grain yield as affected by tillage system in 2006, 2007 and 2008 wet seasons at Zaria, Nigeria.

Treatment	Grain yield ($ton.ha^{-1}$)		
	2006	**2007**	**2008**
HW	1.52660^{ab}	1.20020^{ab}	1.34310^{c}
PPx	1.98380^{a}	1.44150^{a}	2.00540^{a}
GPx	1.72160^{ab}	1.17560^{ab}	2.83520^{a}
HPx	1.80660^{ab}	1.03320^{b}	1.73710^{b}
RPxW	1.82180^{ab}	$1.236.60^{ab}$	1.80860^{b}
RW	1.44360^{b}	7.1020^{c}	1.31230^{c}
SE±	169.070	100.120	96.075

HW = Harrowing followed by weeding, HPx = Harrowing followed by Primextra Gold, RW = Ridging followed by weeding, PPx = Paraquat followed by primextra Gold, RPxW = Ridging followed by primextra Gold followed by weeding, GPx = Glyphosate followed by primextra Gold.

DISCUSSION

Conservation tillage such as PPx and GPx had the highest concentrations of base cations as well as CEC. This could be due to accumulation and decaying of organic matter on the soil surface which resulted to the release of base cations into the soil. Conservation tillage enhances good soil structure and nutrients production, it also conserves water by improving absorption and infiltration and also conserves biodiversity by protecting the natural balance in the field (Anonymous, 1992).

The reduction in the soil bulk density by PPx and GPx treatments could be due to the decaying of the organic matter and its mix up with the soil that resulted to high porosity. In experiments covering a wide range of soil types, the proportion of large pores was higher in no-till than reduced and conventional tillage (Findly, 1998). The superiority that PPx and GPx had over other treatments in terms of grain yield could be due to higher soil nutrients status and better soil structure. Derpsch (2003) reported that conservation tillage produces higher yield than conventional tillage system as a result of adequate soil moisture for enhancing root growth and provision of balance nutrients to plants.

Primextra Gold (Px) 660SC is a Chloroacetanilide Triazine that contains S-metolachlor 290g/Lt and Atrazine 370g/Lt. It is a selective pre-emergence herbicide that is mainly taken up through the shoots of germinating seeds and seedlings of grasses. Glyphosate 41% S. L. (G) is a non selective, post-emergence, translocated herbicide which is highly effective on several annuals and perennials grasses, broad leaf weeds and stubborn weeds. Paraquat 24% EC (P) is a non-selective contact herbicide that is effective against wide range of weeds.

Conclusion

Base on the results obtained, it is concluded that PPx and GPx tillage systems enhanced soil nutrients status and good soil structure that resulted to better grain yield. The two tillage systems are therefore recommended for soil improvement under maize production.

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