EFFECT OF DIFFERENT TILLAGE PRACTICES ON SOME SELECTED SOIL CHEMICAL PROPERTIES, SOIL PENETRATION RESISTANCE AND MAIZE YIELD PARAMETERS IN NORTHERN GUINEA SAVANNA ALFISOLS

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ABSTRACT
Tillage practices exert tremendous effects on soil conditions and are important to crop production. Appropriate tillage results in improved soil condition while inappropriate tillage damages the soil, hence the need to investigate its effects on soil in order to improve yield and cash return. This experiment was conducted at the Institute of Agricultural Research (IAR) farm Samaru, Ahmadu Bello University Zaria, Kaduna state with the aim of studying the effect of tillage practices on some selected soil chemical properties, penetration resistance and maize yield parameters. The treatments consisted of three levels of tillage practices (conventional (CT), minimum (MT) and zero tillage (ZR) replicated 3 times and arranged in Randomized Complete Block Design (RCBD). Data on soil pH, organic carbon (OC), total nitrogen (TN), number of cobs, stover yield, grain weight, 1000 grain weight and soil penetration resistance at 0, 10, 20 and 30cm were collected. The result obtained revealed significant effects of tillage practices on soil chemical properties, penetration resistance at all depths and yield parameters. Minimum tillage has highest value of soil parameters (pH, OC, and TN) while conventional has highest value for penetration resistance and yield parameters. From the findings of this study, it can be concluded that minimum tillage improved soil condition and maize yield. It is also recommended that minimum tillage be adopted in the study area.

Keyword: tillage, maize, Alfisols, savanna, organic carbon, total nitrogen, penetration resistance

INTRODUCTION

Tillage practices manipulate soil physical, chemical and biological conditions and are of fundamental significance in crop production. Tillage influences both soil properties and crop yield (Khairul Alarm *et al.,* 2014) and optimizes conditions for seed germination, emergence and seedling establishment (Lai 1979). Tillage provides a good medium for growth and development and aids in meeting crop requirements. For instance, Maize is susceptible to water logging conditions, and requires well aerated and well-drained soil, because excess soil moisture causes disorders in the rhizosphere zone leading to plant roots suffering from extreme oxygen stress that inhibits growth and development (Zaidi *et al.,* 2003), It also yields poorly on shallow, sandy soils due to its higher susceptibility to moisture and nutrient stress (Zaidi *et al.,* 2003). These beneficial roles of tillage in providing the aforementioned effects through ameliorating soil conditions were confirmed by Mahboubi et al., (1993), and therefore assist maize in meeting its soil requirements for growth and development.

Tillage practices exert tremendous effects on soil conditions. Based on the level of operations and its effects on soil, tillage is categorized as conventional or conservation. Conservation tillage practices that apply minimum soil disturbance, are reported to result in increases in soil moisture contents (Malecka *et al.,*2011), soil pH (Busari and Salako, 2013), soil organic matter content (Stefen *et al*., 2008), and soil total nitrogen content (Spiegel *et al*., 2002). On the other hand, conventional tillage results in maximum soil disturbance and is reported to affect soil positively by increasing its pH (Rahman *et al*., 2008) and organic matter (Jitareanu *et al.,* 2009), and negatively by inducing a higher compaction level (Botta *et al*., 2007). In recent times, conservation tillage has generated attention due to its complexity and fair flexibility in agricultural systems to widely adapting to local conditions (Wall, 2007), and retain moisture apparently due to a higher surface area that reducing the infiltration rate (Ghuza, 2004). Because of the foregoing, conservation tillage could be said to be more favourable for maize due to its ability to retain moisture and increase soil water storage and availability to crops. Although emphases are on conservation tillage, effects of climate change could change the balance in the Savanna Alfisols, hence the need to study the effects of tillage practices on soil properties and crop yield.

MATERIALS AND METHODS

The Study Area

The study was conducted at the Department of Soil Science Experimental Farm of the Institute for Agricultural Research (IAR), Samaru, during the 2020 rainy season. Samaru is located at the geographic coordinates of latitude 11° 11'N and longitude 07° 38'E, with an altitude of 686 m above sea level in the Northern Guinea Savanna Ecological zone of Nigeria. The climate of the study area is characterized by the occurrence of distinct wet and dry seasons (Oluwasemire and Alabi, 2004). The area has a mean annual rainfall of about 1011 ±1610 mm, with an average intensity of 50 mm/hr. A mean annual temperature of about 23°C has also been recorded for the area (IAR Met. Unit, 2017). The annual rainfall attains its highest value in August and drops rapidly to its lowest in October.

Field trials

The treatments consisted of 3 tillage practices replicated 3 times and arranged in Randomized Complete Block Design (RCBD). The Tillage treatments were Conventional (Tractorized tillage), Minimum (Manual Ridge tillage) and Zero tillage (use of herbicide for weed control). The test crop was the hybrid maize variety Oba-Super 2 planted at 75 cm spacing between rows and 25 cm within rows. Urea fertilizer at 150 kg/ha was split and applied at 2 and 6 weeks after sowing (WAS) using the basal application method, while muriate of potash and single super phosphate were applied with the first split dose of N at 2 WAS. Weeding was done at 4 and 8 WAS respectively. Manual weeding was applied to minimum and conventional tillage while herbicide was used for zero tillage. The maize was harvested at maturity which is 112 days after sowing. The harvesting was done manually with a knife by cutting the cobs. The operation was carried out when the cobs had turned brown and dried. Threshing was then carried out after the cobs had been properly air dried.

Post- harvest data collection

Number of cobs: the total number of cobs obtained from each plot was recorded

Stover yield: the dry matter (Stover) yield produced by each plot was recorded in kilo gram. It was done by measuring there maining portion of the plant after cobs were removed. The measurement was done with abeam balance after drying.

Grain yield (tha^{-1}): The air dried cobs were threshed, cleaned and the weight of grain recorded on the basis of grain yield per net plot. The grain yield per hactare was calculated and expressed in tones per hectare.

Grain weight of 1000 seeds (g)*:* The weight of 1000 grains (g) was recorded from grain samples drawn from the produce obtained from each of the plot.

Penetration Resistance

Penetration resistance is an indicator of the level of compaction in the soil. Penetration resistance was measured during the growing period of the plant. The measurement was done when the soil was at field capacity by using a soil penetrometer at a depth of 0-30 cm. The penetrometer was pushed into the soil and the reading of the penetrometer was recorded at each 10 cm depth of the soil. The measurement was repeated at 0, 10, 20, and 30 cm soil depth in each plot and the values were recorded. The surface soil was excavated to the desired depth before measurement.

Soil sampling and Analysis

The soil samples were collected at harvest from 0-15cm using an auger. Collected samples were labeled, air dried in the laboratory, crushed and sieved through 2mm. The soils were then analyzed for the following parameters: soil pH which was determined electrometrically in a soil solution ratio of 1:2.5, using the glass electrode pH meter, organic carbon by the wet oxidation method of Walkley and Black as modified by Nelson and Sommers, (1982) and total nitrogen by the micro- Kjeldahl distillation procedure according to Bremmer, (1996).

Statistical Analysis of the Data

All soil and plant parameters collected were subjected to Analysis of Variance (ANOVA) using the SAS package (SAS, 1999). The means were separated using the Duncan Multiple Range (DMRT) at a 5% level of probability. Correlation analyses were carried out to establish relationships among the variables.

RESULT AND DISCUSSION

Effect of Tillage Practices on Soil Penetration Resistance

The soil penetration resistance (PR) factor provides information on the level of soil compaction and root movement with growth, and should normally be influenced by level of soil pulverization. Readings were taken as stated, at harvest at 0, 10, 20 and 30 cm depths. The effects of treatments on penetration resistance are presented in Table 1. The effects of tillage were statistically not significant at all depths. Zero tillage gave a strong indication of greater compaction in the surface 10cm as values were higher at these depths; however, conventional tillage as expected, induced greater compaction at lower depth as shown at 20cm and 30cm depths. Minimum tillage provided a better rooting medium over the entire depth profile studied (0-30cm), with lower values at the rooting zone. At 20 cm, values were 1.49 kgf/cm^2, 1.22kgf/cm^2 and 1.31 kgf/cm^2 for conventional tillage, minimum tillage and zero tillage practices respectively. By doing so, greater activity is expected with respect to higher microbial activity, better soil aeration and root movement with minimum tillage. The trend of this result agrees with that of Miyamoto *et al*. (2012) who noted an increase in PR with depth after tillage due to high disturbance and a high degree of variability within soil depth. Similarly, Botta *et al.* (2007) observed high penetration resistance in conventional tillage due to heavy machinery traffic.

Table 1: Effect of tillage practices on soil penetration resistance

Treatments	Penetration Resistance (Kgf/cm^2)			
	0cm	10cm	20cm	30cm
Tillage				
Conventional	0.63[b]	1.12	1.49[a]	1.57[a]
Minimum	0.63[b]	1.04	1.22[b]	1.29[b]
Zero	0.84 [a]	1.18	1.31[ab]	1.44[ab]
Mean	0.69	1.11	1.34	1.43
S.E±	0.07**	0.07	0.07*	0.06*

*Means follow by the same letter(s) in the same column are not significantly different at 5% level of probability, *=significance, **=highly significance,*

Effects of Tillage practices on selected Soil Chemical Properties

Results of the effect of tillage on soil pH, organic carbon and total nitrogen are presented in Table 2. Effects at harvest were significant at p>0.05 and followed the trend of relative compaction with zero tillage having the highest (6.22) and conventional tillage having the least (6.01). The pH in H_2O was generally slightly acidic (6.13), and it was more acidic in $CaCl_2$ solution. Similar observation was made by (Rahman *et al.,* 2008).

Table 2: Effect of tillage practices on selected soil chemical properties

Treatments	pH (H_2O)	pH ($CaCl_2$)	Organic Carbon (g/kg)	Total Nitrogen (g/kg)
Tillage				
Conventional	6.01[b]	5.63[a]	7.1[a]	2.7[a]
Minimum	6.17[a]	5.51[a]	7.3[a]	1.6[ab]
Zero	6.21[a]	5.31[b]	5.9[b]	1.1[b]
Mean	6.13	5.48	0.68	0.18
S.E±	0.02**	0.05**	0.02**	0.05*

*Means follow by the same letter(s) in the same column are not significantly different at 5% level of probability, *=significance, **=highly significance*

The effects of tillage on the variation of organic carbon content reveal that tillage practices significantly influenced the amount in soils. This shows that minimum tillage practices provided the best seed bed preparation for the improvement and maintenance of organic carbon in the soils. This is in accord with findings of (Jitareaunu *et al.,* 2009), who reported higher organic carbon in minimum tillage compare to zero tillage as obtained in their study.

The total nitrogen (TN) Values ranged from 1.1 to 2.7 g/kg for the tillage practices, with zero tillage having the least amount and conventional tillage having the highest. This variation in mean values with tillage practices may be attributed to the effect of surface run-off and N losses as a result, and it goes in line with the relative level of surface soil compaction. This was evidenced by the penetration resistance values at the surface (0cm) and at above 20cm depths (Table 1). The higher possible infiltration in conventional tillage relative to zero tillage translated to a higher N content in conventional tillage relative to zero tillage plots. At greater depths, other factors come into play, such as subsoil compaction by higher tractor traffic. In this study, by deduction greater run-off must have occurred in zero tillage plots and less N content in the soils. A similar result was observed by Agbede (2007), who observed a relative improvement in total nitrogen concentration in conventional soil, which was attributed to the decomposition of organic matter and release of minerals and elements into the soil.

Effect of Tillage Practices on yield parameters

The effects of tillage practices on some agronomic parameters, including the number of cobs, stover, 1000 grain weight and grain weight are shown in Table 3. The mean differences in the number of cobs as influenced by tillage practices were highly significant (p>0.01). Though, conventional tillage and minimum tillage effects were similar, (59 and 60cobs/plot), the number of cobs in both tillage practices performed better by 33% over zero tillage (45.22). The factor of root aeration is a significant factor influencing nutrient absorption and plant growth. Asenso *et al.* (2018) obtained similar results in which the highest maize harvest index was attributed to soil tillage compared to zero tillage.

The effects of tillage practices on 1000 grain weights (Table 3) show a similar trend as with number of cobs. Effects were highly significant (p>0.01). Conventional tillage and minimum tillage influenced the parameters similarly (average of 297 g/1000 grains) and were both 29% superior to zero tillage. The 1000 grain weight parameter reveals the response to conditions that influence good grain filling in cobs. An acceptable soil tilth as provided by a tillage practice (conventional or minimum) would improve nutrient and moisture uptake as observed. These responses were least in the zero tillage treatment and corroborated the result of Asenso *et al.* (2018).

Table 3: Effect of tillage practices on maize yield parameters

Treatments	Number of cobs	1000 Grain Weight (g)	Stover Yield (kg)	Grain Yield (kg)
Tillage				
Conventional	60.53[a]	296[a]	5407.3[a]	3570.3[a]
Minimum	59.06[b]	298[a]	6264.8[a]	3388.9[a]
Zero	45.22[b]	231[b]	3687.1[b]	2183.6[b]
Mean	54.96	275	5119	3047.6
S.E±	5.69**	276**	359**	1.03**

*Means follow by the same letter(s) in the same column are not significantly different at 5% level of probability, *=significance, **=highly significance*

The main effects of tillage practices on stover yield were highly significant, with minimum tillage having the highest mean yield value of 6264.8 kg/ha and outperforming zero tillage by 70% and conventional tillage by 16%. This again strongly expresses the benefits of tillage in promoting high yields in the savanna ecology, but it also relies on excessive soil pulverization which is often associated with conventional tillage. Even as the need for tillage is desirable and emphasized, moisture supply by subsoil capillarity may lend some explanation to the high level of response observed for minimum tillage. The combination of the processes of soil surface water infiltration and subsoil capillary water supply processes explained the result obtained for minimum tillage. This combination was not realized in zero tillage and was limited to conventional tillage. This result coroborates work of Asenso *et al*. (2018).

The effects of treatments on maize grain yield were highly significant for the treatment factors. The effects of tillage practices on grain yield seemed to have been significantly influenced by the extent of soil disturbance (type of tillage), in line with the number of cobs, 1000 grain weight stover yield, all of which are strong yield components. Conventional tillage was superior to minimum and zero tillage practices by 5% and 63%, respectively, using the least value in comparison as the denominator in grain yield expression. This seems to suggest that nutrient availability, moisture retention and supply can be controlled by some substantial margin by different tillage practices. As stated for stover yield, minimum tillage may maintain good moisture supply through capillarity, conventional tillage may provide better aeration for microbial decomposition (mineralization) of organic manure (matter), and possibly higher nutrient availability for the plant roots to take up. Similar results emerged from the work of Karlen *et al.* (2003), who investigated the response to low yield in zero tillage compared to conventional tillage, which was observed to be due to low N availability in the soil, leading to a reduction in crop production.

Conclusion and recommendation

Based on the findings of this study, it can be concluded that minimum tillage produced the best effect for maize production in the soils, improved soil properties, and reduced soil compaction. In addition, excessive cultivation activity may not be necessary for high maize yields in these savanna Alfisols. The recommendation package derived from this study is minimum tillage, as may be done by hand hoe or animal or light motorized traction drawn cultivation using the mold board plough.

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