Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Some selected physical and chemical attributes of a Ustalf under different tillage practices at Dutse, Jigawa State Nigeria.

*Nabayi, A., Girei, A.H., Usman, S., Abubakar, M.S., [1]Haruna, F.D., Nkereuwem, M.E., Santuraki, H.A. & M.M. Usman.

Department of Soil Science, Faculty of Agriculture, Federal University Dutse, Jigawa state. Nigeria.

[1]*Department of Crop Production and Protection, Faculty of Agriculture, Federal University Dutsinma, Katsina State.*

ARTICLE INFO

Article history:
Received September 10, 2018
Received in revised form April 30, 2019
Accepted May 2, 2019
Available online May 26, 2019

Keywords:
Tillage practices
Soil organic carbon
Soil total Nitrogen
Bulk density
Dutse Nigeria

Corresponding Author's E-mail Address:

abba.nabayi@fud.edu.ng ; +2347031068906

https://doi.org/10.36265/njss.2019.290109
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ABSTRACT

Different tillage practices are being employed by the farmers of Jigawa state, and as such, there is a need to determine its influence on some physical and chemical properties, so that farmers will base their choices on scientific facts rather than assumptions. An experiment was conducted to investigate the effects of three tillage practices (TP) on soil properties in Federal University Dutse, Teachings and Research farm, Jigawa State. The TP adopted are conventional tillage (CT), reduced tillage (RT) and zero-tillage (ZT). Samples were collected at a depth of 0 -20 cm for the chemical and other physical properties determination, while core samplers were used for bulk density (Bd) determination. All data collected were analyzed using Statistical Analysis Software (SAS and analysis of variance (ANOVA) was used to determine the significant tillage effect on the parameters measured at 5% level of significance and the means were separated using Least Significance Difference (LSD). The results showed that the soil texture of the study area was sandy loam. ZT differed significantly from other TP with higher Bd value of 1.51 Mg m^{-3}, lower porosity (42.7%), and lower moisture content (10.3). ZT also had higher organic carbon (OC), total nitrogen (TN), available phosphorus (AP), exchangeable acidity (0.48 $cmol_{+}$ kg-^{1}) and bases and most importantly higher CEC (7.5 cmol (+) kg^{-1}) which differed significantly from other tillage practices and the lowest of the most parameters were found in RT. Conclusively, ZT is the best TP to be used by the farmers because of the improved physical and chemical parameters and been not only economically sustainable but also socially and environmentally friendly.

1. Introduction

Tillage is among the important operations on a crop production system. The process by which forces are imparted, and changes in soil properties occur are known as tillage, which is comprised of some technical operations such as harrowing and ploughing (Abbas and Al-Rawi, 1989). Tillage practices control weeds, incorporate crop residues into the soil, provide a suitable seedbed for crop plants, make the soil friable, enhance chemical reaction and thereby improves the physicochemical condition of soil which in turn affect the growth and development of crop plants (Klute, 1982: Gajri *et al.,* 2002; El-Titi, 2002; Nabayi *et al*., 2018).

Conventional tillage is defined as the type of tillage system in which a primary tillage operation, such as mold-board ploughing, is followed by secondary cultivation to create a favorable seedbed (Fullen and Catt, 2014). The common practice is ploughing with tractor wheel running over the bottom of the open furrow, where the soil is likely to be more compact than the surface and to a greater depth, owing to higher moisture and lower organic matter content (Broller *et al*., 2004). Such soils are more prone to soil loss through water and wind erosion, directly and indirectly, cause a wide range of environmental problems. A study by Al-Kaisi and Licht (2004) indicated that despite uniform clay mineralogy, conventional tillage-induced a greater modification of soil physical properties resulting in damage to soil structure. Continued soil inversion is likely to cause degradation of soil structure leading to soils composed of fine particles with low soil organic matter levels (Arlauskas, 1993; Gajri *et al*., 2002). Exposure of the soil surface and destruction of the soil structure in conventional tillage also increase the susceptibility of the soil to erosion, especially with heavy rainfall (Agenbag and Stander, 1988).

Reduced tillage is increasingly used in many countries (Uri, 1998). More often mouldboard ploughing is replaced by discs or chisels ploughing in the system. The mulch of crop residues on the soil surface minimizes water loss through evaporation. Shallow tillage results typically in a higher bulk density in the deeper parts of the topsoil layer, which may reduce the yield of the crop (Gajri *et al*., 2002). Reduce tillage systems are somewhat like mulch tillage in that they involve full-width tillage, use the same implement, and may use one to three tillage trips. Reduced-tillage, however, leaves 15-30 percent residue on the soil surface after planting (Draycott, 2006). Zero-tillage thus promotes the surface accumulation of soil organic carbon (Hamblin, 1984; Agenbag, 2012). Tillage also results in partial aggregate destruction and concomitant organic matter loss (Wright *et al*., 2005).

According to Huggins and Reganold (2008), reduce tillage is a more sustainable tillage practice for the environment. This system is primarily aimed at decreasing or shifting the crop residue to facilitate planting or accelerate soil warming (Gajri *et al*., 2002).

The influence of tillage on the soil properties, especially the soil physical properties, can be described as tillage effects or responses (Li *et al*., 2011). These tillage effects can be positive or negative for soil conservation depending on the type of tillage and management strategy and the type of soil and the climatic conditions (Martinez *et al*., 2008). Tillage is a management input that affects soil physical characteristics (Katsvairo *et al.,* 2002). Many farmers perform tillage operations without being aware of the effect of these operations on soil physical properties and crop responses (Ozpinar and Isik, 2004). Tillage is a management input that affects soil physical characteristics (Katsvairo *et al*., 2002). Soil physical properties are essential in ensuring favorable conditions for crop growth and maintaining soil quality (Rachman *et al*., 2003). The suitability of a soil for sustaining plant growth and biological activity is a function of physical and chemical properties (Mulumba and Lal, 2008). Soil tillage in Northern Nigeria is becoming a culture among the farmers; it is necessary to determine its consequences to about soil properties. Although many studies exist which compare conventional tillage practice versus zero tillage management in many parts of the world. However, there are only limited data available on the magnitude of the positive contributions of zero tillage in the Northern part of Nigeria with particular reference to Jigawa State. Aim of the study is to determine the effect of different tillage practices on the physical and chemical properties of the Federal University Dutse (FUD) teaching and research farm.

2. Materials and Methods:

Description of the study area

The study was carried out at Federal University Dutse Teaching and Research Farm (Lat. 11°46’39” N and Long. 9°20’3” E) Jigawa state, Nigeria. The area is under the Sudan savanna ecological zone, characterized by two distinct seasons (Dry and Wet). The mean annual temperature is 29°C with a mean monthly value ranges between 26-38°C and an average yearly rainfall of 681 mm. Total forest cover in the State is very much below the national average of 14.8% (Garba, 1998). Due to both natural and human factors, forest cover is being depleted, making it vulnerable to desert encroachment. The Study area enjoys vast fertile arable land to which almost all tropical crops could adapt, thus constituting one of its highly prized natural resources (Garba, 1998).

Treatments and Experimental Design

The experimental design was a randomized complete block (RCB) design with three tillage practices treatment, which was replicated 3 times each. The three treatments are; Conventional tillage (CT), Reduce tillage (RT) and Zero tillage (ZT). The CT treatment had 1-2 tractor harrow passes per season (year), and the commonly grown crops in this treatment are groundnut, cowpea, millet, or maize. The RT treatment had 1-2 Animal or Ox-plough per season (year), and the commonly grown crops are groundnut, cowpea, or millet. The zero tillage (ZT) treatment comprises of uncultivated land left fallowed under natural vegetatiCT and RT treatments are either opposite or adjacent to the uncultivated (ZT) plots. All treatments (CT, RT, and ZT) in the selected sites were under the prescribed management for about 2-6 years. NPK and phosphate fertilizers are the commonly applied fertilizers by farmers in the cultivated plots (CT and RT).

Samples collection

Soil samples were collected in the Teaching and Research Farm of Federal University Dutse, in various locations as follows; Farm A; conventional tillage, farm B; reduce tillage and farm C; Zero tillage. All the samples were collected at a depth of 0-20 cm for physical and chemical analysis. Core samplers were used in collecting undisturbed soil samples for determination of bulk density. Samples for further analysis of physical and chemical parameters were obtained with the aid of auger in triplicates, which were transferred into a nylon bag, labelled and taken to the laboratory for air drying before been grounded and sieved through 2 mm for chemical analysis.

Physicochemical Analysis

The hydrometer method was used in determining the particle size distribution of the 2 mm sieved soil (Gee and Bauder, 1986), The moisture content of the soil, was determined gravimetrically by subtracting the oven dry weight from the fresh weight of the soil and divided by the oven dried weight to get the moisture content in g g-^{1}. Using the formula below;

$$\text{Soil moisture } (g\ g^{-1}) = \frac{\text{Weight of wet soil} - \text{weight of oven dried soil}}{\text{Weight of oven dried soil}} \quad (1)$$

Dry soil bulk density (Bd) was determined by the core method as described by Blake and Hartge, (1986) while porosity (P) was determined indirectly from the measured Bd and assumed particle density (2.65 Mg m^{-3}) values. The undisturbed soils were oven dried at 105^0C for 24 hours. The Bd and P were determined using the formula below;

$$Bd\ (Mg\ m^{-3}) = \frac{Mass\ of\ oven\ dried\ soil\ (Mg)}{Bulk\ volume\ of\ the\ soil\ (m3)} \quad (2)$$

$$P = 1 - \left(\frac{Bd}{Pd}\right) \times 100 \quad (3)$$

where Pd is particle density.

Chemical analyses

Soil pH was determined using a glass electrode pH meter (Metrohm, 827pH Lab), using a soil: water ratio of 1: 2 (w/v). The mixture was shaken for 30 minutes and leftover night (24 hours). The same suspension used for the pH determination was utilized for the EC determination following the procedure described by Jackson (1962). Organic carbon content was determined by a modified Walkley-Black procedure as described by Nelson and Sommers (1982), while total Nitrogen was determined according to the Kjeldahl procedure (Bremner, 1996). Available P was determined by Bray No 2 method (Bray and Kurtz, 1945).

Exchangeable Bases Determination (Ca, K, Mg, and Na)
Leaching method (Chapman, 1965) was employed in CEC and exchangeable bases determination. Exchangeable K, Ca and Mg were determined by leaching method with 1 M ammonium acetate buffered at pH 7. Ten (10) grams of air-dried soil was weighed and put into a leaching tube, and 100 mL of 1M of ammonium acetate (NH_4OAC) was added. The leachates were collected in 100 mL volumetric flask after 5-6 hours, and the volume was made up to 100 mL with 1N NH_4OAC. Ca, K, and Mg were determined using atomic absorption spectrophotometer (AAS) (Perkin- Elmer, 5100PC, USA) while Na was determined by flame photometer. The same soil was utilized for CEC determination after been washed with 100 mL of 80 % alcohol to remove the ammonium solution left in the pores of the soil. The soil samples were leached again with 100 mL of 0.1 M potassium sulphate (K_2SO_4) for about 5-6 hours. The CEC was determined by quantifying the replaced $NH4_+$ using an autoanalyzer (AA) (Lachat Instruments, USA).

To determine the exchangeable acidity, a soil sample was extracted with unbuffered 1.0 M KCl, and the sum of Al and H was determined by titration following Mc Lean (1965) procedure. It was determined using the formula below;

$$Exchangeable\ acidity\ (cmol_+\ kg^{-1}\ soil) = \frac{a - b \times M \times 2}{S} \quad (4)$$

where a is NaOH used for sample titration in mL, b is NaOH used for blank titration in mL, M is the NaOH molarity, and S is the amount of air-dried soil sample used in grams.

Statistical Analysis.
All data collected were analyzed using SAS (9.4 system for windows by SAS Institute Inc. Newyork, USA, 2011) and analysis of variance (ANOVA) was used to determine the significant treatment effect on the measured parameter at a 5% level of significance and means were separated using the Least Significance Difference (LSD).

3. Results and discussion

Table 1 shows the particle size distribution of the soil under different tillage practices. There was no significant difference in the textural classes of the soils which were sandy loam in texture irrespective of the tillage practice. In the interim, tillage had no impact on the texture of the soils. A higher proportion of sand (≥75%) and a lower proportion of clay contents made the soils to exhibit similar textural class. The result agrees with Gupta and Shukla (1991) that soils in semi-arid and arid regions are mostly sandy and ranged from 70 to 80 %. A higher proportion of sand recorded by ZT could be attributed to the lack of disturbance (no tillage) relative to CT and RT that could break down the larger particles into smaller one.

Table 1: Average values of the Soil particle size distribution of the FUD teachings and research farm under three (3) different tillage practices.

(TP)	Clay (%)	Silt (%)	Sand (%)	Textural class
CT	15	10	75	Sandy Loam
RT	17	8	75	Sandy Loam
ZT	14	6	80	Sandy Loam

CT-conventional tillage, RT-reduce tillage, and ZT-zero tillage.

Figure 1 shows the effect of tillage practices on A (pH water), B (pH $CaCl_2$), C (Electrical conductivity), D (Bulk density), E (Porosity) and F (Moisture Content). A significant difference ($p<0.05$) was observed among the TP. In terms of both pH water and $CaCl_2$ (Figure 1A and B), highest was obtained in RT, which differed significantly ($p<0.05$) from other TP while the lowest was observed in ZT. It was in the order of RT>CT >ZT. Higher pH in reduced tillage (RT) could be as a result of the application of fertilizer and previous crop planted in the land or may be attributed to the inherent acidic nature of the soils. The result agrees with Foth and Ellis (1997) who found that soils are frequently more acidic in the surface layers of conventional tillage and less acidic in the deeper layers of zero tillage when comparing zero tillage and conventional tillage. Higher nitrogen mineralization rates encountered in zero-tillage usually occurred with lower pH compared to conventional tillage (Staley and Boyer, 1997). Significant ($p<0.05$) higher EC was obtained in the ZT system, which was in the order of ZT≥RT>CT. ZT and RT did not differ significantly ($p<0.05$) from each other with each having 0.09 dS m^{-1} which differed significantly from CT (0.04 dS m^{-1}) that had the lower value. Generally, the EC of the soils is low, which could be due to leaching as a result of intense rainfall of the semi-arid region. Lower EC in CT could be as a result of high infiltration rate, as reported by Badalucco *et al*. (2010) that as more water infiltrates into the soil, salts accumulated to the surface are leached downwards into the shale parent material and reduces the salt concentration left in the soil.

Tillage practices also showed a significant influence on bulk density, porosity, and soil moisture content (Figure 1D to 1F). ZT had a higher bulk density (1.51 Mg m^3) and lower porosity and soil moisture content of 42.7 and 10.3 % respectively, which differed significantly ($p<0.05$) from other TP. ZT had an increase in Bd of 1.32 and 3.3 % relative to RT and CT systems. CT had a higher porosity of 44.33%, which differed significantly ($p< 0.05$) from RT with 43.33% and ZT 42.77% practices. The porosity is in the order of CT >RT >ZT. Higher Bd and lower porosity and moisture content in ZT could be as a result of non-activities (farming) in the farm and sealing effect that could happen as a result of organic residue incorporation and decomposition. In another word, lower bulk density of 1.47 Mg m^3, obtained under convention tillage was due to the constant tilling of the soil. The result disagrees with Nabayi *et al*. (2018) who reported significant higher Bd in CT and DT (deep tillage) and the lowest in ZT practice in Hadejia. Hernanz *et al.* (2002) found that in the 0-100 mm dept, zero-tillage had a significant higher bulk density in comparison with RT and CT. The result agrees with Fabrizzi *et al*. (2005) and Sasal *et al.* (2006) who concluded that zero tillage leads to significantly higher bulk densities and lower total porosities, which indicated that a lack of disturbance produces an increase in soil compaction. RT (Figure 1F) had higher soil moisture of 0.19 $gg^{-1,}$ which differed significantly ($p< 0.05$) with CT (0.11 g g^{-1}) and ZT (0.10 g g^{-1}). The soil moisture is in order of RT >CT >ZT. The texture of the soil could be the determining factor of the moisture content. RT had the highest clay (17%) proportion which leads to highest moisture content while ZT had the higher sand proportion with lowest clay (14%) (Table 1) that lead to lowest moisture content. The results disagree with the research conducted by Blevins *et al*. (1983) and Agenbag and Maree (1991) who reported that ZT result in greater soil moisture content which was attributed to reduced evaporation and a greater ability to store water.

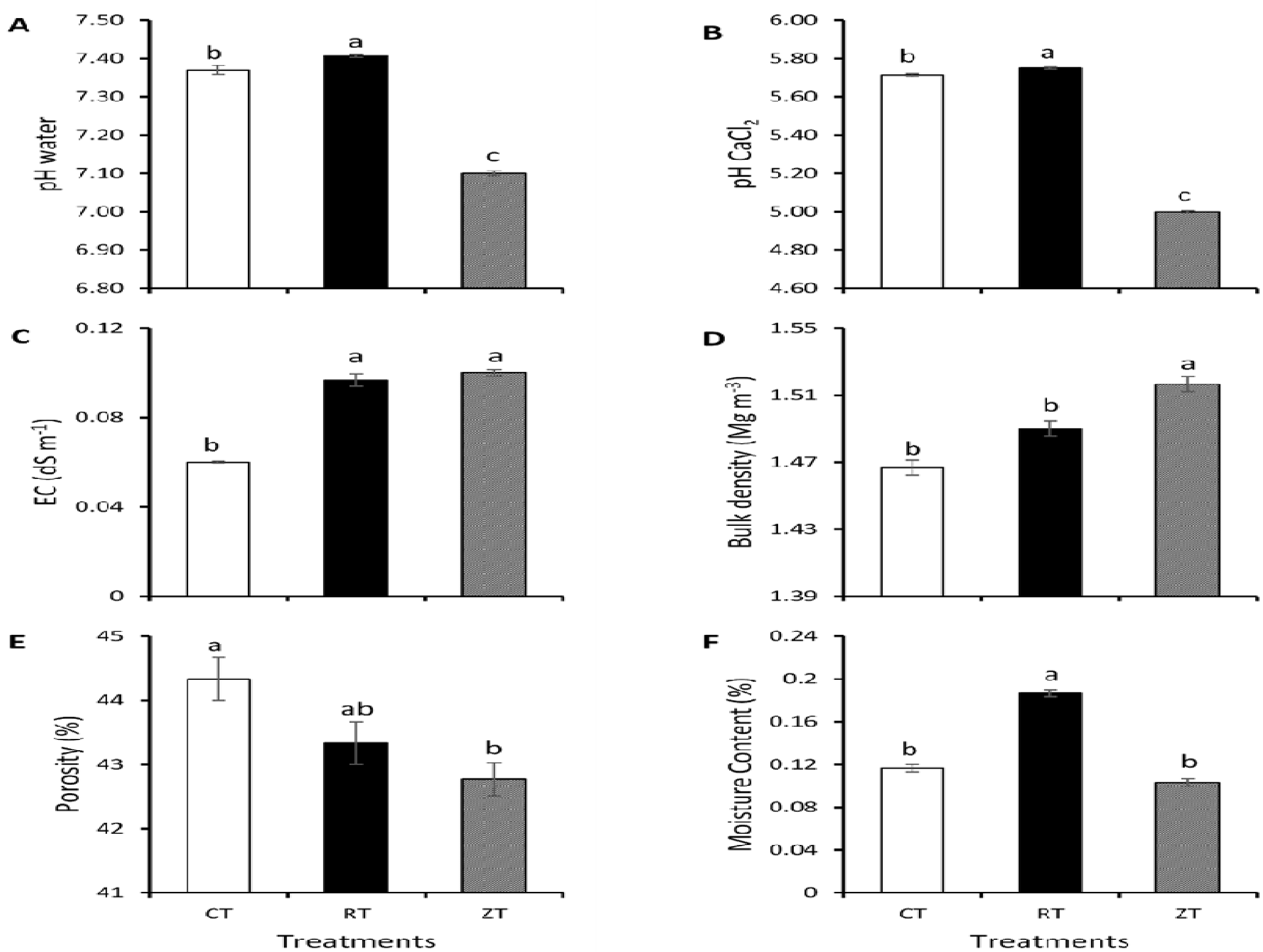

Figure 1: Means (±standard error) of A (pH water), B (pH $CaCl_2$), C (Electrical conductivity), D (Bulk density), E (Porosity) and F (Moisture Content) as influenced by tillage practices. Means with different letters on the same char differed significantly from one another according to the LSD at 5% level of significance.

Figure 2 shows the effect of tillage practices on soil organic carbon (A), total nitrogen (B, and available phosphorus (C). A significant difference (p<0.01) was found among the tillage practices. Significant higher (p<0.01) OC, TN and AP was found in ZT with 0.31%, 0.14% and 136 mg kg^{-1} respectively. Increase of 16.1 and 55% of OC was obtained in ZT relative to RT and CT respectively, while there was no significant difference (p>0.05) between ZT and RT in terms of TN with both having 0.15 % but they differed from CT practice that had 0.11%. ZT and RT had 22% of TN increased relative to CT practice. AP was in the order of ZT>CT>R, which differed significantly (p<0.01). Highest was found in ZT (136 mg kg^{-1}) while the lowest in RT (64 mg kg^{-1}). Higher organic carbon in ZT was due to the non-activities in the far, which results in the accumulation of organic residues in the land. The result agrees with Watts *et al.* (2001), who reported that Incorporation of fresh organic materials could improve the abundance and strength of small aggregates. This observation, however, agrees with Ball *et al.* (1997) and Watts *et al*. (2001) who stated that organic matter content of soil varies drastically in response to different tillage practices. Zero-tillage thus promotes the surface accumulation of soil organic carbon (Hamblin, 1984; Agenbag, 2012).

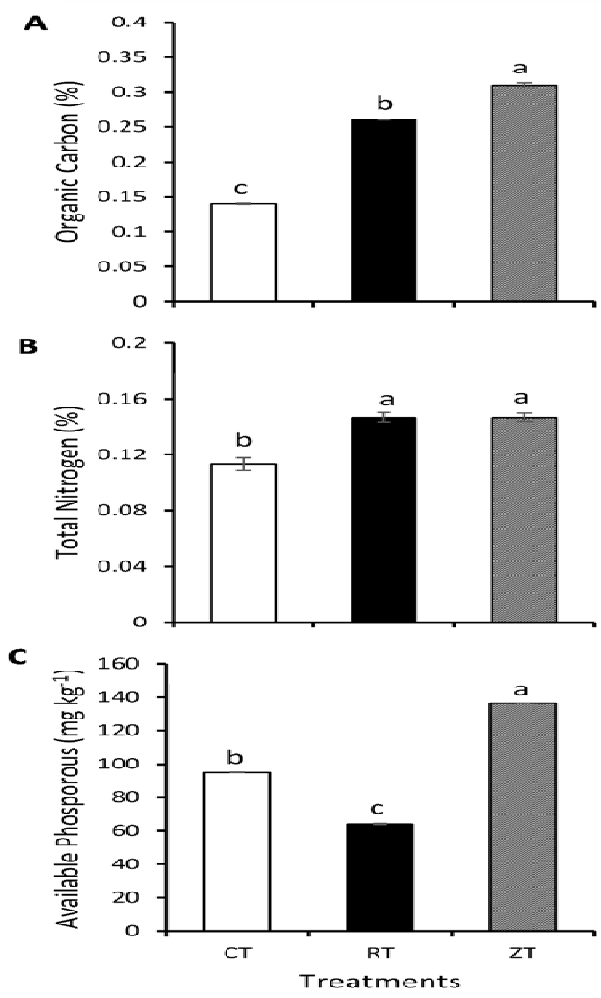

Figure 2: Means (±standard error) of A (Organic Carbon), B (Total Nitrogen), and C (Available Phosphorous) as influenced by tillage practices. Means with different letters on the same char differed significantly from one another according to the LSD at 5% level of significance.

Higher total nitrogen in RT and ZT may be because of less to no-tilling of the soil and as such nitrogen cannot easily escape to the atmosphere via volatilization. There is greater loss of N by denitrification under conventional tillage as reported by Dick *et al.* (1991, which could be the reason for having a lower value of TN under CT in this study. However, it was reported that ZT and RT tillage practice has potentially greater mineralization of total nitrogen compared with CT (Doran, 1980). Higher AP under ZT was due to the organic residues accumulation and non-tilling of the land. As nitrogen is affected by the tillage system, phosphorus availability can equally be affected (Ortiz-Monasterio *et al*., 2002). The result agrees with Motta *et al*. (2000) who maintained that combined low P adsorption capacity and high levels of extractable P is possible due to high organic carbon (OC) of ZT treatment and can contribute to P mobility in soils.

Figure 3A-F show the results of Ca, Mg, K, Exchangeable acidity (Al and H), CEC, and Na as influenced by tillage practices. ZT had higher exchangeable bases and exchangeable acidity (Figure 3), which differed significantly (p<0.05) from other TP. Generally, the lowest values of the parameters were found in RT the except Na content (Figure 3F). Higher values obtained in ZT were translated into greater CEC (7.5 $cmol_+$ kg^{-1}) which differed significantly (p<0.05) from other TP, as shown in Figure 3E. The CEC was in the order of ZT>CT>RT with ZT having an increase of 6.7 and 28% relative to CT and RT practices respectively. The significant higher amount of Na content was found in RT (0.85 mg kg^{-1}) which was in the order of RT>ZT>CT with RT having an increase of 24.7 and 37.6% relative to ZT and CT. The lower amount of exchangeable acidity and bases by RT practice could be as a result of the management practices of the soil. The result disagrees with Thomas *et al.* (2007, who reported that exchangeable magnesium and sodium concentrations were higher under CT compared to RT and ZT. Higher Hydrogen (H) and Aluminum (Al) (Figure 3D) under ZT could be as the result of non-activities in the land which lead to accumulation and decomposition of organic residues and as such greater mineralization and hence higher nutrients availability. The result agrees with Kern and Johnson (1993) who found that an increase in organic matter (OM) and associated organic acids, as well as changes in cation and anion proportions in soils under ZT practices as the result of non-activities. Higher CEC under ZT was mainly due to the accumulation of organic matter, and organic residues after which upon its mineralization by microorganisms, greater nutrients elements are obtained relative to other TP. Since CEC is enhanced by the presence of SOM, any process that will result in the volatilization of organic carbon (organic matter) would also affect the soil CEC. Ploughing exposes the soil organic carbon to volatilization Losses may also occur by soil erosion, which increased by ploughing as a result of exposure of topsoil (Fullen and Catt, 2014).

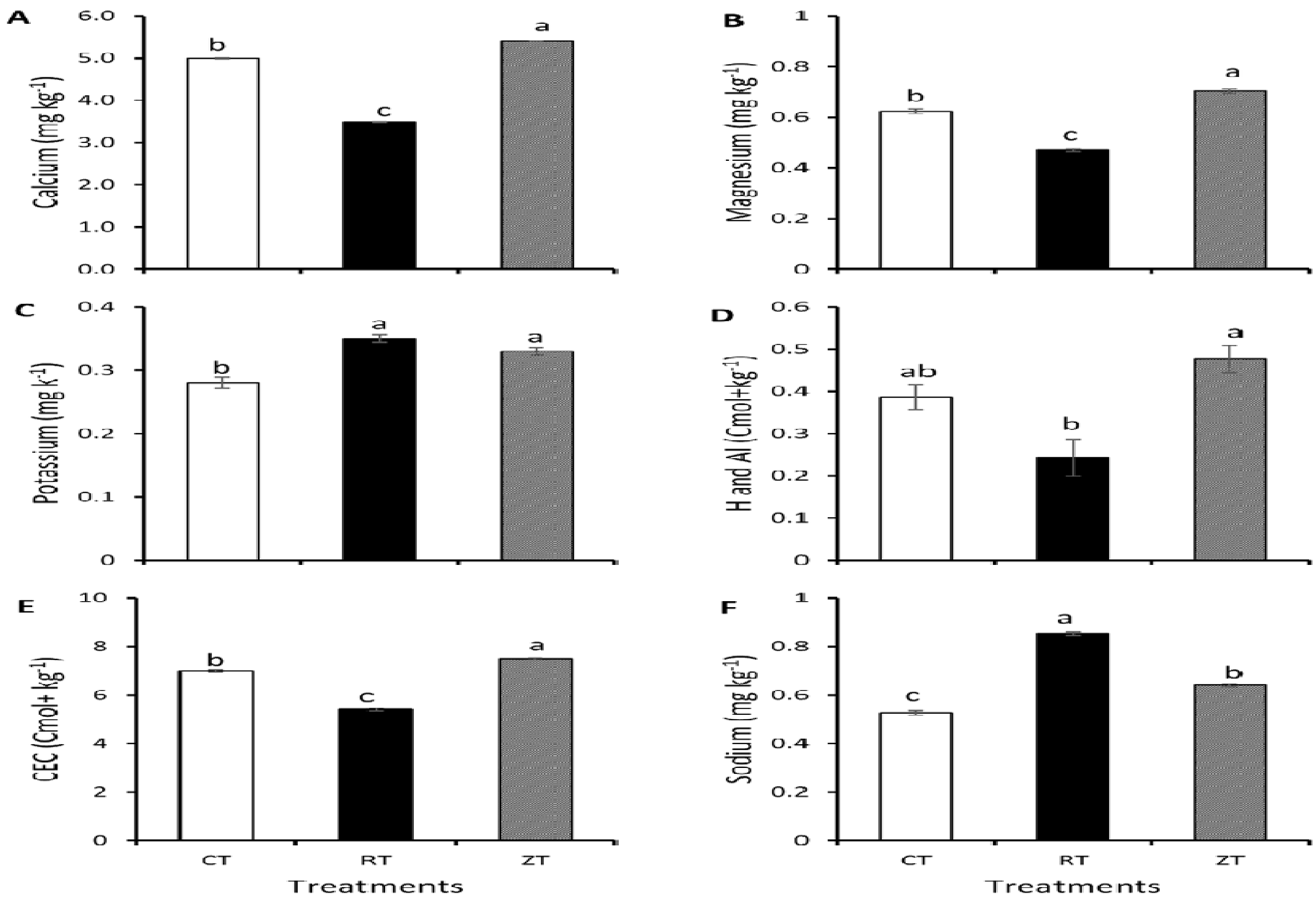

Figure 3: Means (±standard error) of A (Calcium), B (Magnesium), C (Potassium), D (Hydrogen and Aluminium), E (CEC) and F (Sodium) as influenced by tillage practices. Means with different letters on the same char differed significantly from one another according to the LSD at 5% level of significance.

Conclusion

The study showed that tillage practices have an impact on soil physical and chemical status of the FUD teachings and research farm. Conclusively zero tillage had significantly higher parameters such as TN, OC, EC, Ca, Mg, and CEC with higher Bd and lower porosity. Improved physical parameters were also obtained under CT with higher porosity, lower bulk density, and higher moisture content. ZT had more enhanced physical and chemical parameters analyzed and as such ZT practice should be adopted for sustainable crop production in the semi-arid region such as Jigawa state, which experienced different forms of erosion in its larger drier part of the year (October to May). This study indicated that zero tillage is the best practice for the future due to its sustainability towards the lowest environmental impact.

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