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IMPACT OF LONG-TERM TILLAGE, CROP ROTATION AND NITROGEN FERTILIZATION ON SELECTED SOIL PROPERTIES IN NIGERIAN SAVANNAH *ALFISOL*

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ABSTRACT

This study was conducted to evaluate long-term tillage (T) practices, crop rotation (CR) and N-fertilization (NR) on soil chemical properties in savanna *Alfisol*s of Nigeria. The aim of the research was to assess the influence of long-term tillage practices [conventional (CT) and reduced tillage (RT)], cereal/legumes [cowpea-maize (C/M), continuous maize (M/M) and soybean-maize (S/M)] rotation and N-fertilizer [N0 (0 Kg N ha^{-1}), N1 (90 Kg N ha^{-1})] rates on selected soil chemical properties and its interaction on soil fertility status at 0 -15 cm depth. The trial was conducted at the Research Farm of Institute for Agricultural Research (IAR), Samaru-Zaria, Nigeria. Split split-plot experiment design was used with three replications: with tillage as main plot, crop rotation as sub-plot and N-fertilizer rates as sub sub-plot. Selected soil properties were analysed to study the impacts of the treatments on soil chemical properties. Results revealed that tillage practices significantly (P<0.05) affect available P with RT (21.478 mg kg^{-1}) ranking higher than CT (17.831 mg kg^{-1}). Crop rotation had significant effect (P<0.05) on available P (S/M ranked highest while the least was M/M rotation). Exchangeable K, Ca, Mg and CEC were highly significantly (P<0.01) influenced by rotations with trend in this order; M/M > S/M > C/M. The interaction of T*CR on exchangeable Ca, Mg and CEC were significant (P<0.05). Effects of interaction of T*CR*NR showed significant (P<0.05) difference on available phosphorus, exchangeable Ca, Mg and CEC. Therefore, RT*M/M*N0 was rated better in improving exchangeable K, Ca, Mg and CEC, while RT*S/M*N0 ranked highest in available P in savanna *Alfisols*.

Keywords: Tillage; soil chemical properties; crop rotation; nitrogen fertilizer

INTRODUCTION

Agricultural management practices such as tillage impacts significantly on physical, chemical, and biological properties of soil and have immense effects on the productivity and sustainability of soil. Conventional tillage systems affect long-term soil productivity and has been practiced for years around the globe due to its numerous advantages including loosening the soil, increase soil drainage, root growth and development (Fowler and Rockstrom, 2001). Researchers revealed that intensive tillage accelerate soil organic matter oxidation, decrease soil aggregate stability, aggravate greenhouse gas emission (N_2O, NO, CO_2, etc.) and makes the soil vulnerable to soil erosion (Omonode *et al.*, 2011), thereby threatening sustainable crop production. However, sustainable soil management can be practiced through conservation tillage (reduced tillage), high crop residue return, and crop rotation (Hobbs, Sayre. and Gupta, 2008). Conservation tillage which consists of reduced or no-tillage, covered with crop residue; is one of the most effective, efficient and least costly methods of reducing soil erosion, fluctuation in temperature, conserve labour, fuel, and significantly improves soil organic matter and soil moisture (Alvarez, 2005).

Cropping system with quality crop residue returned to the soil can influence soil chemical properties, soil moisture and nutrient uptake. Although crops differ in their capacity to utilize nutrients from the soil, increased residue returned to soil can enhance soil nutrient levels (Sainju *et al.*, 2015a). Grain legumes have long been known to be important components of the traditional cropping systems in the tropics. They are also being considered for soil fertility improvement in cereal-based cropping systems in the Nigerian savannas (Yusuf *et al*., 2008). These legumes in symbiosis with specific microbes have the capacity to fix atmospheric nitrogen (N_2) that enables them to grow well on nitrogen (N) impoverished soils without adding fertilizer N. Researchers have also shown that legume-cereal rotation can improve soil fertility principally by increasing organic matter, soil N content and availability as a result of their residue mineralization (Yusuf *et al.*, 2009).

Fertilizers and amendments are applied to ameliorate nutrient deficiency in soils; but extensive applications were reported to degrade soil and environmental quality through soil acidification, N leaching, eutrophication in streams and lakes, and greenhouse gas emissions (Herrero *et al.*, 2010; Sainju *et al*., 2015a). Soil fertility decline is increasingly viewed as critical problem affecting agricultural productivity and environmental welfare in Africa (Smaling, Nandwa and Janssen, 1997). As soils are exploited, they degrade, especially when continuously cultivated without nutrients and organic matter inputs. The organic matter content of *Alfisols* is easily lost through burning and cultivation. Savanna soils are highly vulnerable to erosion because most of the soils are sandy, low in organic matter and unstable soil aggregates and structure (Odunze, 2003).

Several researchers have worked on the effect of cropping, tillage and various depths though short duration on soil physical, chemical and biological properties in northern Guinea savanna zone of Nigeria (Yusuf *et al*., 2008; Yusuf *et al*., 2009; Odunze, 2014; Omeke *et al.*, 2016). However, there is inadequate information on the effects of long-term tillage, crop rotation, nitrogen fertilization on soil chemical properties on savanna *Alfisols* of Nigeria. Therefore, the research seeks to assess the influence of long-term tillage (conventional and reduced tillage) practices, under cereal (*Zea mays* L.) legumes rotation (*Vigna unguiculata* (L.) Walp., and *Glycine max* (L.) Merr.), and nitrogen (N) fertilization on selected soil chemical properties and the influence of the interaction of tillage, crop rotation and N fertilizer rates on soil fertility status. Findings from this study will suggest efficient soil management practices that scientists, extension agent and resource poor farmers can adopt to improve their productivity on a sustainable basis.

MATERIALS AND METHODS

Experimental Site

The study was a long-term cropping system research programme that was conducted at one of the research fields of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria; located in northern Guinea savanna zone (latitude 11^0 10. 186`N and longitude $07^0$ 36.872`E, with an altitude of 686 m above sea level) having an annual rainfall of 1033 mm distributed between the months of May to October. The rainfall pattern is monomodal. Samaru has a mean temperature of 19.88^{o}C (minimum), 35.07^{o}C (maximum) (IAR Meteorological Station, 2017). The soil is low in inherent fertility; organic matter, cation exchange capacity and dominated by low activity clays (Odunze, 2003). The main soil sub – group is Typic Haplustalf (*Alfisols*) USDA Soil Taxonomy (Ogunwole *et al.,* 2001).

Description of the Field Trials

The study was based on a 15-year old field trial, which began in 2003 with two tillage practices (reduced and conventional tillage), three rotation crops (cowpea, maize and soybean) and two nitrogen fertilizer rates (0 and 90 kg N ha^{-1}); which were laid in a randomized complete block design in a split-split plot arrangement with three replications. Tillage systems were in the main plot, crop rotations were in sub-plot and N fertilizer rates were in the sub-sub plot. The conventional tillage (CT) involved the use local hoe to make ridges. While in reduced tillage (RT), ridges were not made cutlass or hoe was used to tilt the soil when sowing the seeds and herbicides applied to control weeds. Cowpea (IT89 KD – 288), soybean (TGx 1448 – 2E) and maize (SAMMAZ 14) were planted in the first phase (first year) of the rotation, in which the legumes received 40 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1} only; whereas the maize received N fertilizer rates stated, in addition to uniform application of 60 kg P_2O_5 $ha^{-1}$and 60 kg K_2O ha^{-1} respectively. In the second phase, maize was grown in all the plots (second year). Each plot was divided into two during the maize phase to accommodate the N fertilizer rates. The rotation system was therefore cowpea – maize, soybean – maize and continuous maize (maize – maize). Each sub-plot has a length of 6m^2 and with of 4.5m^2 with six ridges in the plot. There are total of 36 plots.

Soil Sample Collection

Soil samples were collected in October 2018. Five soil samples were randomly collected in each plot at 0 – 15 cm depth using an auger. The samples were bulked to form a composite sample. The samples were air-dried under shed; plant residues and pebbles were removed from the samples and gently grounded in a porcelain mortar with pestle which were sieved through 2 mm mesh sieves and subjected to routine soil analysis according to the standard procedure described in IITA (1989).

Laboratory Analysis

The sieved air-dried samples were subjected to physical and chemical analysis. Particle size distribution was determined using hydrometer method (Gee and Bauder, 1986).

Soil pH was determined by the use of a pH meter connected to a glass electrode in ratio 1:2.5 soil to water and soil to 0.01 M $CaCl_2$ (Hendershot *et al.*, 1993). The modified Walkley and Black procedure as described by Nelson and Sommers (1982) was used to determine organic carbon. Total nitrogen was determined by micro – Kjeldahl method involving digestion and distillation method as described by Bremner and Mulvaney (1982). Available phosphorus was determined by Bray No. 1 method (Bray and Kurtz, 1945). Basic cations (K^+, Ca^{2+}, Mg^{2+} and Na^+) were extracted in 1.0 M ammonium acetate (NH_4OAc) at pH 7 (IITA, 1989).

Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using the Proc ANOVA programme of SAS package (SAS, 2010). Where significant F – values among the treatment combination were separated using Duncan Multiple Range Test (DMRT) at $P \leq 0.05$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effects of Tillage, Crop Rotation and N-Fertilizer Rates on Soil Properties

The results on selected soil properties are presented in Table 1. The result shows that the soil texture was predominantly sandy loam soil. This result agrees with the findings of Omeke *et al.* (2014) who revealed sandy loam but varied with the results of Yusuf *et al.* (2009) and Odunze *et al.* (2014) who reported loam and silt loam texture respectively in the same agro-ecological zone. This difference could be attributed to the duration of the cropping; where they focused on short-term crop rotation while this worked on long-term tillage, crop rotation and N-fertilizer rates. Malgwi *et al.* (2000) and Voncir *et al.* (2008) reported that the dominance of sand contents in northern Guinea savanna soils is as a result of sorting of materials by clay eluviation and surface wind erosion. The fact that clay content of the soil was low could be due to sorting of soil material by biological activities, clay migration down the profile or surface erosion by run-off or a combination of these factors (Odunze, 2006). Overall, it implies that such soils are well drained, relatively stable and are suitable for arable crop production.

The effect of tillage on soil pH in H_2O and 0.01 M $CaCl_2$ (Table 1) were not significant. Though, the pH in salt of Reduced Tillage (RT) (pH 5.02) was 0.07 times higher than that of Conventional Tillage (CT) (pH 4.95), and these pH values fall within moderately to strongly acidic range. The soil pH is within the range in which most nutrients are available for crop uptake. Similarly, total nitrogen (TN), organic carbon (OC) and exchangeable bases (K, Na, Ca, Mg) and CEC were not significantly influenced by tillage; although, RT recorded marginal increase than CT (Table 1). Also, all the exchangeable bases and CEC are within the moderate fertility status range while TN and OC are low. However, tillage significantly ($P \leq 0.05$) influenced available phosphorus with RT treatment (21.48 mg Kg^{-1}) ranked higher than CT (17.83 mg Kg^{-1}). The significant increase in available P observed in RT could be due to soil management practices that lead to gradual decomposition of crop residues left on the soil surface, thus minimize soil erosion as well as conserve residual P that was applied. The result in this study corroborates with the findings of Dorr de Quadros *et al.* (2012) who revealed significant difference in avail. P influenced by RT, indicating improvement in available P in the system.

The effects of crop rotation on soil pH were not significant. Though, soil pH under continuous maize (M/M) was slightly higher than in the cowpea/maize (C/M) and soybean/maize (S/M) rotation by 0.01–0.16 units (Table 1). The result is in contrast with the report of Yusuf *et al.* (2009) who demonstrated marginal increase in soil pH of legume-cereal rotation than continuous maize. Variation in soil pH of M/M could be due to the quality of maize residues incorporated in the soil and the type of fertilizer applied in the treatments.

From the result obtained, the TN and OC were not significantly influenced by the crop rotation (Table 1). However, the results disagreed with the findings other researchers who noted significant ($P \leq 0.05$) difference in TN and OC (Dorr de Quadros *et al.*, 2012 and Omeke, 2017). The differences could be attributed to quality of crop residues incorporated in the soil, depth of sampling and duration of the cropping system. This study also revealed significant ($P \leq 0.05$) difference on the effect of crop rotation on available phosphorus. Thus S/M rotation was ranked highest, followed by C/M rotation and the least was continuous maize (M/M). These findings agree with the reports of several researchers who revealed higher concentration of soil P in legume-cereal rotation than in cereal mono-cropping (Hammoc *et al*., 2016). In contrast, some researchers observed that legume-cereal rotation had no significant effect of cropping system on available P. (Odunze, 2006; Sainju *et al*., 2015; Sainju *et al*., 2020) This might be because of improvement in the soil management practices, residual P from fertilizer applied, variation in depths or the duration of the cropping systems. Overall, it implies that the legumes have potential to fix available P. and S/M rotation have higher capacity to fix available P. than C/M and continuous maize treatment through their nodules in the roots

Similarly, effects of crop rotation on exchangeable bases (K, Ca, Mg), and CEC were highly significant ($P \leq 0.01$), and continuous maize treatment ranked higher than the legume-cereal rotation (Table 1). These results differed with those of Hammoc *et al*. (2016) who reported that crop rotation increased K concentration compared to monocropping after 16 years. In the same vein, some researchers found that crop rotation increased soil Ca and Mg concentration compared with continuous monoculture after 28 years (Lal *et al*., 1994 and Sainju *et al*., 2015). However, Odunze (2006) reported non-significant difference in exchangeable cations and CEC in legume-cereal rotation. These results variation may be partly attributed to lower leaching losses of the bases due to the litter on the soil surface, influence of residual effect of fertilizer applied and improvement on long-term impact of cropping system on the stated soil parameters; specifically continuous maize (M/M) which depicted the highest values of exchangeable bases and CEC compared to other crop rotations.

Influence of N-fertilizer rates on soil pH were non-significant ($P > 0.05$) (Table 1). Though, N1-fertilizer rate (90 kg N ha^{-1}) was 0.03 units greater than N0-fertilizer rate (0 kg N ha^{-1}). It indicates that N1 fertilizer rate is strongly acidic compared to N0 fertilizer rate. This suggests that increase in N-fertilizer rate tends to decrease soil pH.

Table 1: Effects of Long-term Tillage, Crop Rotation and N-fertilizer Rates on Selected Soil Properties

Treatment	Sand	Silt	Clay	Textural Class	pH in H_20	pH in $CaCl_2$	OC	TN	Avail. P	Exchangeable Bases Cmol kg^{-1}				CEC Cmol kg^{-1}
	g kg^{-1}						g kg^{-1}		mg kg^{-1}	K	Na	Ca	Mg	
Tillage (T)														
RT	563.22	315.56	121.11	SL	5.82	5.02	8.00	0.46	21.48a	0.21	0.20	5.58	1.50	8.32
CT	531.67	333.89	134.44	SL	5.76	4.95	7.99	0.42	17.83b	0.21	0.18	5.09	1.40	7.65
SE±					0.03	0.04	0.04	0.03	1.16	0.01	0.02	0.21	0.09	0.25
CR														
C/M	546.59	310.08	143.33	SL	5.83	5.03	8.03	0.04	18.70ab	0.21b	0.18	4.80b	1.28b	7.25b
M/M	551.67	323.33	125.00	SL	5.80	5.04	8.05	0.04	17.56b	0.26a	0.22	6.03a	1.71a	9.00a
S/M	545.00	340.00	115.00	SL	5.74	4.88b	7.92	0.05	22.70a	0.18b	0.18	5.17b	1.36b	7.71b
SE±					0.04	0.05	0.05	0.01	1.43	0.02	0.02	0.26	0.10	0.31
N-Rate (kg ha^{-1})														
N0	531.11	347.78	121.11	SL	5.79	5.00	8.00	0.42	20.14	0.23	0.21	5.13	1.88	7.79
N1	563.89	301.67	134.44	SL	5.79	4.97	8.00	0.46	19.16	0.20	0.17	5.53	1.52	8.18
SE±					0.03	0.04	0.44	0.01	1.16	0.01	0.02	0.21	0.09	025
Interactions														
T * CR	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	0.01*	0.01*	0.01*
T * NR	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CR * NR	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T * CR * NR	NS	NS	NS		NS	NS	NS	NS	*	NS	NS	**	**	**

CT = Conventional tillage, RT= Reduced tillage, NR= Nitrogen fertilizer rate, SL = Sandy loam, C/M = Cowpea-Maize Rotation, M/M = Continuous Maize, S/M = Soybean-Maize Rotation, N0 = 0 kg N ha^{-1}, N1 = 90 kg N ha^{-1}, TN = Total Nitrogen, OC = Organic carbon, Aval. P = Available Phosphorus, K = Potassium, Na = Sodium, Ca = Calcium, Mg = Magnesium, CEC = Cation Exchange Capacity, * = Significant at P<0.05, ** = Significant at P<0.01, NS = Not significant at either P<0.05 or P<0.01.

Furthermore, the impact N-fertilizer rates on OC and TN was not significant ($P \leq 0.05$). This result corroborates the report of Odunze (2003) and Yusuf *et al.* (2009) but varied with the findings of Odunze *et al.* (2014) and Omeke (2017) in the same agro-ecological zone. The variation may be due to difference in N-fertilizer levels, variety of legumes grown as well as the duration of the cropping system. Available P. was not significantly influenced by N-fertilizer rates. This finding is in contrast with the result of Odunze *et al.* (2014) who demonstrated significant ($P \leq 0.05$) difference. This could be attributed to the variation in the rate of N fertilizer applied in their treatment. Overall, this result revealed high available P in N0-fertilizer rate (20.14 mg kg^{-1}) compared to N90-fertilizer rate (19.16 mg kg^{-1}) (Table 1). Similarly, the effects of N-fertilizer rates on exchangeable bases (K, Na, Ca and Mg) and CEC were not significant ($P \leq 0.05$) (Table 1). Although, exchangeable bases and CEC were moderate according to the rating of Esu (1991).

Effects of Interaction of long-term tillage and crop rotation (T*CR) on Ca, Mg and CEC

The impact of the interaction of tillage and crop rotation on Ca is shown in Figure 1. The results revealed that exchangeable calcium (Ca) was significantly higher under combination of reduced tillage (RT) and continuous maize (M/M) treatment followed by RT and S/M (soybean/maize) rotation.

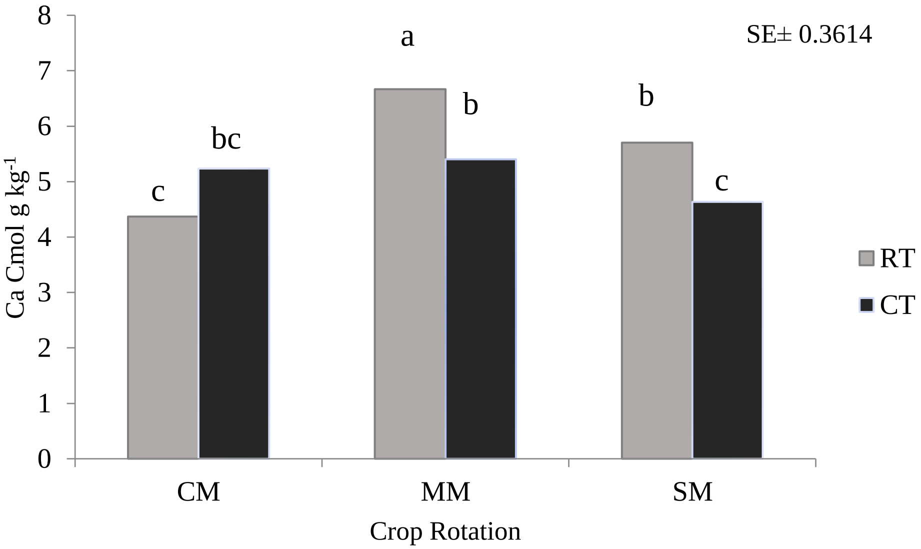

Figure 1: Interaction of long-term tillage and crop rotation on exchangeable calcium

While the interaction of conventional tillage (CT) and S/M rotation was at par with RT and cowpea/maize (CM) rotation. The higher rank noticed in RT*MM might be due to the presence of crop residue on the soil surface that reduced soil erosion and also minimized the leaching of exchangeable calcium. The result of this study is at variance with the reports of Sainju *et al*. (2015) and Degu *et al.* (2019) who reported higher calcium content in reduced tillage under legume-cereal rotation compared to reduced tillage under mono-cropping. The difference could be attributed to the length of the cropping system, soil type, quality of the crop used in the rotation or variation in the climatic conditions.

Influence of interaction of tillage and crop rotation (T*CR) on exchangeable Magnesium (Mg)

Interaction of long-term tillage and crop rotation on Mg is presented in Figure 2. It revealed that Mg was ranked highest under combination of reduced tillage (RT) and continuous maize (MM) while the least ranked was observed in RT and CM (cowpea-maize) rotation. Other treatment combinations were similar. It worth to note the exchangeable Mg followed a similar trend with the exchangeable Ca content in Figure 1. The high Mg content in RTMM treatment could be due to crop residue inputs on the soil surface which minimized soil erosion and leaching of basic cations.

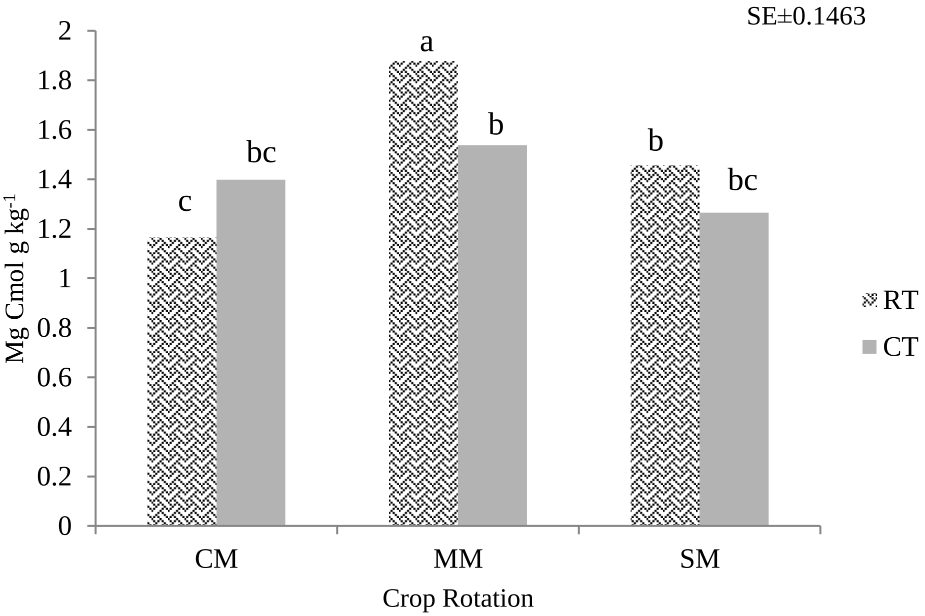

Figure 2: Interaction of long-term tillage and crop rotation on exchangeable magnesium (Mg)

Impacts of interaction of tillage and crop rotation (T*CR) on cation exchange capacity (CEC)

The results showed that reduced tillage continuous maize has greater CEC content (a) followed by RT*SM and CT*MM which is at par; and the least was observed in RT*CM and CT*SM treatment combinations (Figure 3). Also, similar trend was observed in the influence of the interaction of T*CR on exchangeable Ca and Mg. The higher CEC values could be due to the presence of greater concentrations of basic cations (K, Ca and Mg) in the trial. Although, the increase in CEC alternates among tillage practices; in other words, there was no consistent pattern.

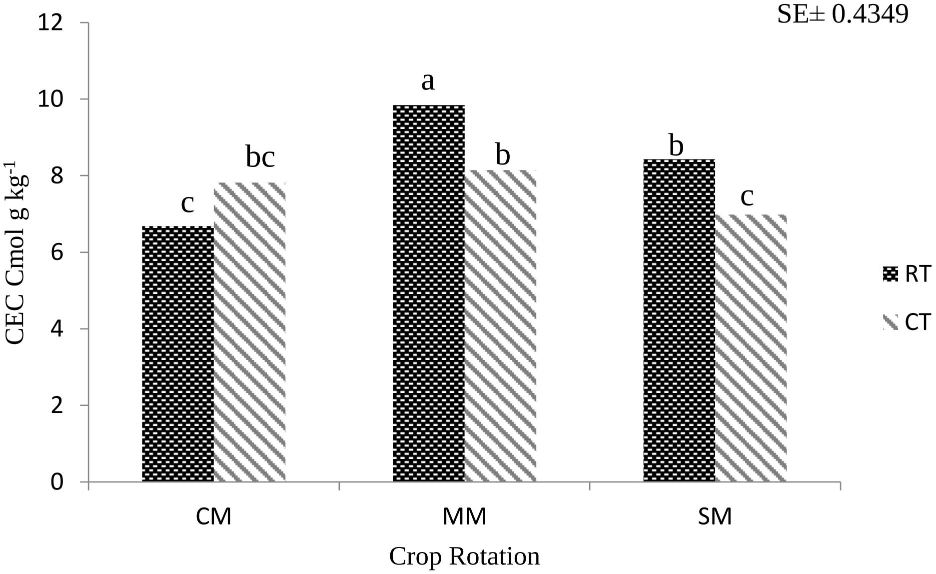

Figure 3: Interaction of tillage and crop (T*CR) rotation on cation exchange capacity (CEC)

Effects of the interaction of tillage practices, crop rotation and N-fertilizer rates (T*CR*NR) on significant soil chemical properties

Interaction of long-term tillage, crop rotation and N-fertilizer rates on available phosphorus (avail. P.) were depicted in Table 2. Influence of T*CR*NR on available P in RTSMN0 treatment was ranked the highest (28.75 mg kg^{-1}) followed by RTSMN1, RTCMN0 and RTMMN (23.85 mg kg^{-1}, 23.85 mg kg^{-1} and 23.36 mg kg^{-1}) while the least ranked was observed in RTSMN0 (13.23 mg kg^{-1}) (Table 2). The result differed from Sainju and Alasinrin (2020) who reported that mono-cropping increased Olsen-P compared with crop rotation. They revealed greater Olsen-P in no-tillage continuous barley/wheat (NTCB/W) than no-tillage barley/wheat-peas (NTB/WP) rotation. However, these findings agreed with the reports of several researchers who showed higher available P values in reduced tillage under crop rotation and 0 kg N fertilizer application (Sweeney, 2017; Sainju *et al*., 2015). The improvement in available P could be attributed to the reduced tillage, crop rotation, zero N fertilizer applied, crop residues incorporated in the soil surface and length of the cropping system.

Impact of interaction of long-term tillage, crop rotation and N-fertilizer rates on exchangeable calcium (Ca) were highly significant ($P \leq 0.05$) (Table 2). Reduced tillage continuous maize and 0 kg N ha^{-1} (RTM/MN0) was ranked highest followed by RTSMN1 and CTM/MN1, next were RTM/MN1 and CTC/MN0 while the lowest ranked exchangeable Ca was depicted in RTC/MN0 (Table 2).

Interaction of tillage, crop rotation and N-fertilizer rates (T*CR*NR) on cation exchangeable capacity (CEC) was highly significant (*$P \leq 0.01$*) and was depicted to have followed similar trend with the exchangeable bases (Table 2); with RTM/MN0 ranked the highest followed by RTS/MN1 and CTM/MN1, next were RTM/MN1 and CTC/MN0 respectively, while the lowest ranked was depicted in RTC/MN0 (Table 2). The greater CEC with RTM/MN0 was probably attributed to the presence of greater concentrations of basic cations in the cropping systems. This result disagrees with that of Sainju and Alasinrin (2020) who reported greater concentration of CEC. The difference could be due to the length of the cropping system, variety of crops in the rotation, soil type, climatic condition and variation in depths. Overall, there was significant improvement in soil fertility status of the interaction of T*CR*NR in savanna *Alfisol*. Except TN and OC that need to be improved through application of organic manure and fertilizers.

Table 2: Interactions of Long-term Tillage, Crop Rotation and N-fertilizer Rates on Significant Chemical Properties

Soil Property/ Treatment and Unit	Conventional Tillage (CT)						Reduced Tillage (RT)						SE±
	C/M		M/M		S/M		C/M		M/M		S/M		
	N0	N1	N0	N1	N0	N1	N0	N1	N0	N1	N0	N1	
Avail. P mg kg^{-1}	21.72bc	16.01de	14.54d	16.50d	19.27c	18.95cd	13.23d	23.85b	23.36b	15.84d	28.75a	23.85b	2.855
Exch. Bases													
Ca Cmol kg^{-1}	6.00bc	4.53cd	4.33cd	6.47b	4.27cd	5.00c	3.80de	5.00c	7.40a	6.00bc	5.07c	6.33b	0.511
Mg Cmol kg^{-1}	1.47bc	1.32cd	1.19d	1.88b	1.16de	1.37cd	1.02e	1.31cd	2.18a	1.57bc	1.24d	1.67b	0.207
CEC Cmol kg^{-1}	8.60bc	7.03cd	6.93cd	9.40b	6.60cd	7.37c	6.07d	7.30c	10.87a	8.83bc	7.67c	9.20b	0.615

C/M = Cowpea-Maize Rotation, M/M = Continuous Maize, S/M = Soybean-Maize Rotation, N0 = 0 kg N ha^{-1}, N1 = 90 kg N ha^{-1}, Aval. P = Available Phosphorus, Exch. = Exchangeable, K = Potassium, Na = Sodium, Ca = Calcium, Mg = Magnesium, CEC = Cation Exchange Capacity, Means with similar letters across the row are the same at *P<0.05* using DMRT, NS = Not significant at either P<0.05.

CONCLUSION

Long-term tillage, crop rotation and nitrogen fertilization were evaluated; the soil texture was sandy loam, soil pH ranged from strongly to moderately acidic, total nitrogen and organic carbon were generally low. The main treatment effects showed significantly high available P though other soil fertility indicators (exchangeable bases and CEC) were moderate; crop rotation effects were significant on some soil chemical properties (available P, exchangeable K, Ca, Mg and CEC) among the cropping systems. Also, interaction of tillage and crop rotation depicted significant difference among exchangeable calcium, magnesium and CEC across the treatment combinations. Interaction of tillage, crop rotation and N-fertilizer rates revealed significant effects on available P., Ca, Mg and CEC. Hence, the study demonstrated that reduced tillage under continuous soybean-maize rotation and 0kg N ha^{-1} in savanna *Alfisol* of Nigeria will ensure maintenance of soil fertility and ensure sustainable crop production despite the yield declined.

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