SOIL BIOCHEMICAL AND MICROBIAL PROPERTIES OF SANDY LOAM ULTISOLSAS AFFECTED BY SOME TILLAGE AND NUTRIENT MANAGEMENT PRACTICES.

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ABSTRACT
Tillage-nutrient management research has largely focused on soil physical/chemical properties, neglecting biochemical/microbial properties. The study involved zero-tilled flatbed (ZT-FB), conventionally tilled flatbed (CT-FB) and conventionally tilled tie-ridge (CT-TR), each with and without poultry droppings (PD) and/or NPK15:15:15 (NPK) in a coarse-textured acid (pH, 5.5) Ultisols in southeastern Nigeria. The amendments 20 t PD ha^{-1}(PD_{20}), 10 t PD ha^{-1} plus0.20 t NPK ha^{-1}(PD_{10}+$NPK_{0.20}$), 0.40 t NPK ha^{-1} ($NPK_{0.40}$) and a control had 2 kg ha^{-1} Agrolyser Micronutrient-Fertilizer (AMF) factored in. Sweet potato was grown till maturity before soil sampling. Tillage-×-nutrient interaction showed that CT-FB+PD_{10}/$NPK_{0.20}$+AMF, CT-TR+PD_{20}+AMF,and NT-FB+PD_{10}/$NPK_{0.20}$+AMFhad the highest dehydrogenase (465.20 umol g^{-1} h^{-1}), phosphatase (245.76 umol g^{-1} h^{-1}) and beta-glucosidase (285.60 umol g^{-1} h^{-1}) activities, respectively. TheCT-TR+PD_{20}+AMF, ZT-FB+$NPK_{0.40}$+AMF and CT-TR+$NPK_{0.40}$+AMFhad the highest microbial biomass carbon (0.171 mg g^{-1}), nitrogen (0.172 mg g^{-1}) and phosphorus (20.16 mg g^{-1}), respectively. The ZT-FB plots had the highest dehydrogenase(233.06 umol $g^{-1}h^{-1}$) and microbial biomass nitrogen (0.145mg g^{-1}), but the lowest phosphatase (141.95 umol $g^{-1}h^{-1}$), betaglucosidase (208.55 umol $g^{-1}h^{-1}$),and microbial biomass carbon (0.109 mg g^{-1}) and phosphorus (13.67 mg g^{-1}).The CT-TR plots had the highest beta glucosidase (229.22 umol g^{-1} h^{-1}), phosphatase (175.96 umol g^{-1} h^{-1}), total microbial count (487) and microbial biomass carbon (0.139 mg kg^{-1}) and phosphorus (16.16 mg kg^{-1}). These results together suggest that zerotillage, compared with tillage-ridging, engendered sub-optimal soil aeration, leading to impaired activity of enzymes/microbes involved in carbon-phosphorus cycling and transformations. Treatments having PD_{10}/$NPK_{0.20}$+AMF were the best followed by PD_{20}+AMF_2. Zero tillage with sole NPK seems to reduce soil enzyme and microbial activities in tropical agriculture.

Key words: soil enzyme activity; integrated nutrient management; micronutrient fertilizer; tillage options

INTRODUCTION
In agronomic production, the term 'tillage' comprises various soil preparation and cultivation options involving manual or mechanised instruments. Busari *et al*., (2015) defined no-till system as land preparation type with no soil surface disturbance during cultivation except at planting, while minimum tillage involves reduced level of soil manipulation by using only primary tillage implements during land preparation. Use of no-till and minimum tillage options in agricultural productivity has increased in recent times (Gathala *et al.*, 2015; Alam *et al*., 2018).Conventional tillage system of soil inversion and ridging operations and associated soil structure destruction and exposure to the surface could, like inappropriate nutrient management practices, affect soil functions. However, research on tillage-nutrient management has largely focused on soil physical and chemical properties, neglecting biochemical and microbial properties. This is particularly true in tropical Africa. As such, there is dearth of information on tillage impact on functional properties of the soil such as biochemical and microbial properties in the region.

Tillage actually exposes farmlands to traction and heavy equipment, which degrades the soil and makes the soil vulnerable to erosion (Van den Putte *et al.*, 2010). Inefficient tillage can ruin the soil structure, clog the pores and hinder water infiltration leading to decline in soil fertility (Birkás *et al.*, 2009, Špoljar *et al.*, 2011). The soil, however, suffers from compaction when not tilled which can negatively affect plant growth. When tilled, crops benefit from the improved looseness, oxygen supplies and water intake. Consequently, tillage systems are crucial part of soil management, thus creates appropriate seedbed condition for seed emergence, plant development and unhindered root growth. Zero tillage crop production can reduce labour and input costs and conserve the soil. Reduced tillage against conventional tillage does not invert the soil thereby minimizing soil disturbance and hence could be effective in combating erosion. Selection of appropriate tillage practice for the production of crops is a step in realizing optimum crop growth and yield. For such crop like sweet potatoes, studies on tillage effect on sustaining soil fertility is still sparse especially in the southern part of Nigeria (Agbede and Adekiya, 2011). And such important aspect of soil fertility is the biological properties evidenced by enzymatic activity and microbial biomass. Sweet potato is a root crop and a heavy feeder (Osundare, 2004), which exhausts the soil. Therefore, it's very important to investigate how tillage affects soil biochemical and microbial properties under sweet potato cultivation. Good soil management and tillage practice should protect the soil from water and wind erosion, provide a good, weed-free seedbed for planting, destroy

compacted soil layers for appropriate root development and maintain soil organic matter.

Proper management of soils ensures adequate functional processes in the soil, mineral nutrition to plants and environmental sustainability (White *et al.*, 2012). Nyakatawa *et al.* (2001) suggested that it is possible to increase crop yield on physically degraded soils by using organic manure for soil fertility improvement after adopting appropriate tillage systems. It is paramount to establish a complimentary link between tillage and nutrient management options. Therefore, this research studied the effects of zero-tilled flatbed (ZT-FB), conventional tilled flat-bed (CT-FB) and conventional tilled ridge (CT-TR) with organic and/or inorganic nutrient management options on soil biochemical and microbiological properties after the growth of sweet potato in the derived savannah ecology of Nigeria.

The interest in microbial functionality has grown in recent years to understand the relationship between microbial communities and their surrounding environment (Barral *et al.*, 2009, Roca-Pérez *et al.*, 2009). Biochemical and microbiological properties of the soil are known to be more responsive to crop and soil management practices(Masto *et al.*, 2009, Piotrowska, 2014).They are also biological indicators of soil fertility. They are actually used as early warning signs of the effect of management systems on soil quality. According to Gil-Sotres *et al.* (2005), soil biochemical properties are probably the most widely known indicators of soil quality. Soil enzyme activities are useful biological soil quality indicators since they are very sensitive, integrative, easy to measure and more responsive to soil tillage and structure than other soil variables (Piotrowska, 2014). Soil enzymes involved in hydrolysis and degradation of main litter components are used most often for evaluating soil quality (Adetunji *et al.*, 2017). Enzyme activities are measures of soil fertility and index of microbial functional diversity (Maurya *et al.*, 2011). They catalyse several biochemical reactions that are fundamental to life in the soil. Soil microbial population is the driving force that regulates soil processes such as organic matter decomposition and nutrient cycling. It is therefore imperative to have a better understanding of the factors that regulate microbial population, activity and structure (Masto *et al.*, 2006). Soils containing a high microbial diversity are characteristic of a healthy soil-plant relationship; whereas those with low microbial diversity are characterized as unhealthy soils that hardly respond to environmental changes (Tejada *et al.*, 2011). Therefore, the objective of this research was to determine the effect of tillage and nutrient management practices on biochemical and microbial properties of a degraded coarse-textured soil after sweet potato cultivation.

MATERIALS AND METHODS

Location/Study Area

The experiment was carried out at the University of Nigeria Teaching and Research Farm, Nsukka (06° 51 N; 07° 25 E), southeastern Nigeria. This location is on altitude of approximately 400 m above sea level. The climate of the study area is characterized generally by mean annual total rainfall of about 1600 mm Rainfall distribution is characteristically bimodal, with peaks in July and October. The entire wet season lasts from April to October, whereas the dry season lasts from November to March. Temperature is uniformly high throughout the year, with mean minimum and maximum values of 21 and 31° C respectively. Rarely does it exceed 35° C during the hottest months (Obi and Salako, 1995).

The soil at the experimental site is an Ultisol which belongs to Nkpologu series and had been classified, according to the Soil Survey Staff (2003)and the FAO/UNESCO (1988) revised legend as Typic Paleustult and Haplic Acrisol, respectively. Its clay mineralogy is composed mainly of kaolinite (Akamigbo and Igwe 1990). The area has an ustic soil moisture regime and an isohyperthermic soil thermal regime. The soils are characterized with low values of total exchangeable acidity, total exchangeable bases, cation exchange capacity, and base saturation (Asadu *et al*., 1990). The soil is low in SOM with perennial leaching problem (Igwe, 2004). The location is derived savannah zone with predominantly grassland vegetation (Mbagwu, 1991).

Land Preparation, Experimental Treatments and design

The portion selected for the study was 37 m × 16.5 m which was slashed manually using a cutlass and weeded using a hoe. Thereafter, the entire area was demarcated into three blocks and further divided into three plots for the main plot treatment. Each main plot was demarcated into seven subplots for the subplot treatments. These gave 63 plots. Inter-rep distance was 2 m while the inter-plot distance was maintained at 1 m. The land was prepared manually into zero-till flatbed (ZT-FB), conventionally tilled flatbed (CT-FB) and conventionally tilled tie-ridges (CT-TR) using the hoe, which were the main plot treatments. The seven nutrient management practices as follows: 400 kg ha^{-1} NPK 15:15:15 ($NPK_{0.40}$); 400 kg ha^{-1} NPK 15:15:15 + 2 kg ha^{-1} agrolyzer ($NPK_{0.40}$ + AGF); 20 t ha^{-1} poultry droppings (PD_{20}); 20 t ha^{+1} (PD_{20}) plus 2 kg ha^{-1} agrolyzer (PD_{20} + AGF); 10 t $ha^{-1}PD_{20}$ + 200 kg ha^{-1} NPK 15:15:15 (PD_{10} + $NPK_{0.20}$); 10 t $ha^{-1}PD_{20}$ + 200 kg ha^{+1} NPK 15:15:15 + 2 kg ha 1 agrolyzer fertilizer; (PD_{10} + $NPK_{0.20}$ + AGF); and control (no amendment) were the subplot treatments.

The poultry droppings were air dried, sieved and applied on the 27th of August, 2016 which corresponded to two weeks before planting while the NPK 15:15:15 fertilizer and agrolyzer micronutrient

fertilizer were applied by band placement method on the 24th of September, 2016 which corresponded to two weeks after planting. The agrolyser contained secondary macronutrients and micronutrients of Ca - 20.14%, Na - 1.04%, Zn - 0.11%, Mg - 0.19%, Cu - 0.19%, S - 2.72%, Fe - trace, Mn - trace, Bo - trace, and Mo -trace.

The treatments were laid in a split plot arrangement fitted into randomized complete block design (RCBD) with the three tillage treatments in the main plots and seven nutrient treatments as the sub-plots giving 21 treatments. Treatments were replicated three times giving a total of 63 sub-plots. Each sub-plot measured 3 m × 1.5 m.

Planting, Agronomic and Cultural Practices

Sweet potato was propagated by means of vine cuttings and was cut at about 20 - 25 cm length with eight noodles. Planting of the orange-fleshed sweet potato vines was carried out on the 10th of September 2016. Planting was done using a small stick to open the soil at depth of 3 cm and distance of 75 cm × 30 cm. Replacement of failed stands was done at 2 weeks after planting (WAP). This gave 20 stands per plot translating into plant population of 1, 260 stands ha^{-1}. During the first six weeks, weeding was done manually using a hoe at two weeks' intervals.

Soil sampling and Laboratory Analysis

Random soil sampling was done over the entire plot about 20 points before planting and bulked into one for preplanting soil description. At crop harvest, in each subplot at depth of 0 - 20 cm, soil samples were collected randomly from five points for laboratory determination of biochemical and microbial properties of the soil.

Determination of Soil chemical properties

Soil pH was determined using a combined glass electrode pH method of 1:2.5 soil water reactions as described by (McLean, 1982). Available phosphorus was determined using Bray-2 method of Bray and Kurtz as described by Page *et al*. (1982). Total nitrogen was measured by kjeldahl method according to the procedures reported by (Bremner and Mulvaney, 1982). Soil organic carbon was determined by wet digestion method.

Soil biochemical properties

Soil dehydrogenase enzyme activity was determined by the method of Garcia *et al. (*1993). The dehydrogenase activity was assessed in 1 g of soil exposed to 0.2 ml of 4% 2-P-iodophenyl-3-P-nitrophenyl-5-phenyl-tetrazolium chloride (INT) at 22° C in darkness. The iodonitrotrtrazolium formazan (INTF) formed was extracted with a mixture of 1:1.5 ethylene chloride/acetone by shaking vigorously and filtrated. Iodonitrotrtrazoliumformazan (INTF) was measured using spectrophotometer at 490 nm. Soil phosphatase enzyme activity was determined by the method (Tabatabai and Bremner 1969). Two ml of 0.1 M maleate buffer (pH 6.5) and 0.5 ml of 115 M P-nitro phenyl phosphate were added to 0.5 g of soil sample and incubated at 37° C for 90 min. Cooling to 2° C for 15 min. stopped the reaction. Then 0.5 ml of 0.5 M $CaCl_2$ and 2 ml of 0.5M NaOH were added and the mixture was centrifuged to 4000 rpm for 5 min. P-nitro phenol (PNP) was determined in a spectrophotometer at 398 nm. Soil beta glucosidase enzyme activity was determined by the method of (Masciandaro *et al.,* 1994). Two ml of 0.1 M maleate buffer (pH 6.5) and 0.5 ml of 50 mM P-nitro phenyl-β-D-glucopyranoside (PNG) were added to 0.5 g of soil sample and incubated at 37° C for 90 min. Cooling to 2° C for 15 min. stopped the reaction. Then 0.5 ml of 0.5 M $CaCl_2$ and 2 ml of 0.5 M NaOH were added and the mixture was centrifuged to 4000 rpm for 5 min.

Soil microbiological properties

Soil microbial biomass carbon (SMBC) was determined by fumigation extraction method according to Vance *et al.* (1987) using correction factor. Soil microbial biomass nitrogen (SMBN) was determined by the method employed by Brookes (2001) using correction factor. Soil microbial biomass phosphorus (SMBP) also was determined by the chloroform fumigation extraction method of 0.5 N $NaHCO_3$ for both fumigated and unfumigated samples according to Morel *et al.* (1996). Total microbial count was determined by serial dilution method (Foght and Aislabie, 2005).

Statistical Analyses

Data were tested for significant differences using two-way analysis of variance (ANOVA) for a split plot fitted into an RCBD. The analysis was done using the software Genstat Discovery Edition 4. With this, separation of treatment means (for statistical differences) was achieved by the least significant difference (LSD). Correlation and regression analyses were done using the software Statistical Product and Service Solution (SPSS) for windows version 20.0.

RESULTS AND DISCUSSION

Characteristics of the Soil Used for the Field Trial

The data for the physico-chemical properties of the soil before the experiment and chemical properties of the poultry droppings amendment are shown (Table 1). The texture of the soil of the study area was predominantly sandy and classified as sandy loam. Based on its sandy loam texture, water movement is expected to be moderately rapid and this may have nutrient leaching implications, especially with the basic cations. The bulk density was moderate (1.58 g cm^{-3}) and the soil was of low fertility potential as

indicated by its low levels of soil organic matter (17.88 g kg^{-1}), total N (0.56 g kg^{-1}) and available soil phosphorus (8.39 mg kg^{-1}) according to the rating of (Landon 1991). It was also strongly acidic with a pH in water value of 5.5. The CEC value of 12.40 cmol kg^{-1} was rated moderate while percentage base saturation of 80.27% was rated high(Landon 1991). The poultry manure was alkaline (pH in water was 8.5), had 4.33 g kg^{-1} of N and 6.08 exch. Mg, other nutrient contents were low.

Table 1: Physicochemical properties of the soil at onset and chemical composition of the poultry droppings used as amendment

Parameters	Soil	Parameters	Poultry manure
Textural Class	Sandy loam	pH - H_2O	8.5
Coarse sand (g kg^{-1})	510	pH - KCl	8.3
Fine sand (g kg^{-1})	240	Organic carbon (g kg^{-1})	26.74
Silt (g kg^{-1})	70	Total nitrogen (g kg^{-1})	4.20
Bulk density (g cm^{-3})	1.58	Potassium (cmol kg^{-1})	0.42
Total porosity (%)	30.40	Calcium (cmol kg^{-1})	1.96
Soil pH - H_2O	5.5	Magnesium (cmol kg^{-1})	6.80
Soil pH - KCl	4.8	Sodium (cmol kg^{-1})	0.38
Organic carbon (g kg^{-1})	10.37		
Total nitrogen (g kg^{-1})	0.56		
Available phosphorus (mg kg^{-1})	8.39		
Exchangeable Potassium (cmol kg^{-1})	0.040		
Exchangeable Calcium (cmol kg^{-1})	3.20		
Exchangeable Magnesium (cmol kg^{-1})	0.80		
Exchangeable Sodium (cmol kg^{-1})	0.028		
Exchangeable Hydrogen (cmol kg^{-1})	1.00		
Exchangeable Aluminum (cmol kg^{-1})	Trace		
Cation exchange capacity (cmol kg^{-1})	12.40		
Base saturation (%)	80.27		

Soil Tillage and Nutrient Management Effects on Biochemical Properties of the Soil

Table 2 shows that theeffect of the main plot and subplot treatment on soil biochemical properties. Tillage significantly ($f<0.05$) affected all the measured biochemical properties of the soil. ZT-FB had the highest dehydrogenase activity (233.06) but least phosphatase (141.95) and glucosidase enzyme activity (208.55). CT-TR had the highest phosphatase (175.96) and glucosidase activity (229.22) while CT-FB had the least glucosidase activity (172.51) but higher dehydrogenase and phosphatase enzyme activity than ZT-FB.

Subplot treatments also significantly ($f < 0.05$) affected all the soil biochemical properties (Table 3). Looking at the subplot effect, soil amendment either with poultry droppings applied alone or in combination with NPK fertilizer and/or agrolyzer fertilizer resulted in improved dehydrogenase enzyme activity relative to the un-amended soil (control). Complementary application of PD_{20}+AGF gave the highest dehydrogenase activity relative to other nutrient management practices evaluated in this study. This was followed by plots amended with PD_{10}+$NPK_{0.20}$+AGF. However, plots amended with $NPK_{0.40}$+AGF had reduced activities of dehydrogenase, phosphatase and beta glucosidase enzymes relative to the control and a similar trend was also observed with respect to phosphatase and beta glucosidase enzyme activities. Incorporation of PD_{20}+AGF increased the dehydrogenase enzyme activity of the soil by more than 45% compared to when same rate of the poultry droppings was applied sole. Also the activity of phosphatase enzyme was enhanced by poultry droppings amendment especially when applied at a rate lower than PD_{20}. Enhancement of phosphatase activity was particularly highest in plots treated with PD_{10}+$NPK_{0.20}$+AGF with an increase of 45% relative to the control. In addition, plots treated with PD_{10}+$NPK_{0.20}$ had an increase of 12% over the control.

Table 2: Main and subplot treatment effect on soil biochemical properties

Main plot treatment (Tillage type)	Biochemical parameters (Ug g^{-1} h^{-1})		
	Dehydrogenase	Phosphatase	Glucosidase
ZT-FB	233.06	141.95	208.55
CT-FB	172.51	161.31	221.98
CT-TR	178.29	175.96	229.22
FLSD (0.05)	0.15	0.03	0.13
Subplot treatment (Nutrient type)			
Ctrl	101.54	165.36	240.20
PD_{20}	217.90	184.00	225.30
PD_{10}+AGF	316.70	133.52	199.50
PD_{10}+$NPK_{0.20}$	206.60	185.67	227.20
PD_{10}+$NPK_{0.20}$+AGF	284.40	221.92	258.87
$NPK_{0.40}$	128.20	126.48	195.9
$NPK_{0.20}$+AGF	95.40	101.20	192.5
FLSD	0.17	0.04	0.21

ZT-FB - no-till flatbed; CT-FB - conventionally tilled flatbed; CT-TR - conventionally tie ridge; PD20 - 20 t/ha poultry droppings; PD20 + AGF - 20 t/ha poultry droppings + agrolyzer micronutrient fertilizer; PD10 + NPK0.20 - 10 t/ha poultry droppings + 200 kg/ha NPK; PD10 + NPK0.20 + AGF - 10 t/ha poultry droppings + 200 kg/ha NPK + agrolyzer micronutrient fertilizer; NPK0.40 - 400 kg/ha NPK; NPK0.40 + AGF - 400 kg/ha NPK + agrolyzer micronutrient fertilizer

Interaction of tillage and nutrient management practices on soil biochemical properties are shown on table 3, and they significantly affected all the biochemical properties of the soil (Table 2). The CT-FB+PD_{10}+NPK_{20}+AGF (465.20 Ug g^{-1} h^{-1}) gave the highest dehydrogenase activity followed by CT-TR+PD_{20}+AGF (456.20 Ug g^{-1} h^{-1}). The least was gotten from CT-TB+NPK+AGF (40.20 Ug g^{-1} h^{-1}), followed by CT-TR+control (52.60 Ug g^{-1} h^{-1}). Comparing the tillage types under each nutrient management type, ZT-FB gave significantly highest dehydrogenase activity over other tillage types. In zero application (control), ZT-FB had 161.20 Ug g^{-1} h^{-1} dehydrogenase activity followed by CT-FB (90.80 Ug g^{-1} h^{-1}) and the least was CT-TR (52.60 Ug g^{-1} h^{-1}). Also in PD_{20}, ZT-FB + PD_{20} (386.80 Ug g^{-1} h^{-1}) gave the highest dehydrogenase activity and the sequence was same for other sole nutrient management options. This differed in PD_{20}+AGF and PD_{10} +NPK_{20} +AGF, ZT-FB plots did not give the highest dehydrogenase activity over other tillage types and this could have resulted from overshadowing effect of the nutrient added in these combined application of nutrient sources on the effect of tillage.

Looking at interaction of ZT-FB with the seven nutrient management options, the best nutrient management combination with ZT-FB, was ZT-FB +PD_{20} (386.80 Ug g^{-1} h^{-1}), whichgave the highest dehydrogenase activity, followed by ZT-FB +PD_{20}+AGF (369.20 Ug g^{-1} h^{-1}). All treatment combinations without poultry droppings had lower dehydrogenase activity than those treatments with poultry droppings with ZT-FB +$NPK_{0.40}$+AGF (130.20 Ug g^{-1} h^{-1}) having the least value. This was followed by ZT-FB +$NPK_{0.40}$ having 140.60 Ug g^{-1} h^{-1} and the third worst in dehydrogenase activity under ZT-FB was ZT-FB +Control (161.20 Ug g^{-1} h^{-1}). This shows that ZT-FB requires organic matter or combination of organic matter with inorganic nutrient sources to improve dehydrogenase activity. Based on this research, to obtain high dehydrogenase activity, ZT-FB will require PD at 20 t ha^{-1} or a combination of PD at 10 t ha^{-1} + NPK at 200 kg ha^{-1}. Considering CT-FB, the best nutrient management option based on this research was PD_{10}+$NPK_{0.20}$+AGF (465.20 Ug g^{-1} h^{-1}). This means that combination of organic, NPK, secondary elements and micronutrient is required to obtain the highest dehydrogenase activity under conventional flatbed tillage. This was followed by CT-FB+PD_{10}+$NPK_{0.20}$ (253.20 Ug g^{-1} h^{-1}) and the least was CT-FB+$NPK_{0.40}$+AGF (40.20 Ug g^{-1} h^{-1}). For the CT-TR, the best soil amendment was PD_{20}+AGF (456.20 Ug g^{-1} h^{-1}) followed by PD_{10}+$NPK_{0.20}$+AGF (214.60 Ug g^{-1} h^{-1}) and the worst was the control (52.60 Ug g^{-1} h^{-1}).

Phosphatase activity significantly differed among treatments and there was significant interaction between tillage and nutrient management practices. CT-TR+PD_{10}+AGF and CT-TR+PD_{10}+$NPK_{0.20}$ (245.76 Ug g^{-1} h^{-1}) had the highest phosphatase activity followed by ZT-FB +PD_{10}+$NPK_{0.20}$+AGF (226.36 Ug g^{-1} h^{-1}). Under no nutrient application (control), ZT-FB gave the highest phosphatase activity (Table 3) over the other tillage practices. The nutrient management options for ZT-FB with the highest phosphate activity was ZT-FB +PD_{10}+$NPK_{0.20}$+AGF (226.36 Ug g^{-1} h^{-1}), followed by ZT-FB +control (192.96 Ug g^{-1} h^{-1}) and ZT-FB +PD_{20} (183.84 Ug g^{-1} h^{-1}). Under no nutrient

application (control), ZT-FB (283.50 Ug g^{-1} h^{-1}) gave the highest Beta glucosidase activity compared with other tillage types. Considering the Interaction of tillage and nutrient management practices, ZT-FB +PD_{10}+$NPK_{0.20}$+AGF (285.60 Ug g^{-1} h^{-1}) had the highest beta glucosidase activity, which was followed by ZT-FB +$NPK_{0.20}$+AMF (283.50 Ug g^{-1} h^{-1}) and the least was ZT-FB +PD_{20}+AGF (118.50 Ug g^{-1} h^{-1}). Judging from the result of this research, nutrient management option with poultry droppings improved enzyme activity except in ZT-FB +PD_{20}+AGF for Beta glucosidase activity and those with NPK significantly lowered enzyme activity except in combination with poultry manure or other nutrient sources.

Table 3: Effect of tillage practices and integrated nutrient management on soil biochemical properties

Treatment combinations	Dehydrogenase activity	Phosphatase activity	Beta glucosidase activity
		(Ug g^{-1} h^{-1})	
ZT-FB + Ctrl	161.20	192.96	283.50
CT-FB + Ctrl	90.80	138.72	193.60
CT-TR + Ctrl	52.60	164.40	241.50
ZT-FB + PD20	386.80	183.84	199.50
CT-FB + PD20	102.80	205.91	250.60
CT-TR + PD20	164.10	162.24	225.60
ZT-FB + PD20 + AGF	369.20	10.32	118.50
CT-FB + PD20 + AGF	124.60	144.48	208.50
CT-TR + PD20 + AGF	456.20	245.76	271.50
ZT-FB + PD10 +NPK0.20	269.20	140.16	210.60
CT-FB + PD10 +NPK0.20	253.20	213.32	247.50
CT-TR + PD10 +NPK0.20	97.20	245.76	223.50
ZT-FB + PD10 +NPK0.20 + AGF	173.20	226.36	285.60
CT-FB + PD10 +NPK0.20 + AGF	465.20	198.72	232.50
CT-TR + PD10 +NPK0.20 + AGF	214.60	240.72	258.60
ZT-FB + NPK0.40	140.60	145.44	192.60
CT-FB + NPK0.40	130.80	128.88	207.60
CT-TR + NPK0.40	113.20	105.12	187.50
ZT-FB + NPK0.40+ AGF	131.20	94.56	283.50
CT-FB + NPK0.40+ AGF	40.20	99.12	195.60
CT-TR + NPK0.40+ AGF	114.70	109.92	241.50
F-LSD (0.05)	0.30	0.08	0.36

ZT-FB - no-till flatbed; CT-FB - conventionally tilled flatbed; CT-TR - conventionally tie ridge; PD20 - 20 t/ha poultry droppings; PD20 + AGF - 20 t/ha poultry droppings + agrolyzer micronutrient fertilizer; PD10 + NPK0.20 - 10 t/ha poultry droppings + 200 kg/ha NPK; PD10 + NPK0.20 + AGF - 10 t/ha poultry droppings + 200 kg/ha NPK + agrolyzer micronutrient fertilizer; NPK0.40 - 400 kg/ha NPK; NPK0.40 + AGF - 400 kg/ha NPK + agrolyzer micronutrient fertilizer

Effect of main plot and subplot treatment on Microbial Biomass Carbon, Nitrogen, Phosphorus and Total Microbial Count

Table 4 shows the effect of main plot and subplot treatments on soil microbiological properties. The results show that soil tillage type and nutrient management can affect microbial biomass composition, activities and proliferation in tropical agriculture. ZT-FB had the highest SMBN (0.145) but least SMBC (0.109) and SMBP (13.67) while CT-TR had the highest total microbial count (487), SMBC (0.139) and SMBP (16.16) but least SMBN (0.080). CT-FB had the least total microbial count (392) but contained higher SMBC and SMBP than ZT-FB and higher SMBN than CT-TR. The control plots, NT-FB had significantly lowest values except for soil microbial biomass nitrogen (SMBN) in which it had higher value (0.071 mg kg^{-1}) than CT-TR (0.062 mg kg^{-1}). CT-FB had significantly highest total microbial count (460) and SMBN (0.082 mg kg^{-1}). Meanwhile, CT-TR had highest SMBC (0.075 mg kg^{-1}) and SMBP (10.18 mg kg^{-1})

Nutrient management options significantly ($P < 0.05$) affected the soil microbial properties. Application of PD_{20}+AGF produced the highest average SMBC value of 0.158 mg kg^{-1} across the three tillage methods. This value (0.158 mg kg^{-1}) represents 132 and 103% increases over the SMBC value recorded in the control and the $NPK_{0.40}$ plots, respectively. On the other hand, the increase in SMBC content obtained in plots that received NPK fertilizer treatment was only 15% higher than the control, which was much less than that recorded when the soil was amended with PD_{20}. Comparing application of AGF to NPK ($NPK_{0.20}$ +AGF) and application of AGF to PD (PD_{10} +AGF) showed that combined application of AGF and NPK had a more profound

effect on SMBC, thus having 52.56% increase over sole NPK than the combined application of PD_{10} +AGF, which had only 8.97% increase over sole PD application. Incorporation of agrolyzer micronutrient fertilizerinto either poultry dropping(PD_{10} + AGF = 0.158) or NPK fertilizer ($NPK_{0.20}$+AGF = 0.119) imparted a stronger positive effect on soil microbial biomass carbon production compared to when either of the treatments (PD_{20} = 0.145or $NPK_{0.20}$ =0.078) was applied even at a higher rate without agrolyzer. Furthermore, there was a 15% increase in SMBC content when the soil was amended with PD_{10}+$NPK_{0.20}$+AGF compared to PD_{10}+$NPK_{0.20}$ that was not complemented with agrolyzer. This trend was expected because microorganisms in general use not only macronutrients for their metabolic activities but also micronutrients like cobalt, chromium, copper, iodine, manganese, selenium, zinc and molybdenum. They require these micronutrients throughout life in small quantities to orchestrate a range of physiological functions.

Table 4: Main and subplot treatment effect on soil microbiological properties

Main plot treatment (Tillage type)	Microbiological parameters (mg kg^{-1})			
	Total microbial count	SMBC	SMBN	SMBP
ZT-FB	419	0.109	0.145	13.67
CT-FB	392	0.126	0.116	16.01
CT-TR	487	0.139	0.080	16.16
FLSD (0.05)	1.37	0.002	0.001	0.017
Subplot treatment (Nutrient type)				
Ctrl	357	0.068	0.072	7.99
PD_{20}	357	0.145	0.124	16.66
PD_{10}+AGF	500	0.158	0.128	18.79
PD_{10}+$NPK_{0.20}$	510	0.150	0.113	15.50
PD_{10}+$NPK_{0.20}$+AGF	433	0.154	0.134	17.38
$NPK_{0.40}$	404	0.078	0.111	12.15
$NPK_{0.20}$+AGF	460	0.119	0.110	18.48
FLSD	2.09	0.003	0.002	0.025

ZT-FB - no-till flatbed; CT-FB - conventionally tilled flatbed; CT-TR - conventionally tie ridge; PD20 - 20 t/ha poultry droppings; PD20 + AGF - 20 t/ha poultry droppings + agrolyzer micronutrient fertilizer; PD10 + NPK0.20 - 10 t/ha poultry droppings + 200 kg/ha NPK; PD10 + NPK0.20 + AGF - 10 t/ha poultry droppings + 200 kg/ha NPK + agrolyzer micronutrient fertilizer; NPK0.40 - 400 kg/ha NPK; NPK0.40 + AGF - 400 kg/ha NPK + agrolyzer micronutrient fertilizer

Interaction effect of tillage type and nutrient management option on Microbial Biomass Carbon, Nitrogen, Phosphorus and Total Microbial Count

Table 5 contains the microbial properties of the soil as affected by interaction between tillage types and nutrient management options. Interaction of tillage type and nutrient management option significantly ($p < 0.05$) affected all the measured soil microbial properties. ZT- FB+PD_{10}+$NPK_{0.20}$+AMF gave the highest total microbial count (610) followed by CT-TR+PD_{20}+AMF (600) and CT-TR+PD_{10}+$NPK_{0.20}$ (600); the least was ZT- FB+control (230) followed by CT-FB+$NPK_{0.40}$ (270). The highest SMBC was recorded from CT-TR+PD_{20}+AMF (0.171 mg kg^{-1}), followed by CT-TR+PD_{10}+$NPK_{0.20}$+AMF (0.169 mg kg^{-1}) and the lowest was ZT- FB+control (0.060 mg kg^{-1}). ZT- FB+$NPK_{0.20}$+AMF (0.172 mg kg^{-1}) had the highest SMBN, followed by ZT- FB +PD_{10}+$NPK_{0.20}$+ AMF (0.163 mg kg^{-1}). ZT- FB across the nutrient options had the highest SMBN. The lowest SMBN was recorded from CT-TR+control. With regard to SMBP, ZT- FB +control (5.62 mg kg^{-1}) gave the lowest values among the three tillage types and the highest was recorded from CT-TR+ control (10.18). Overall interaction effect had significantly highest value of SMBP from CT-FB+PD_{20}+ AMF (21.12 mg kg^{-1}), followed by CT-TR + $NPK_{0.40}$+AMF (20.16 mg kg^{-1}).

Table 5: Interaction effect of tillage type and nutrient management option on soil microbial properties

Tillage type x nutrient management options	Total microbial count	SMBC	SMBN	SMBP
			(mg g^{-1})	
ZT-FB + Ctrl	230	0.060	0.071	5.62
CT-FB + Ctrl	460	0.068	0.082	8.16
CT-TR + Ctrl	380	0.075	0.062	10.18
ZT-FB + PD20	320	0.132	0.154	19.62
CT-FB + PD20	360	0.142	0.137	14.32
CT-TR + PD20	420	0.162	0.081	16.03
ZT-FB + PD20 + AMF	460	0.145	0.160	17.11
CT-FB + PD20 + AMF	420	0.158	0.139	21.12
CT-TR + PD20 + AMF	600	0.171	0.085	18.13
ZT-FB + PD10 +NPK0.20	510	0.138	0.158	12.13
CT-FB + PD10 +NPK0.20	400	0.146	0.101	17.20
CT-TR + PD10 +NPK0.20	600	0.166	0.080	17.16
ZT-FB + PD10 +NPK0.20 + AMF	610	0.142	0.163	15.04
CT-FB + PD10 +NPK0.20 + AMF	360	0.150	0.129	19.80
CT-TR + PD10 +NPK0.20 + AMF	320	0.169	0.110	17.28
ZT-FB + NPK0.40	420	0.065	0.132	10.22
CT-FB + NPK0.40	270	0.077	0.135	12.10
CT-TR + NPK0.40	520	0.092	0.065	14.13
ZT-FB + NPK0.40+ AMF	380	0.080	0.172	15.92
CT-FB + NPK0.40+ AMF	470	0.140	0.086	19.35
CT-TR + NPK0.40+ AMF	530	0.136	0.072	20.16
F-LSD (0.05)	3.63	0.004	0.004	0.044

ZT-FB - no-till flatbed; CT-FB - conventionally tilled flatbed; CT-TR - conventionally tie ridge; PD20 - 20 t/ha poultry droppings; PD20 + AGF - 20 t/ha poultry droppings + agrolyzer micronutrient fertilizer; PD10 + NPK0.20 - 10 t/ha poultry droppings + 200 kg/ha NPK; PD10 + NPK0.20 + AGF - 10 t/ha poultry droppings + 200 kg/ha NPK + agrolyzer micronutrient fertilizer; NPK0.40 - 400 kg/ha NPK; NPK0.40 + AGF - 400 kg/ha NPK + agrolyzer micronutrient fertilizer

DISCUSSION

This experiment showed that zero tillage had higher dehydrogenase activity over other tillage types (Table 2).Among the three enzymes studied only dehydrogenase activity was higher in ZT across the seven nutrient management options.The higher dehydrogenase activity recorded from ZT-FB treatment over CT-FB and CT-TR treatments agrees with findings of other researchers (Celik *et al.*, 2012, Majchrzak *et al*., 2016). They found increased dehydrogenase activity under zero-tillage and they associated it to higher organic C in the soil. Tillage causes faster degradation of organic C. Soils under zero-tillage have greater storage of diverse plant biomass which conserves soil moistureand showcase low temperature with efficient microbial activity (Benitio, 2010; Celik,*et al*., 2012; Naudin *et al*., 2010). Notably, dehydrogenase activity measures the respiratory activity of soil microbes ((Majchrzak, *et al*., 2016). Any management system that increases living microorganisms favors the activity of dehydrogenase enzyme. Dehydrogenase is an oxide-reductase, which is only present in viable cells. CT-TR plot had the highest phosphatase and glycosidase activity based on this research across the nutrient management options. In addition, under control plots, when no amendment was applied, all the enzymes studied were higher in ZT-FB over other tillage types (Table 3). This means that in absence of amendments or fertilizer application, ZT will improve enzyme activity better than either conventional or minimum tillage. (Roldán *et al*., 2005) reported greater values of water soluble C, dehydrogenase, urease, protease, phosphatase, alpha-glucosidase activities and aggregate stability under zero tillage over conventional tilled soils. This could have resulted from less soil disturbance in ZT-FB plots, which has concomitant effect on soil organisms via enhancement of soil organic carbon needed by soil organisms. Others observed higher enzyme activity under zero tillage (Parihar et al 2016; Majchrzak*et al.*, 2016) when compared with conventional tillage. Heidari*et al* (2016) explained that ZT system, which largely increases the surface of crop residues, is the most effective method for improving soil microbial biomass of carbon and enzymes activities in a relatively short term and for sustaining agricultural ecosystems.

Soil amendment with poultry droppings or its combination with either NPK fertilizer or agrolyzer micronutrient fertilizer) resulted in improved dehydrogenase enzyme activity relative to the un-amended soil (control) or sole NPK or AGF. This improvement peaked with the complementary application of PD_{20}+AGF relative to other nutrient management practices evaluated in this study. The best result in terms of dehydrogenase enzyme

activity was obtained on CT-FB plots amended with PD_{10}+$NPK_{0.20}$+AGF. With combination of organic manure and other nutrient sources, the populations of the living microbes are expected to increase leading to increase in dehydrogenase activity.

Phosphatase catalyzes the hydrolysis of P organic compounds to inorganic P forms available to plants. In this research under no nutrient addition (control), ZT had higher phosphatase activity over other tillage types. Pandey *et al*. (2014) observed increased phosphatase activity on ZT plots over conventional tillage. Interaction of tillage with the seven nutrient management options had the highest phosphatase activity on plots of CT-TR+PD20+AGF and CT-TR+PD20+NPK+AGF. And also across the tillage types, the highest phosphatase activity was recorded in PD_{10}+$NPK_{0.20}$+AGF. According to Banerjee et al. (2012) phosphatase activity is affected by tillage, total microbial count and nutrient constituent of the soil including those added by organic materials, inorganic and organic fertilizers and other agricultural practices. It also varies with microbial count ((Banerjee, *et al*. 2012). In this research, under tillage types, the treatment with highest phosphatase activity had also the highest total microbial count. Organic fertilizers or in combination with inorganic fertilizers were also found to increase phosphatase activity and most other microbial properties by other researchers(Kalembasa and Symanowicz 2012, Piotrowska-Długosz and Wilczewski 2014, Srivastava *et al*. 2012). Increase in phosphatase activity with addition of organic materials could be attributed to stimulation of microbial growth (Adetunji, *et al*., 2017).

According to Pandey, *et al*. (2014), ZT or reduced tillage increases the activity of beta glucosidase activity as well as microbial biomass C and N over conventional tillage system. They explained that ZT reduces soil disturbance with concomitant reduction in degradation of organic matter. Conventional tillage depletes organic matter (Miralles *et al*., 2012), which could result in reduction in simple sugars for microbial functioning owing to a decrease in beta glucosidase. Research also shows that organic fertilization increases beta glucosidase than inorganic fertilization (Meyer *et al*., 2015) as shown also in this research (Table 2). Organic substrate induces the activity of beta glucosidase which according to Adetunji, *et al*. (2017) makes it a reliable indicator for soil quality changes. They also noted that level of beta glucosidase in the soil constitute an early warning symptoms of changes in organic C.

Soil amendment with sole or combined with poultry droppings (applied alone or in combination with NPK fertilizer and agrolyzer micronutrient fertilizer) resulted in improved dehydrogenase enzyme activity relative to the un-amended soil (control) or sole NPK or AGF. This improvement peaked with the complementary application of PD_{20}+AGF relative to other nutrient management practices evaluated in this study. The higher SMBC, SMBN and SMBP abundance and enzyme activities generally recorded on soil amended plots reflected a better substrate and higher nutrient cycling as a result of theamendment. A common feature of biochemical cycles is that microorganisms are key agents in the transformations. The work of Kobierski *et al*. (2017) showed that as poultry droppings undergoes decay in the soil, C, N and P may appear in plant available forms. The results presented in Table 4 show that SMBC, SMBN and SMBP contents were significantly affected by method of soil tillage. The main effect of tillage had the highest average SMBC and SMBP contents of 0.139 mg kg^{-1} C and 16.16 mg kg^{-1} P respectively and total microbial count of 487 obtained from CT-TR plots indicating that tillage by ridging provided a more favorable habitat for microbial proliferation and activities of enzymes involved in C and P cycling and transformations than the other tillage types. The highest SMBN average of 0.145 mg kg^{-1} N was obtained under ZT-FB treatment. The low content of SMBN from CT plots could have resulted from high mineralization rate, reduced moisture and increased temperature as a result of tillage (da Silva *et al*., 2014; Morris *et al*., 2010; Young and Ritz, 2000).

Integrated nutrient management approach (which allows for diversification of nutrient sources in crop production systems) tend to favor microbial activities and proliferation more than sole application of nutrients in the soil as evident in the high total microbial count recorded in this study on plots that received combined applications of nutrients from diverse sources (Table 2 and 4).

Conclusion

The results of this study have shown that tillage and nutrient management practices on coarse-textured Ultisols of inherently low fertility status could influence enzymes and microbial biomass activities. Application of 20 t ha^{-1} poultry droppings plus 2 kg ha^{-1} agrolyzer micronutrient fertilizer produced the highest average microbial biomass carbon across the three tillage methods investigated. Addition of agrolyzer micronutrient fertilizer into either poultry droppings or NPK fertilizer had a positive effect on microbial biomass carbon. Microbial biomass carbon and microbial biomass phosphorus showed highest values in plots amended with poultry droppingsat 20 t ha^{-1} and complemented withagrolyzer micronutrient fertilizer. Of the three tillage methods, conventionally tilled tie-ridge enhanced phosphatase and beta glucosidase enzyme activities the most. Among the seven nutrient management practices evaluated, half dose each of poultry droppings or NPK fertilizer and complemented with agrolyzer micronutrient fertilizer gave the highest phosphatase and beta glucosidase. Highest dehydrogenase

enzyme activity was recorded in ZT-till flatbed and in plots amended poultry droppings at 20 t ha^{-1} and complemented with agrolyzer micronutrient fertilizer. Soil biochemical properties significantly differed across the tillage methods and nutrient management practices.

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