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Dynamics of soil organic carbon, nitrogen and microbial biomass in an organically manured ultisol in a guinea savanna agroecological zone of Nigeria

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ABSTRACT

A field study was conducted to evaluate the effects of integrated use of agricultural wastes and a compound mineral fertilizer NPK (commercially available compound fertilizer containing N. P. K) on the fluxes (sources and sinks) of soil nutrients. Agricultural wastes applied were: livestock manure (cow dung and poultry litter), shoots of Chromolaena odorata and Parkia biglosa (locust bean), neem (Azadiracta inidca)seed powder/cake and melon shell. These materials were applied at zero (control), 100% (i.e. organic wastes applied at the recommended rates of 10t/ha) and 70% of their recommended rates plus 30% of the recommended rate of the mineral fertilizer (NPK:400 Kg/ha). The dynamics of biota population and soil mineralization (soil nutrients) measured in terms of organic carbon status, net N mineralization and microbial biomass (microbial biomass C and N) pool differed among the treatments. Differences were obtained for inorganic N released from the soil at the various dates of sampling. The trends of the time dynamics of SOC and plant available forms of N (NH_4-N and NO_3-N) show that peak values were obtained at 30 and 60 days after planting (DAP) and these values declined subsequently after. Average values of SOC were 1.94, 1.68, 1.36 and 1.38 for organic wastes alone, organic waste plus mineral fertilizer (NPK), mineral fertilizer and unamended control. Across sampling dates, SOC values were highest in poultry manure and neem seed cake. The average values of SOC, NH_4^+ and NO_3^- turnover rates indicated that these parameters were comparatively greater in the organic amended (1.94; 19; 119) than in the unamended (1.36; 15.5; 54) soils. The values of NO_3^- N plus exchangeable NH_4^+ N which constitutes plant available nitrogen (PAN) that were recovered were significantly higher for organically amended soils (550) and wastes applied at reduced rates combined with 120 kg/ha mineral NPK (470) than the unamended control (277). NO_3^- N plus exchangeable NH_4^+ N were relatively high at 30 and 60 days after planting, and this trend was consistent among the agricultural waste materials applied. The higher values were followed by consistent decline afterwards especially at the end of the experiment (120 DAP). This indicates that the manures whether applied solely or at the reduced rates combined with 120 kg/ha mineral NPK had high mineralisation rates. Mineral N (NO_3^- N plus NH_4^+ N) pools and % C microbial to C organic ratio were higher in the nutrient-rich organically amended soils which indicated that increased N mineralisation were facilitated by higher amounts of SOC. The time changes in SOC, NH_4-N and NO_3-N contents was monitored, declines in the values of SOC with time was obtained. This time dependent declining in SOC is linearly related with ($Y = 0.18x + 1.07$; $R^2 = 0.34$) A sharp decline in NO_3-N with time under organic amendment alone and the control The nature of the decline in NO_3-N is related with time by a power function ($Y = 48.084x^{-1.79}$; $R^2 = 0.91$). The nature of the decline in NH4-N is related with time by a polynomial function ($Y = -28.75x + 130.65x -57.25$; $R^2 = 0.61$). Although the trend of the effects of wastes application on cfu were inconsistent however, the time dynamics of microbial population (cfu) follows trends obtained for SOC. The differences in the quality of the agricultural wastes measured in terms of C/N ratios differed and could have driven the observed temporal variations in soil chemical properties (soil organic carbon, mineral N and microbial biomass-C and N). The values of % C mic: Corg (indicator of microbial activity in terms of the utilisation of organic carbon by the microbes and hence organic matter turnover rate) obtained could be indicative of greater access of nutrients for microbes. Although the % microbial carbon to organic carbon ratios were stable for all treatments, its magnitude was not similar among treatments, higher % microbial carbon to organic carbon ratios were obtained from organically amended soils.

KEYWORDS

Organic; Amendment; Carbon; Mineral N; Microbial biomass; Savanna; Ultisol; Tropics.

INTRODUCTION

In Nigeria, the vegetation zones and the agroecologies vary from the humid tropical rainforest to the savanna. However, soils of the southern guinea savanna zones are inherently low in soil nitrogen and organic matter and crop yields on these soils are low[8]. In this zone, there is widespread use of both organic and inorganic fertilizer s to improve soil and crop productivity. The merits of organic over inorganic fertilizers include better crop establishment and improved efficiency of utilization of the applied materials[9]. Organic manure improves physical properties of soils and replenishes depleted soil organic matter. However, the use of organic manure is faced with limitations such as slow decomposition and mineralization rates, bulkiness, dirt etc. Integrated use of inorganic and organic fertilizer is therefore required for sustainable soil and crop productivity.

Due to the problems associated with the use of inorganic fertilizers, combine use of organic and inorganic manures may be beneficial to soil and crop productivity in this agroecology. A balanced use of organic and mineral fertilizer could enhance soil chemical, physical and biological properties in addition to rapid rate of nutrient turn over within the soil-plant system. Integrated use of organic wastes and mineral fertilizer is reported to reduce the cost and amount of fertilizer required by crops[5, 6, 7]. Bair[3] opined that proper soil fertility management and sustainable agriculture can be achieved with the use of both mineral fertilizer and organic manure. Paul and Mannan[11] suggested that integrated nutrient management through combined use of organic wastes and chemical fertilizers can be an effective approach to combat nutrient depletion and promote sustainable crop productivity. Replenishing the nutrients removed by crops by recycling agricultural wastes into the soil can sustain soil and crop productivity[11]. Practices which focus on recycling agricultural wastes into the soil would contribute to improved quality and health of the soil.

There is dearth of information on effect in integrated application of agricultural wastes and mineral fertilizer on soil physical and chemical properties in a southern guinea savanna zone of Nigeria an agroecological zone that is characterised by inherently low soil fertility status and rapid nutrient depletion especially organic matter depletion. However, the southern guinea savanna is also characterized by abundant agricultural land and high potential for crop production, however, soils of this agroecology are characterized by inherently low in soil fertility and rapid nutrient depletion and other forms of soil degradation. Tropical soils under different soil nutrient management practices have a wide range of mineralization potentials inadequate information on C and N fluxes in these soils. Understanding the C and N dynamics in the soil-plant system is essential to successful soil nutrient management. In addition, understanding the chemical and biological processes of fluxes of carbon and nitrogen in organically amended soils would help to fine tune nutrient management strategies, improve crop nutrient use efficiency and the quality of the environment.

The role of microbial immobilisation, clay fixation, denitrification and ammonia volatilisation in determining soil mineral N dynamics following organic amendment has been reported. For example, Sørensen[18] and[4] reported that after manure addition to soil, a decrease of soil mineral N as observed in the short term in the manured compared to the unmanured control treatment, probably due to microbial immobilization. Moreover, studies conducted using 15N suggest that part of this immobilized N is stored in the soil in organic form, at least for a few years after manure addition[19]. The process of organic matter accumulation as a result of repeated manure applications has been studied from field experiments[2, 14, 15]. The study of the fate of added N in different compartments are affected by the confounding effect of other inputs or outputs[4, 18, 20]. Laboratory experiments permit the measurement of the net N mineralisation of manures, thus reducing the confounding effects of other inputs or outputs. However, under field conditions the fluxes of soil N in different compartments are due to the contemporary processes of crop N uptake, N loss, and mineralisation of native and added organic matter.

Soil N dynamics is characterized by a series of transformation processes between organic and inorganic forms of N. Soil N pool is affected by inorganic N which is derivable from mineralization process, N addition via fertilizer usage and soil N losses via leaching or volatilization, N removal by crops and/or addition of N fertilizer materials to soil, microbial immobilization/fixation.

Accurate estimation of the capacity of the soil to mineralize organic nitrogen is important. Nitrogen is the key element to plant production and modern farming systems require an ample supply of N fertilizer necessary for maximum crop yield. The relationship between total N and mineralized N has been widely studied. Soil or native ammonium fixation is involved in the N dynamics of soil and may be an important component of the N fertility status of some agricultural soils[13]. Native fixed ammonium is reported as the dominant N form in some soils[16].

Carbon to nitrogen ratio is an indicator of the decomposing ability of soil organic matter and consequently of the N supplying potential of the soil. Organic (agricultural) wastes have the potential to slow down nitrification process possibly via slow hydrolysis of the mineral fertilizer (reduced nitrification rate of urea). Patra et al.[12] reported that agricultural wastes have the potential to inhibit urease activity and slow down the release of NH_4-N into the soil. Application of organic wastes to agricultural soils contribute not only to the short term fertility but also determine the residual pool of nutrients in the soil. It is not clear how different manure types (due to the different rates of decomposition of the organic fraction) and different soils (due to different clay content which may impact on microbial turnover and clay fixation) in soil such as the Ultisols of the humid tropics. A detailed analysis of carbon and nitrogen sinks from organically amended tropical soils Ultisols in particular has yet to be undertaken. Tropical soils have a wide range of mineralization potentials inadequate information on C and N fluxes in these soils, there adequate understanding of the chemical and biological processes of fluxes of carbon and nitrogen from tropical soils is required. Ultisols occupy a great part of the soils resources in Nigeria and information on C and N fluxes in these soils is inadequate.

This study examines the effects of integrated management of some agricultural waste materials and mineral fertilizer (commercially available compound fertilizer containing N. P. K) on the fluxes (sources and sinks) of soil nutrients on a Ultisol in a humid savanna agroecological zone of Nigeria. The objectives therefore are to investigate the effects of organic amendment on stocks of soil organic carbon, microbial biomass C and N, and forms of plant available soil N (NO_2-N + NO_3-N and NH_4-N) in the soil

MATERIALS AND METHODS

Field experiments were conducted at the Lower Niger River Basin Development Authority (L.N.R.B.D.A) farm located in Isanlu, Isanlu Local Government Area of Kogi State in the Southern Guinea Savanna zone of Nigeria in 2008a and 2009cropping seasons.

Treatments

Treatments consisted of sole and combined application a compound mineral fertilizer (NPK 15:15:15) and agricultural waste materials (cow dung and poultry litter, shoots of Chromolaena odorata and Parkia biglosa (locust bean), neem (Azadiracta inidca) seed cake and melon shell). The mineral fertilizer and agricultural wastes were separately applied at their recommended rates of 400kg/ha and 10t/ha (IAR&T, 2000) while integrated use of NPK and wastes consisted of application of 30 and 70% of their recommended rates (120kg/ha NPK + 7 t/ha of waste). There was an unmanured control.

The mineral fertilizer (N P K 15 – 15 – 15) and agricultural wastes were split applied. The organic materials were applied a week before planting and NPK at planting whilethe second application was at 6 weeks after planting (WAP). Weeding was carried out manually at 3 and 8 WAP.

Chemical analysis of agricultural waste materials

Samples of the agricultural wastes were taken for chemical (C:N ratio, organic carbon, N, P, K, Ca and Mg) analyses.

Soil sampling and analysis

Before the commencement of the experiment, surface soil samples (O – 15cm depth) were taken randomly from the field plots and at crop maturity. The samples were bulked, air dried and sieved using a 2mm sieve and were subjected to routine physical (particle size, bulk density, soil moisture and temperature regimes) and chemical (pH, organic matter, N, P, K, Ca Mg and CEC) analyses in the laboratory. The mineral (plant available N; NH4–N and NO3–N) forms of N were extracted with 100 mL 1 M KCl from 30 g of soil.

Suspensions were shaken for 1 h and then filtered through Whatman 40 filter paper. Concentrations of NH_4–N and NO_3–N of the KCl extracts were determined by flow injection analysis and spectrometric detection (FIAstar 5000 Analyzer, Foss Tecator, Denmark). Analysis of NH_4–N was by the gas semi-permeable membrane method according to the ISO 11732 procedure (1997). Analysis of NO_3–N was by the sulphanilamide-naphtylethylendiamine dihydrocloride method, after preliminary reduction of NO_3 to NO_2 by a copper-cadmium reductor column, according to the ISO 13395 procedure (1996). Plant available N (PAN) was calculated as the SMN in the manured treatments minus the SMN in the unmanured control. PAN was expressed as a fraction of added manure N.

Statistical analysis

Data collected from each year experiment were subjected to analysis of variance (ANOVA) test SPSS statistical package. Treatment means were compared using the Least Significant Difference (LSD) test at ($P = 0.05$).

RESULTS AND DISCUSSION

The dynamics of biota activity and soil nutrient contents in terms of soil organic carbon, total and plant available N and microbial biomass-C and N) were monitored following organic amendment of an Ultisol using agricultural wastes: Farm yard manure (cow dung and poultry litter), shoots of Chromolaena odorata and Parkia biglosa (locust bean), neem (Azadiracta inidca) seed powder/cake and melon shell.

The results confirmed the influence of organic amendments on the fluxes of soil nutrients of an Ultisol of the southern guinea savanna agroecological zone of Nigeria. The dynamics of microbial biomass pool (biomass C and N) and soil organic carbon and plant available N varied for the unmanured and manured soil (under application of agricultural wastes alone and in combination with mineral NPK fertilizer). Organic amendment alone and in combination with mineral fertilizer (NPK) affected the status of soil chemical properties especially SOC and plant available forms of N (NH_4-N and NO_3-N).

Agricultural wastes alone and in combination with mineral fertilizer (NPK) affected the status of soil physical and chemical properties. From the results of the time dynamics in soil organic carbon (SOC) and mineral N (NH_4^+ and NO_3^- N) pools, differences were obtained at the various dates of sampling. Thus from the time dynamics in SOC and plant available forms of N (NH_4-N and NO_3-N) pools, highest values of these parameters were obtained at 30 and 60 days after planting (DAP), these values declined subsequently after. Across the sampling dates, the values of SOC were highest in poultry manure and neem seed cake, the average values of SOC were 1.94, 1.68, 1.36 and 1.38 for organic wastes alone, organic waste plus mineral fertilizer (NPK), mineral fertilizer and unamended control. Differences were also obtained for inorganic N pool in the soil at the various dates of sampling. However, average values indicated that SOC, NH_4^+ and NO_3^- turnover rates were comparatively greater (1.94; 19; 119) in the organic amended than the unamended (1.36; 15.5; 54) soils. The values of NO_3^- N plus exchangeable NH_4^+ N which constitutes plant available nitrogen (PAN) that were recovered were significantly higher for organically amended soils (550) and wastes applied at reduced rates combined with 120 kg/ha mineral NPK (383) than the unamended control (277). NO_3^- N plus exchangeable NH_4^+ N were relatively high at 30 and 60 days after planting, and this trend was consistent among the agricultural waste materials applied. The higher values were followed by consistent decline afterwards especially at the end of the experiment (120 DAP). This indicates that the manures whether applied solely or at the reduced rates combined with 120 kg/ha mineral NPK exhibited high mineralisation rates. Among the wastes applied, poultry manure plus 120kg/ha NPK produced the highest values of SOC and mineral N while the unamended soil had the least values of these parameters.

The slow nitification process of soil applied manure and fertilizer implies increased retention period of plant available form of nitrogen (NO_3-N and NH_4-N).

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The time trends of soil organic carbon and inorganic N released from the soil showed that differences were obtained at the various dates of sampling.

The NO_3^- + exchangeable NH_4^+ (PAN) recovered from organically amended soils were higher than the unamended control. PAN was high among the agricultural waste materials applied especially for poultry manure and neem seed cake. This indicates that agricultural wastes whether applied solely or at reduced rates combined with 120 kg/ha mineral NPK exhibited high mineralisation rates of added organic wastes. This may have been due either to clay fixation or microbial immobilization of soil N. Whatever the process involved, highest release of sequestered N occurred up to 60 days after planting (treatment application). Among the organic wastes tested, rates of N release (mineralization) were similar. This suggests that the forms of organic N contributing to the mineralizable forms of N among the applied organic wastes are similar.

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Although the trend of the effects of wastes application on cfu were inconsistent however, the time dynamics of microbial population (cfu) follows trends obtained for SOC. The highest values were obtained for poultry manure, Parkia and Neem seed cake while combined application of wastes and NPK depressed microbial population. The differences in the quality of the agricultural wastes measured in terms of C/N ratios differed and could have driven the observed temporal variations in soil chemical properties (soil organic carbon, mineral N and microbial biomass-C and N). The % C microbial to C organic ratio was stable for all treatments, its magnitude was not similar among treatments, higher values were obtained from organically amended soils. The values of % C mic: Corg (indicator of microbial activity in terms of the utilisation of organic carbon by the microbes and hence organic matter turnover rate) obtained could be indicative of greater access of nutrients by soil microbes.

Mineral N (NO_3^- N plus NH_4^+ N) pools and % C microbial to C organic ratio were higher in the nutrient-rich organically amended soils which indicated that increased N mineralisation were facilitated by higher amounts of SOC.

TABLE 1 : Chemical composition of agricultural waste materials tested

Chemical parameters	Poultry waste	Cow dung	Chromo laena leaf	Parkia leaf	Neem seed cake	Mellon shell
Organic carbon (%)	7.60	3.20	3.40	11.68	4.48	13.80
Total n (%)	1.60	1.05	0.86	0.43	1.43	0.98
C:N ratio	2.11	3.05	3.95	27.16	3.13	14.08
Phos phorous(%)	1.34	1.08	1.28	1.02	1.31	0.66
Potassium (%)	3.12	0.81	1.47	2.06	1.98	0.58
Calcium(%)	1.23	1.19	1.05	0.96	1.03	0.63
Magnesium (%)	0.32	0.24	0.65	0.21	0.12	0.41

TABLE 2 : Pre and post planting soil physical and chemical properties

properties	2008	2009	Mean
Sand (%)	54.8	60.4	59.6
Clay (%)	27.2	23.2	25.2
Silt (%)	18.0	15.6	16.8
Soil texture	Sandy loam	Sandy loam	Sandy loam
pH (Water)	6.8	6.7	5.75
Bulk density (g.cm^{-3})	1.31	5.3	6.05
Total porosity (%)	41.1	1.47	1.39
Organic matter (%)	1.93	43.3	42.2
Total N (%)	0.18	1.83	1.88
Available P (mg kg $^{-1}$)	2.34	0.09	0.14
Exchangeable Ca (c mol kg $^{-1}$)	0.22	2.74	2.54
Exchangeable Mg (c mol kg $^{-1}$)	2.60	0.16	0.19

TABLE 3 : trends in soil microbial population as affected by application of agricultural wastes and a compound mineral fertilizer

Treatments	Fungi sfu/g x 10^3			Bacteria (sfu/g x 10^3)			Organic matter (g/g)		
	30	60	90	30	60	90	30	60	90
NPK	93	130	67	293	280	245	1.24	1.64	1.62
Chr	95	65	85	420	324	254	1.25	1.55	1.50
Chr+ NPK	89	130	128	266	270	223	0.83	1.12	1.06
Nm	93	110	95	296	340	271	1.42	1.71	1.67
Nm + NPK	80	92	110	310	353	231	1.26	1.56	1.48
Pak	64	77	85	384	386	265	1.20	1.23	1.20
Pak+ NPK	97	110	103	412	389	224	0.94	1.03	0.98
CwD	73	63	83	327	365	271	1.06	1.30	1.16
CwD + PK	78	85	86	338	320	237	1.21	1.28	1.88
Ptr	81	90	94	384	412	285	1.27	2.51	1.71
Ptr + NPK	93	100	96	343	361	256	1.18	2.43	2.05
Mel	95	113	98	302	344	277	1.44	1.75	1.70
Mel + NPK	82	95	114	313	356	234	1.26	1.56	1.48
Ctrl	78	61	88	301	345	286	0.87	0.96	0.89
LSD (0.05)	6.4	8.7	9.2	21.5	27.2	8.5	0.19	0.94	0.21

NPK alone; Chromolaena alone (Chr); Chromolaena + Urea (Chr+ NPK); Neem seed powder alone (Nm), Neem + NPK (Nm +NPK), Parkia leaves alone (Pak), Parkia leaves + NPK Pak+NPK), Cowdung alone (CwD), Cowdung + NPK (CwD + NPK), Poultry manure alone (Ptr), Poultry manure + NPK (Ptr + NPK), Melon shell powder (Mel), Melon shell powder + NPK (Mel + NPK), Unmanured control (Ctrl)

TABLE 4 : Dynamics of microbial biomass-C and N as affected by application of agricultural wastes and a compound mineral fertilizer

Treatments	Organic carbon (mg/g)			Microbial biomass – C (µg/g)			Microbial biomass – N (µg/g)			Ratio of organic carbon to microbial biomass-C		
	30	60	90	30	60	90	30	60	90	30	60	90
NPK	1.24	1.64	1.62	611	456	372	79	63	50			
(Chr)	1.25	1.55	1.50	423	305	241	71	60	46			
(Chr+ NPK)	0.83	1.12	1.06	607	412	358	83	68	52			
(Nm)	1.42	1.71	1.67	653	423	366	84	70	55			
(Nm) + NPK	1.26	1.56	1.48	515	285	231	70	56	41			
(Pak)	1.20	1.23	1.20	615	405	361	86	72	56			
(Pak+ NPK)	0.94	1.03	0.98	511	296	237	72	58	42			
(CwD)	1.06	1.30	1.16	631	408	417	82	70	54			
(CwD + NPK)	1.21	1.28	1.24	508	283	234	68	56	38			
(Ptr)	1.27	2.51	2.07	847	678	293	71	59	44			
(Ptr + NPK)	1.18	2.43	2.05	733	471	344	88	75	60			
(Mel)	1.44	1.75	1.70	656	427	369	87	73	57			
(Mel + NPK)	1.26	1.56	1.48	511	277	226	68	55	48			
Ctrl	0.87	0.96	0.89	417	372	279	64	52	36			
LSD	0.36	0.68	0.53	3.4	37.9	21.4	9.5	11.3	8.4			

NPK alone; Chromolaena alone (Chr); Chromolaena + Urea (Chr+ NPK); Neem seed powder alone (Nm), Neem + NPK (Nm +NPK), Parkia leaves alone (Pak), Parkia leaves + NPK Pak+NPK), Cowdung alone (CwD), Cowdung + NPK (CwD + NPK), Poultry manure alone (Ptr), Poultry manure + NPK (Ptr + NPK), Melon shell powder (Mel), Melon shell powder + NPK (Mel + NPK), Unmanured control (Ctrl)

TABLE 5a : Dynamics of mineral N as affected by application of agricultural wastes and a compound mineral fertilizer

Treatments	NH4-N (μg/g)					NO_3-N (NO_2+NO_3) (μg/g)				
	0	30	60	90	120	0	30	60	90	120
NPK	62	370	191	86	17	47	36	18	8	2.4
Chr	43	331	157	53	5	36	28	11	4	1.2
Chr+ NPK	54	363	173	71	11	42	32	15	5	1.5
Nm	40	326	154	54	6	34	26	10	4	1.3
Nm + NPK	52	347	168	63	10	41	33	13	5	1.6
Pak	37	322	152	48	5	35	25	9	3.4	1.1
Pak+ NPK	50	341	164	62	9	40	30	12	4	1.5
Cow dung	35	328	147	50	6	30	22	8	3.2	1.2
CwD + NPK	48	350	160	61	10	38	28	13	4	1.5
Ptr	37	334	148	54	7	35	25	8	3.1	1.0
Ptr + NPK	52	358	163	68	12	40	33	14	5	2.0
Melon shell	42	329	152	51	8	31	28	12	5	1.5
Mel + NPK	54	344	171	61	12	44	32	15	6	1.8
Control	31	293	130	47	4	31	22	6	2.4	0.8
LSD	8.2	11.6	14.8	12.5	4.3	8.4	5.3	4.2	2.1	0.6

TABLE 5b : Dynamics of soil organic carbon and plant available nitrogen of organically amended and unamended soil

Soil amendments	Organic carbon (mg/kg)				NO_3-N (NO_2+NO_3) (μg/g)				NH_4-N (μg/g)			
	0	30	60	90	0	30	60	90	0	30	60	90
Unamended control	1.07	1.34	1.71	1.34	37	23	9	3	33	124	41	17
NPK (15:15;15)	0.91	1.19	1.64	1.28	41	36	18	8	58	191	87	34
Organic manure	1.18	2.43	2.05	1.65	35	25	12	4	37	243	108	46
Organic + NPK	1.13	1.36	1.76	1.48	40	33	14	6	48	268	116	54
LSD (0.05)	0.19	0.22	0.41	0.45	4.3	6.2	4.3	4.0	8.1	11.4	16.3	9.5

TABLE 6 : Effect of application of agricultural waste and mineral fertilizer on soil organic matter content after 3 years of continuous maize cultivation.

Soil amendments	Initial soil organic matter (%)	Final soil organic matter (%)	% change In SOM
NPK 15:15:15 (400 kg/ha)	1.93	2.43	0.49
Chromoleana (10 t/ha)	1.93	3.18	1.25
Chromoleana (7 t/ha + 120 kg/ha NPK)	1.93	3.82	1.89
Parkia (10 t/ha)	1.93	2.92	0.99
Parkia (7 t /ha + 120 kg/ha NPK)	1.93	3.02	1.09
Neem seed cake (10 t/ha)	1.93	2.92	0.99
Neem seed (7t/ha + 120 kg/ha NPK)	1.93	2.73	0.80
Cow dung (10 t/ha)	1.93	3.05	1.12
Cow dung (7t/ha + 120 kg/ha NPK)	1.93	3.15	1.22
Poultry dung (10 t/ha)	1.93	3.96	2.03
Poultry dung (7t/ha + 120 kg/ha NPK)	1.93	4.01	2.08
Melon shell (10 t/ha)	1.93	2.47	0.54
Melon shell (7 t/ha + 120 kg/ha NPK)	1.93	2.06	0.13
Unamended control	1.93	2.01	0.08
LSD (0.05)	--	0.73	0.42

The values of % C mic: Corg (indicator of microbial activity in terms of the utilisation of organic carbon by the microbes and hence organic matter turnover rate) obtained could be indicative of greater access of nutrients for microbes. Although the % C microbial to C organic ratio was stable for all treatments, its magnitude was not constant but increased with increases in soil C concentration. The results of this study confirm that the organic wastes examined have markedly different decomposition patterns confirming the results of[1, 2].

SOM increased after two years of cultivation irrespective of the organic wastes applied (TABLE 6). Application of organic wastes plus mineral fertilizer (NPK) increased SOM over sole application of wastes. In soil amended with poultry manure, highest SOM values were recorded, the control plots showed slight increases (17%) in SOM at the end of the two year experiment. The trends of increases in SOM stocks were poultry manure, cowdung, chromolaena and Parkia shoot biomass, and neem seed cake applied in addition to 120kg/ha NPK mineral fertilizer.

Time trends in soil organic carbon and plant available N (NO_3-N and NH_4-N)

The time changes in SOC contents is shown in Figure 1. Declining SOC with time was obtained and the declining in the status of SOC is linearly related with (Y = 0.18x + 1.07; R2 = 0.34), Positive changes were obtained at 40 and 80 DAP possibly via increased rates of decomposition of added organic materials (SOM). Declines in SOC beyond 80 DAP may be associated with declining SOM pool. SOC is outstandingly higher in organically amended plots throughout the sampling period. The observed changes can also be attributed to SOM-enhanced microbial population and activities.

Figure 2, shows changes in soil nitrate nitrogen (NO_3-N) contents with time, soil NO_3-N decreased with time during the growth of maize. The values of soil NO_3-N was highest at 20 and lowest at 120 days after planting. Sole application of NPK fertilizer produced the highest released of NO_3-N, which was closely followed by combined application of agricultural wastes and NPK. The unamended control and plots amended with agricultural wastes had highest valves of NO_3-N at 20 days after planting. However, at 40 days, sole application of agricultural wastes released NO_3-N more than unamended control, this pattern was followed up to 120 days.

The time changes in soil NO_3-N contents is presented in Figure 2. The result showed that there were negative changes in soil NO_3-N with time. Sharp decline in NO_3-N with time under organic amendment alone and the control, this may possibly be attributed to

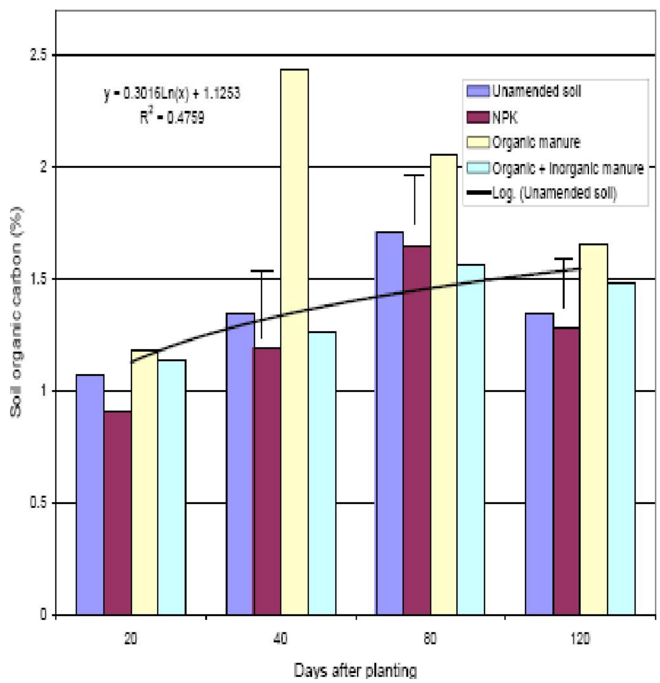

Figure 1 : Time changes in soil organic carbon content

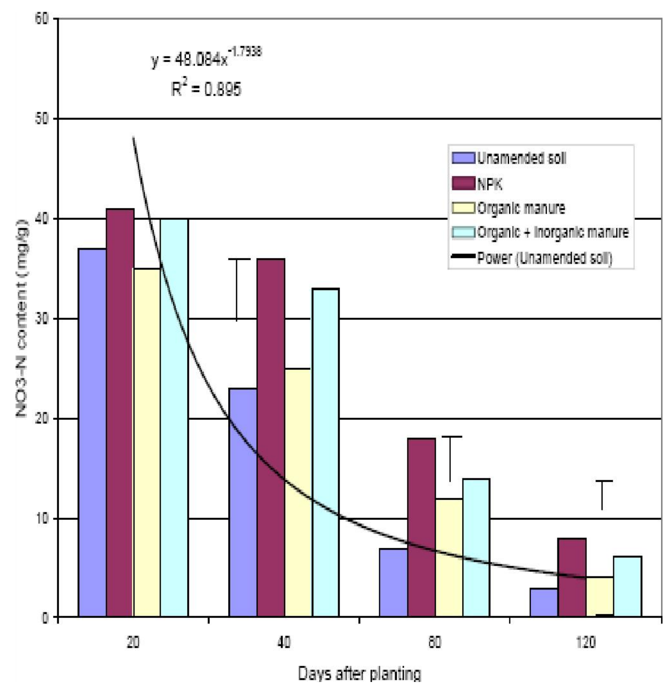

Figure 2 : Time changes in available N (NO3-N)

faster mineralization from SOM-enhanced microbial population and activities. Loss pathways of nitrates are leaching, plant uptake and denitrification. The nature of the decline in NO3-N is related with time by a power function ($Y = 48.084x^{-1.79}$; $R2 = 0.91$).

Figure 3 shows time changes in NO_4-N, its values increased from 20 to 40 DAP, declining trends in the values of NO_4-N followed afterwards and a considerably low values were obtained at 120 DAP. At 20 days after planting, sole application of NPK produced highest available soil NH_4-N, followed by application of agricultural wastes plus reduced level of NPK. About 40 days after planting appeared to be period of peak of NH_4-N availability; The combined application of waste and NPK released the highest NH_4-N, followed by sole agricultural wastes and sole NPK fertilizer, un amended control recorded the least value of soil NH_4-N. The pattern was consistent at both 80 and 120 days after planting.

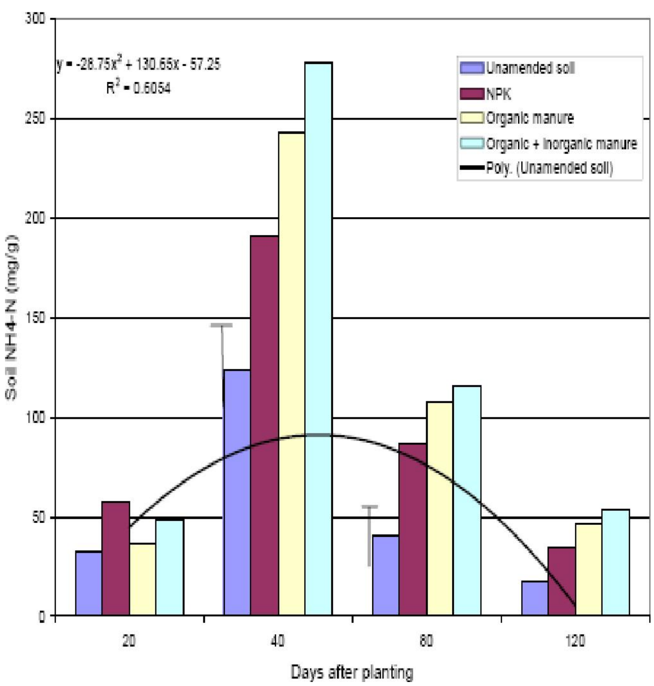

Figure 3 : Time changes in soil available N (NH4-N)

The time changes in soil NH_4-N contents is presented in Figure 3. Increasing trend in NH_4-N contents in the soil was found between 20 and 40 DAP followed by declining NH4-N contents from 40 to 120 DAP. The inhibition of nitrification greater in organic waste application combined with mineral fertilizer (NPK). Mineral N enhanced inhibition of nitrification has been implicated in previous study where organic wastes were used in combination with mineral N[12]. The nature of the decline in NH4-N is related with time by a polynomial function ($Y = -28.75x + 130.65x -57.25$; $R2 = 0.61$).

A complete minerasliation of SOM and The lowest values of NH_4-N obtained from the applied fertilizer was observed from soil samples at 120 days after treatment application may indicate complete minerasliation of SOM of the applied organic wastes

The effects of sole and combine application of wastes and mineral fertilizer on the pattern of NH_4-N release among the applied wastes varied. The differences in the time dynamics of NH_4-N release is presumed to have stemmed from the variable rates of decomposition of SOM which could explain the variable effects of the applied agricultural wastes in slowing down the nitification process. Increased soil retention of NH_4-N due to slow rates of nitrification of applied fertilizer materials is reported[12, 17].

Nitrification inhibition by wastes is known, high SOM contents is reported to attenuate nitrification process[12]. Agricultural wastes have the potential to inhibit urease activity and slow down the release of NH_4-N into the soil[12]. Also, organic matter via its sorption action are protected from rapid degradation and this slows down NH_4-N release (Brady, 1990). Organic (agricultural) wastes have been reported as having the ability to slow down nitrification process possibly due to their high contents of organic matter[12]. In this study, the applied agricultural) wastes appeared to have slowed down the nitrification process, and following application, the high SOM contents could have attenuated nitrification process. In addition, under the combined application of wastes and mineral NPK, agricultural wastes could have possibly reduced nitrification rate via slow hydrolysis of the mineral fertilizer (NPK).

Higher SOM contents are known to attenuate nitrification process. Organic matter via its sorption action are protected from rapid degradation which slowed down NH_4-N release (Brady, 1990). Hence the applied agricultural wastes exhibited differences in the pattern of release of inorganic N in particular where wastes were applied with mineral fertilizer (NPK). The possible slow nitrification of applied mineral fertilizer in treatments involving combined use of organic wastes and mineral fertilizer would have affected the release and the period of availability of NH_4-N in the soil. However reduction in soil NO_2 + NO_3-N and NH_4-N contents under sole application of wastes was obtained. Slow release of NO_2 + NO_3-N and NH_4-N and resultant increases in nutrient availability time in the soil for crops may imply a better synchronization of nutrients with crop demand and possibly enhancement of nutrient use efficiency of the applied manures/fertilizer. Increases in the concentrations of plant available forms of N (NO_2 + NO_3-N and NH_4-N) and its period of availability in soil may possibly enhance the use efficiency of applied fertilizer and reduced rates of soil N losses.

Hence the applied agricultural wastes exhibited variable pattern of release of inorganic N. In treatments involving combined use of organic wastes and mineral fertilizer, slow release of plant available forms of N (NO_3-N and NH_4-N). The possible slow nitrification process of applied mineral fertilizer in the integrated use of wastes and NPK may imply increased retention of NH_4-N and could prolong the period of release and soil availability of NH_4-N. The increased retention of NH_4-N and hence increases in time availability of plant available forms of N (NO_3-N and NH_4-N).

The slow rates of the nitification of applied fertilizer materials may imply increased retention of NH_4-N and hence increases in time availability of plant available forms of N (NO_3-N and NH_4-N). Rapid nutrient depletion and low fertilizer use efficiency especially in tropical agricultural systems may stem from high rates of losses of nitrogen via denitrification, volatilization and leaching[4].

NO_2 + NO_3-N and NH_4-N are the forms of soil nitrogen that are readily available to plants, NO_3-N are negatively charged and are not readily adsorbed by negatively charged clay colloids. They are thus susceptible to rapid losses via leaching (Brady, 1990). Low rates of the nitification and increases in time of availability of plant available forms of N (NO_3-N and NH_4-N) may slow down nutrient depletion. Lengthening the period of availability of soil nutients especially N may bring about a reduction in the rates of soil N losses. Reduction in the rates of nutrient losses/depletion and improvements in fertilizer use efficiency will promote and sustain ecosystem health.

NH_4-N released from the decomposition of applied manure/fertilizer are substrates for soil nitrifying bacteria. Differences in amount of NH_4-N in the soil may be related to differences in organic matter and CEC.

Agricultural wastes alone appeared to have negatively affected the population (and activities) of soil microbial community possibly the nitrifying bacteria and hence a possible inhibition of NH_4-N nitrification. This inhibition appeared to have consequently increased the time of availability and concentrations of NH_4-N in soil. Brady (1990) reported that soil contents of organic matter and CEC are basic to nutrient retention.

The quality of applied organic materials had profound effects on the soil chemical properties (status of SOC and mineral N). In this study SOC contents (a potentially mineralisable N) varied among the organic materials applied. The carbon to nitrogen ratio is an indicator of the decomposing ability of soil organic matter and consequently of the N supplying potential of the soil. This variation might have stemmed from the C/N ratios of the applied organic materials and hence SOC and mineral N contents in the soil. Hema et al. (1999) reported that the addition of organic wastes with low C/N ratio increased inorganic N in soil in addition to higher microbial biomass C. In another study, Paul and Mannan[11] obtained higher microbial C and N formation through addition of straw of high C/N ratio. In this study, the application of plant litter/stubble increases the input of carbon into the soil. Eaton (2001) reported that farming systems of the humid tropics sustain soil quality and productivity by maximizing nutrient (C and N) cycling, soil biota population and activities via the application or retention of plant litter/stubble.

CONCLUSION

This study examined the effects of integrated use of some agricultural waste materials and a mineral fertilizer (commercially available compound fertilizer containing N. P. K) on the fluxes of soil nutrients on a Ultisol in a humid savanna agroecological zone of

Nigeria. The cultivated field was organically manured using partially cured poultry manure, cow dung and plant residues (shoots of Chromolaena odorata and Parkia biglosa (locust bean), neem seed cake (Azadiracta inidca) and melon shell. The mineral fertilizer and agricultural wastes applied increased stocks of organic carbon, microbial biomass C and N, and forms of plant available N (NO_2-N+NO_3-N and NH_4-N) in the soil. Higher plant available N was obtained from the manured compared to unmanured soils. The applied residue biomass appeared to have contributed to the build up of C stock in the soil. Organic waste (livestock manure and plant biomass) amendment enhances/improves short term fertility of the soil and its contribution goes beyond its role of increasing SOC build up and as nitrogen source for crop growth but also determine also the residual pool of nutrients in the soil. The application of organic wastes to agricultural soils contributes not only to the short term fertility but also determine the residual pool of nutrients in the soil. Soil amendment using organic wastes (livestock manure and plant biomass) appeared to have enhanced the build up of SOC beyond its role as nitrogen source for crop growth. Differences were obtained in the pattern and amount of NO_2 + NO_3-N and NH_4-N released from the applied wastes. In particular, in treatments involving combined application of organic wastes and mineral fertilizer, nitrification process appeared to have slowed down and the slow release of plant available forms of N would have increase availability time of NH_4-N in the soil. Increases in the concentrations of plant available forms of N (NO_2 + NO_3-N and NH_4-N) and its period of availability in soil may possibly enhance the use efficiency of applied fertilizer and reduced rates of soil N losses. The results would advance knowledge about the chemical and biological processes of fluxes of carbon and nitrogen in the soil following organic amendment. The trends in the time dynamics of C and N in microbial biomass would help to fine tune nutrient management strategies especially for Ultisols of the humid savanna agroecology. Tropical soils under organic amendment in particular, have a wide range of mineralization potentials and this study enhances understanding of the fluxes of C and N in a tropical Ultisol.

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